WELCOME to ICSP 2016

Dear participants,

It is a great pleasure to welcome you all to the XIV International Conference on Stochastic programming in Búzios.

We are proud to host this meeting, jointly organized by Brazil and Chile. The 2016's conference is the latest edition of a prestigious series that began in Oxford in 1974, and continued in Koszeg, 1981; Laxemburg, 1983; Prague, 1986; Ann Arbor, 1989; Udine, 1992; Nahariya, 1995; Vancouver, 1998; Berlin, 2001; Tucson, 2004; Vienna, 2007; Halifax, 2010; Bergamo, 2013.

For the first time in more than 40 years, the conference leaves the axis North America – Europe. We see ICSP 2016 as a great opportunity to promote the exchange of ideas between South American researchers and Stochastic Programming experts from all around the globe.

In addition to the usual conference structure, with plenary, semi-plenary, contributed talks and tutorials, for this ICSP edition we put in place a system with thematic sessions, proposed by members of the SP community as a group of four presentations on a homogeneous topic. We received an enthusiastic response to this new scheme, as shown by the 35 thematic sessions scheduled in the conference program. The subject, speakers, and title presentations of each thematic session were examined and approved by the Program Committee.

We also counted with the precious collaboration of ICSP 2016 semiplenary speakers, who organized six minisymposia, focusing on recent advances in the state-of-the-art, the "hot" topics in the area.

We are looking forward to a great conference, with many interesting professional exchanges accompanied by pleasant social gatherings.

Check all the different activities in the subsequent pages of this program and enjoy ICSP 2016!

Claudia Sagastizábal
on behalf of the organizing committee

ICSP 2016 Coordinators:

Claudia Sagastizábal, Chair
Tito Homem-de-Mello, Co-Chair
Alejandro Jofré, Co-Chair

Organizing Committee

Alfredo Iusem
Juan Pablo Luna
Welington de Oliveira
Claudia Sagastizábal
Mikhail Solodov
Jorge Zubelli

Program Committee

Giorgio Consigli
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Alejandro Jofré
Anton Kleywegt
Jim Luedtke
Nelson Maculan
David P. Morton
Nilay Noyan
Teemu Pennanen
Georg Pflug
Andy Philpott
Rüdiger Schultz
Melvyn Sim
Roger Wets

From behind the scene: our invaluable staff

Without these persons, organizing this conference would not have been possible

- From the Scientific Activities Division (DAC): Sônia Alves, Paula Dugin, Pedro Faro (head), Renata Maiato, Letícia Ribas, Jurandira Ribas, Ana Paula Rodrigues.
- From the Scientific Information Division (DDIC): Maria Celano (head).
- From the Laboratory for Analysis and Mathematical Modeling in the Applied Sciences (LAMCA): Arminda Lobo, Raphaela Pelosi.
- IMPA Graphical designer: Sérgio R. Vaz.
- The IT team: the System Development (DDSS), Network (DSR), and Multimedia Divisions.
- Suely Alves Lima.

We gratefully include in this list Cristián Murillo, from CMM – Chile, for his great design of the conference poster.

Michele Leite from MMX, for her tireless good will and negotiation skills.

SPONSORS:

A conference with so many participants from different parts of the world would not be possible without the generous sponsorship of many public and private institutions, listed below.

EWGSP

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CONTENTS

OVERVIEW OF EVENTS

1. Group Picture

Tuesday, June 28, immediately after Andrzej Ruszczynski's plenary talk: at 10h50 we will gather in the area near the back door of Atlântico hotel to take a picture of with all the conference participants.
Don't forget to come, to help us immortalizing an ICSP2016 moment!

2. Wednesday Afternoon

a. Special Session and Round Table

On June 29th, from 15h to 17h30 in the joint rooms Tucuns and Tartaruga, participants are invited to a Special Session in Honor of Jitka Dupacova, followed by a round table on the provocative subject *Are SP solvable?* Don't miss these interesting sessions!

b. Business Meeting and Awards

Also on Wednesday June 29th, at 17h45, the members of the Stochastic Programming Society will gather to elect the SPS Committee for the following three years, choose the next conference site, and discuss different topics related to the SP community. The meeting will be held in the joint rooms Tucuns and Tartaruga.

During the Business Meeting the SPS Student Paper Prize will be awarded, following the recommendation of a jury formed by Nilay Noyan (chair of the committee), Andrew B. Philpott, and Suvrajeet Sen. The three finalists will present their papers in Geriba room, during a session scheduled on Tuesday 28 at 11h15.

3. Social Program

In addition to offering a host of top-notch scientific talks, ICSP 2016 will give its participants the opportunity to socialize and enjoy several off-meeting activities.
Here is a list of the social events:

- June 26th (Sun): tennis and football tournaments, welcome cocktail.
- June 28th (Tue): happy hour with caipirinhas, food, music, and dance.
- June 29th (Wed): free morning, boat excursion.
- June 30th (Thu): gala dinner, a Brazilian BBQ in Insolito Boutique Hotel at Ferradura Beach (the menu includes several vegetarian options).

All these activities are included in the registration fee, except the last one: for the gala dinner, ICSP 2016 organization depends upon attendees contributing with part of the cost. Details can be found below.

a. Welcome cocktail

Sunday, June 26, from 18h30 to 20h30 in the area around the swimming pool in hotel Atlântico.
The fee for accompanying persons includes this activity.
Please remember to bring your ICSP2016 badge.

b. Happy hour

Tuesday, June 28, from 20h00 to 23h30 in Privilege Club, about 5 minute walk from Atlântico Hotel (reference 1 in map below).
We will gather between 19h30 and 19h45 in the hotel exit that is behind the swimming pool and gives to *Orla Bardot* street, to walk there together in groups.
The fee for accompanying persons includes this activity.
Please remember to bring your ICSP2016 badge.

c. Boat Excursion

Wednesday, June 29, from 9h00 to 13h00. Two schooners will leave from Armação beach (reference 2 in map below), at a location less than 10 minute walk through Orla Bardot from the hotel backdoor. One schooner will tour for sightseeing and the other one will make 3 swimming stops.
We will gather at 9h00 in the hotel exit that is behind the swimming pool and gives to Orla Bardot street, to walk there together in groups.
The fee for accompanying persons includes this activity.
Please remember to bring your ICSP2016 badge.

d. Gala Dinner

Thursday, June 30, from 19h30 to 23h00.
We will gather at 19h00 in the main entrance of the hotel, to take the buses. The hype Boutique Hotel Insolito is on Ferradura beach, a ride less than 15 minutes away from Atlântico hotel.
For the gala dinner we require a contribution of R$ 300 per person, which can be paid following the link PayPal in the conference web-page. All those who already bought tickets will find an invitation in their participant kit.
Please remember to bring your Gala Dinner invitation.

MENU

<u>DRINKS</u>: 1 caipirinha and **open bar** with beer, wine, juices

<u>TABLE WITH SIDE DISHES</u>
-Green salad, and couscous Salad with roasted vegetables and nuts
-Cold cuts and cheeses
-Garlic bread, crunchy garlic farofa
-Mousseline of Baroa potato
-Glazed carrots, grilled onion, baked Potato with herb butter
-Rosemary rice
Dressings: Jack Daniels BBQ, mustard and honey, Brazilian peppers, herbs, aioli Urucum, banana vinaigrette, and lemon.

<u>MAIN</u>
-Special meat cuts: fraldinha, alcatra, contrafilet, picanha, bife de chorizo argentino
-Pork ribs, chicken and spicy sausage.
-Grilled zucchini, wweet potato, aubergine, bell pepper, cheese

<u>DESSERTS</u>
-Grilled banana with dulce de leche and cinnamon
-Caramelized apple
-Brigadeiro cake with cashew nuts
-Ice cream

<u>COFFEE and TEA</u>

4. When is what?

a. PhD tutorials

The traditional PhD tutorials are held in the joint rooms Tucuns and Tartaruga on Saturday June 25th from 15h30 to 19h00 and on Sunday June 26th from 09h30 to 17h30.

b. Plenary and Semiplenary Lectures

Plenary talks will be given in the joint rooms Tucuns and Tartaruga on the mornings of Monday June 27th, Tuesday 28th and Thursday 30th, and the afternoon of Friday July 1st.

Three semiplenary talks and their minisymposia are held in parallel in the rooms Tucuns, Tartaruga and Geriban, on the afternoons of Monday June 27th and Tuesday 28th.

c. Thematic and Contributed Sessions

Every day except Wednesday 29th, on the morning and afternoon there will be six parallel sessions held in the rooms Tucuns, Tartaruga, Geriba, Joao Fernandes, Amor e Canto.
Sessions were organized into the tracks below

- Energy I = talks related to energy planning
- Energy II = talks related to energy operations
- Theory I = talks related to various aspects of SP theory such as chance constraints, integer programming, etc.
- Theory II = talks related to models for risk, distributionally robust, or equilibrium problems
- Computational = talks related to computational/algorithmic aspects of SP , including decomposition methods
- Finance = talks related to SP applications in finance
- Applications = talks related to general application areas, such oil & gas, transportation, etc.

GUIDELINES FOR SPEAKERS AND CHAIRS

Each room has a laptop connected to a video projector.
Only pdf files will be uploaded (no ppt please)

The role of the Chair is to ensure a smooth running of the session and to introduce each speaker.
We kindly ask the chair of the session to make sure all the presentations are in the computer before the beginning of the session. If gathered in advance, the package with all the talks in the session can be sent to <u>multimedia@impa.br</u>. Please make sure to use a name that identifies sufficiently well the session.

ICSP2016 will provide help for uploading the talks and using the microphones in the larger rooms.

We recommend respecting strictly the time slot of each talk, to allow participants to move between rooms. The time available for each type of talk, including questions, is the following:
- Plenary and semiplenary talks: 45 minutes
- Minisymposium, thematic and contributed session talks: 25 minutes

PRACTICAL INFORMATION

Badge

Conference participants are required to carry ICSP2016 badge during the conference and to access the conference sector in Atlantico hotel.

Internet accessand computers

IMPA staff will make available two computers for ICSP2016 participants to use during the conference.

The organization offers free WiFi access in the hotel area surrounding the conference rooms.
SSID: IMPA
Password: IMPA2016

To maintain a good quality in the connections, we kindly ask participants
1. to make sure any unused device is disconnected from the network;
2. to minimize the transference of heavy files or streaming.
3. not to connect in a VPN.

Bulletin board

A message board will be set up in the conference hall; please check the announcements from time to time as we will communicate changes to the posted schedule, and other messages using this board.

Lunch options

A buffet lunch is included for participants staying in Atlântico hotel. Several other restaurants can be found on *Orla Bardot,* both walking towards Rua das Pedras in Downtown, and towards praia dos Ossos (see map below).

Book stand

During ICSP2016, there will be a stand by Springer, showcasing SP books and journals.

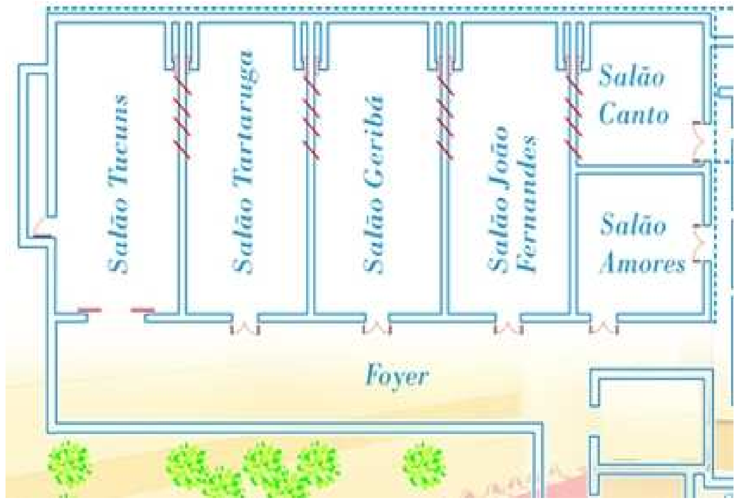
Practical matters

We suggest that participants purchase a travel health insurance.

The voltage in the state of Rio de Janeiro is 110V. Electrical outlets are not universal, you can buy adaptors in Rio (or better bring them with you, of course).

We advise against drinking tap water – prefer bottled mineral water or filtered water.

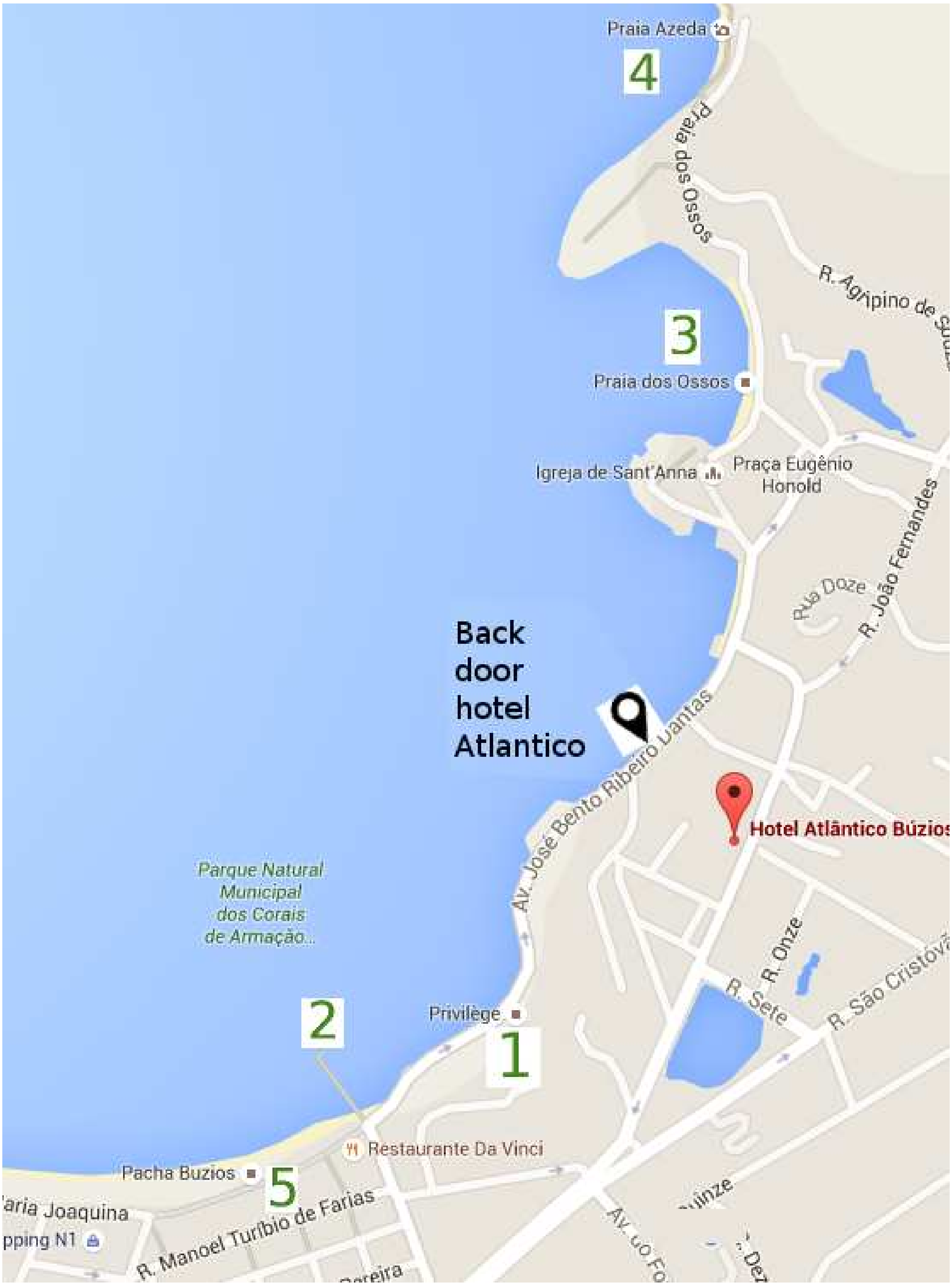
CONFERENCE ROOMS



LOCAL TIPS

- ***Orla Bardot*** is the name of a short piece of Estrada *José* Bento *Ribeiro Dantas.*
- **Rua das Pedras** is the continuation of the same street into Downtown.
- Downtown is on the left, when getting out of Atlantico hotel through the back door.
- Praia dos Ossos is a short walk away from the hotel, going to the right (reference 3 in the map). A little further away, about 20 minute walk (up and downhill) hides the beautiful Azeda beach (reference 4 in the map).
- All along estrada J. Bento Ribeiro Dantas you will find plenty of hype shops and restaurants.
- In downtown, the street parallel to Rua das Pedras, *Rua Turíbio de Farias*, has cheaper restaurants and shops (reference 5 in the map).

MAP


Praia Azeda
4
Praia dos Ossos
R. Agripino de
3
Praia dos Ossos
Igreja de Sant'Anna
Praça Eugênio Honold
R. João Fernandes
Rua Doze
Back door hotel Atlantico
Av. José Bento Ribeiro Dantas
Hotel Atlântico Búzios
Parque Natural Municipal dos Corais de Armação...
R. Onze
R. Sete
R. São Cristóvã
Privilège
2
1
Restaurante Da Vinci
Pacha Buzios
5
R. Manoel Turíbio de Farias

	Sat. 25	Sun. 26	Mon. 27	Tue. 28	Wed. 29	Thu. 30	Fri. 01
09:00		Tutorial: Introduction to Stochastic Programming (Part I)			Excursion		TS: Finance Applications TS: MicroGrid Management TS: SP for Planning and Economics of Networks
10:00	Leaving to Búzios	Coffee break	Plenary: Stochastic Programming	Plenary: Risk-Averse Dynamic		Plenary: Quantifying Uncertainty	Coffee break
			Coffee break	Coffee break		Coffee break	
11:00		Tutorial: Introduction to Stochastic Programming (Part II)	TS: Computational Stochastic Optimization CS: Applications in	CS: Applications in Finance CS: Sampling Methods Student Prize		CS: Equilibrium Problems CS: Applications in Health Care CS: Robust and	TS: (Un)Conventiona SP Algorithms for Gas Networks TS: Decomposition Methods
12:00		Lunch	Lunch	Lunch		Lunch	Lunch
13:00					Lunch		

14:00		Tutorial: Risk Measures (Part I)	MS: G. Bayraksan -- Data-driven Methods MS: D. Brown -- Stochastic Dynamic Programming MS: D.	MS: A. Pichler -- Applications of SP in Finance MS: H. Xu-- Stochastic MPECs MS: W. Powell -- Applications of Machine		TS: SP Models for Asset Allocation and Downside Risk Control TS: High-Performance	Plenary: Blessings of Binary in
15:00	Tutorial: Stochastic Integer Programming (Part I)	Coffee break			Special Session in Honor of Jitka Dupacova		Closing ceremony --- Shabbir
16:00		Tutorial: Risk Measures (Part II)	Coffee break	Coffee break	Special Session: Roundtable	Coffee break TS: Stochastic VIs and Complementarity Models TS: SDDP: Computation and Theory TS: Hydropower Reservoir Management	See you in ICSP 2019
17:00	Coffee break Tutorial: Stochastic Integer Programming (Part II)		TS: ALM and Long-Term Financial Optimization TS: Bounds and Decomposition Methods TS:	TS: Financial Engineering Applications TS: Scenario Reduction, Partition, and Clustering TS: SP under Uncertain Probability Distributions	Coffee break Business Meeting		
18:00		Cocktail	Applications of Stochastic Programming TS: Mixed-Integer Stochastic Programming TS: SDDP - Risk Aversion TS: Unit Commitment under Uncertainty				
19:00				Happy Hour in Privilege - Drinks, Food and Dance		Gala Dinner	
20:00							
21:00							

Sunday, June 26, 2016

Time	Session
9:00 (1h30)	**Tutorial: Introduction to Stochastic Programming (Part I)** *Johannes Royset, Naval Postgraduate School, USA* › Tucuns+Tartaruga
10:30 (30min)	**Coffee break**
11:00 (1h30)	**Tutorial: Introduction to Stochastic Programming (Part II)** *Johannes Royset, Naval Postgraduate School, USA* › Tucuns+Tartaruga
12:30 (1h30)	**Lunch**
14:00 (1h30)	**Tutorial: Risk Measures (Part I)** *Alexander Shapiro, Georgia Institute of Technology, USA* › Tucuns+Tartaruga
15:30 (30min)	**Coffee break**
16:00 (1h30)	**Tutorial: Risk Measures (Part II)** *Alexander Shapiro, Georgia Institute of Technology, USA* › Tucuns+Tartaruga
18:30 (2h)	**Cocktail**

Monday, June 27, 2016

<table>
<tr><td>10:00</td><td colspan="6">›10:00 (45min)
Plenary: Stochastic Programming Models for Energy Planning --- Mario Veiga Pereira
Chair: Claudia Sagastizabal
› Tucuns+Tartaruga</td></tr>
<tr><td>11:00</td><td colspan="6">›10:45 (30min)
Coffee break</td></tr>
<tr><td>12:00</td><td>›11:15 (1h15)
TS: Computational Stochastic Optimization
David Morton
› Amores</td><td>›11:15 (1h15)
CS: Applications in Natural Resources
Hector Ramirez
› Canto</td><td>›11:15 (1h15)
TS: Risk-Averse Dynamic Optimization
Andrzej Ruszczynski
› Geriba</td><td>›11:15 (1h15)
TS: Chance Constrained Optimization
Abdel Lisser
› Joao Fernandes</td><td>›11:15 (1h15)
TS: SDDP for nonconvex problems
Andy Philpott
› Tartaruga</td><td>›11:15 (1h15)
TS: Brazil's Oil Industry
Silvio Hamacher
› Tucuns</td></tr>
<tr><td></td><td colspan="6">›12:30 (2h)
Lunch</td></tr>
<tr><td>15:00
16:00</td><td colspan="2">›14:30 (2h)
MS: G. Bayraksan -- Data-driven Methods
Chair: Anton Kleywegt
› Geriba</td><td colspan="2">›14:30 (2h)
MS: D. Brown -- Stochastic Dynamic Programming
Chair: David Morton
› Tartaruga</td><td colspan="2">›14:30 (2h)
MS: D. Woodruff -- Applications of SP in Natural Resources
Chair: James Luedtke
› Tucuns</td></tr>
<tr><td></td><td colspan="6">›16:30 (30min)
Coffee break</td></tr>
<tr><td>17:00
18:00</td><td>›17:00 (1h40)
TS: ALM and Long-Term Financial Optimization
Giorgio Consigli
› Amores</td><td>›17:00 (1h40)
TS: Bounds and Decomposition Methods
Francesca Maggioni
› Canto</td><td>›17:00 (1h40)
TS: Applications of Stochastic Programming
James Luedtke
› Geriba</td><td>›17:00 (1h40)
TS: Mixed-Integer Stochastic Programming
Miguel Lejeune
› Joao Fernandes</td><td>›17:00 (1h40)
TS: SDDP - Risk Aversion
Luiz Carlos Costa Jr.
› Tartaruga</td><td>›17:00 (1h40)
TS: Unit Commitment under Uncertainty
Erlon Finardi
› Tucuns</td></tr>
</table>

Tuesday, June 28, 2016

Time						
10:00 (45min)	**Plenary: Risk-Averse Dynamic Optimization and Control --- Andrzej Ruszczynski** *Chair: Rene Henrion* › Tucuns+Tartaruga					
10:45 (30min)	**Coffee break**					
11:15 (1h15)	**CS: Applications in Finance** *Frantisek Zapletal* › Amores	**CS: Sampling Methods** *Urmila Diwekar* › Canto	**Student Prize Finalists Presentations** *Suvrajeet Sen* › Geriba	**CS: Stochastic Vehicle Routing & TSP** *Ricardo Fukasawa* › Joao Fernandes	**CS: Applications in Oil & Gas** *Jorge Rodríguez-Veiga* › Tartaruga	**CS: Theory and Practice** *Robert Bassett* › Tucuns
12:30 (2h)	**Lunch**					
14:30 (2h)	**MS: A. Pichler -- Applications of SP in Finance** *Chair: Darinka Dentcheva* › Geriba		**MS: H. Xu-- Stochastic MPECs** *Chair: Andy Philpott* › Tartaruga		**MS: W. Powell -- Applications of Machine Learning** *Chair: Giorgio Consigli* › Tucuns	
16:30 (30min)	**Coffee break**					
17:00 (1h40)	**TS: Financial Engineering Applications** *Giorgio Consigli* › Amores	**TS: Scenario Reduction, Partition, and Clustering** *Yongjia Song* › Canto	**TS: SP under Uncertain Probability Distributions** *Anton Kleywegt* › Geriba	**TS: Probabilistic Constraints: Applications and Theory** *W. Van Ackooij* › Joao Fernandes	**TS: Planning Problems in the Electric Power Systems** *Francisco Munoz* › Tartaruga	**TS: Brazil's Oil and Energy Industries** *Welington de Oliveira* › Tucuns
19:30 (3h30)	**Happy Hour in Privilege - Drinks, Food and Dance**					

Wednesday, June 29, 2016

Time	Session	Location
›9:00 (4h)	**Excursion**	
›13:00 (2h)	**Lunch**	
›15:00 (1h15)	**Special Session in Honor of Jitka Dupacova** *Chair: David Morton*	› Tucuns+Tartaruga
›16:15 (1h15)	**Special Session: Roundtable** *Chair: Suvrajeet Sen*	› Tucuns+Tartaruga
›17:30 (15min)	**Coffee break**	
›17:45 (1h15)	**Business Meeting**	› Tucuns+Tartaruga

Thursday, June 30, 2016

Time						
10:00	›10:00 (45min) **Plenary: Quantifying Uncertainty using Epi-Splines --- Johannes Royset** *Chair: Alejandro Jofre* › Tucuns+Tartaruga					
	›10:45 (30min) **Coffee break**					
11:00–12:00	›11:15 (1h15) **CS: Equilibrium Problems** *Leonidas Sakalauskas* › Amores	›11:15 (1h15) **CS: Applications in Health Care** *Tito Homem-de-Mello* › Canto	›11:15 (1h15) **CS: Robust and Stochastic Optimization** *Marida Bertocchi* › Geriba	›11:15 (1h15) **CS: Applications in Inventory and Logistics** *Laureano Escudero* › Joao Fernandes	›11:15 (1h15) **CS: Optimization of Dynamic Models** *Nicolas Langrené* › Tartaruga	›11:15 (1h15) **CS: Modeling Languages and Computation** *Christian Valente* › Tucuns
	›12:30 (2h) **Lunch**					
15:00	›14:30 (1h40) **TS: SP Models for Asset Allocation and Downside Risk Control** *Cristiano Valle* › Amores	›14:30 (1h40) **TS: High-Performance Computing** *Victor Zavala* › Canto	›14:30 (1h40) **TS: Risk-Averse Optimization** *Darinka Dentcheva* › Geriba	›14:30 (1h40) **TS: Stochastic VIs and Complementarity Models** *Asgeir Tomasgard* › Joao Fernandes	›14:30 (1h40) **TS: SDDP: Computation and Theory** *Vincent Guigues* › Tartaruga	›14:30 (1h40) **TS: Hydropower Reservoir Management** *Stein-Erik Fleten* › Tucuns
16:00	›16:10 (30min) **Coffee break**					
	›19:30 (3h30) **Gala Dinner**					

Friday, July 1, 2016

Time						
09:00	›9:00 (1h40) **TS: Finance Applications** *Leonard MacLean* › Amores	›9:00 (1h40) **TS: MicroGrid Management** *Bernardo Pagnoncelli* › Canto	›9:00 (1h40) **TS: SP for Planning and Economics of Networks** *Alexei Gaivoronski* › Geriba	›9:00 (1h40) **TS: Multi-Stage Models for Investment** *David Wozabal* › Joao Fernandes	›9:00 (1h40) **TS: SDDP - Modeling Uncertainty and Hydro Plants** *Vitor De Matos* › Tartaruga	›9:00 (1h40) **TS: Applications of SP in the Power Sector** *Maria Teresa Vespucci* › Tucuns
10:00	›10:40 (20min) **Coffee break**					
11:00	›11:00 (1h40) **TS: (Un)Conventional SP Algorithms for Gas Networks** *Ruediger Schultz* › Amores	›11:00 (1h40) **TS: Decomposition Methods** *Vincent Leclère* › Canto	›11:00 (1h40) **TS: SDDP - Practical Applications** *Raphael Chabbar* › Geriba	›11:00 (1h40) **TS: Structures of SP Models** *Kai Spurkel* › Joao Fernandes	›11:00 (1h40) **TS: SP for Real Hydrothermal Power Generation** *Andre Diniz* › Tartaruga	›11:00 (1h40) **TS: SP for Planning in the Energy Sector** *Asgeir Tomasgard* › Tucuns
12:00	›12:40 (1h50) **Lunch**					
	›14:30 (45min) **Plenary: Blessings of Binary in Stochastic Integer Programming --- Shabbir Ahmed** *Chair: Tito Homem-de-Mello* › Tucuns+Tartaruga					
15:00	›15:15 (15min) **Closing ceremony** › Tucuns+Tartaruga					
16:00	›16:00 () **See you in ICSP 2019**					

Plenary Speakers

- **Shabbir Ahmed**, Georgia Institute of Technology, USA
  Blessings of Binary in Stochastic Integer Programming

- **Johannes Royset**, Naval Postgraduate School, USA
  Quantifying Uncertainty using Epi-Splines

- **Andrzej Ruszczyński**, Rutgers University, USA
  Risk-Averse Dynamic Optimization and Control

- **Mário Veiga Pereira**, PSR, Brazil
  Stochastic Programming Models for Energy Planning

Semi-plenary Speakers

- **Güzin Bayraksan**, Ohio State University, USA
  Data-driven Methods for Stochastic Programming

- **David Brown**, Duke University, USA
  Approximations to Stochastic Dynamic Programs via Information Relaxation Duality

- **Alois Pichler**, University of Vienna, Austria
  Risk Measures and Ambiguity in Finance

- **Warren Powell**, Princeton University, USA
  Applications of Machine Learning in Stochastic Optimization

- **David Woodruff**, University of California, Davis, USA
  Things that Make Applications of Stochastic Programming in Natural Resources Special

- **Huifu Xu**, University of Southampton, UK
  Stochastic Mathematical Programs with Equilibrium Constraints

Tutorials

- **Stochastic Integer Programming** (Saturday afternoon)
  James Luedtke, Industrial Engineering, University of Wisconsin-Madison, USA

- **Introduction to Stochastic Programming** (Sunday morning)
  Johannes Royset, Naval Postgraduate School, USA

- **Risk measures** (Sunday afternoon)
  Alexander Shapiro, Georgia Institute of Technology, USA

List of Talks

Plenary: Stochastic Programming Models for Energy Planning — Mario Veiga Pereira

Chair: Claudia Sagastizábal

ICSP 2016

Búzios, Brazil
25 June – 1 July, 2016

Stochastic Programming Models for Energy Planning

Mario Veiga Pereira
PSR, Rio de Janeiro, Brazil
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Abstract

For several decades, power system planning and operations has been one of the most active application areas for multistage stochastic optimization techniques. This is due to the combination of the following factors: (i) ever increasing social and economic importance of electricity supply for both developed and emerging countries; (ii) yearly investment and operation costs on the order of hundreds of billions of dollars; (iii) coupling of time stages due to storage, originally from hydro reservoirs and, more recently, batteries and other devices; (iv) uncertainties on several key parameters, such as the production variability of hydropower, wind and other renewables; annual demand growth; fuel costs; construction times; macro-weather effects such as El Niño, plus climate change; and short-term electricity prices. In this talk, I will describe some recent algorithmic and modeling advances on one widely applied technique, stochastic dual dynamic programming (SDDP): (a) implicit representation of the immediate cost function in each stage as a pre-calculated piecewise linear surface, which allows the detailed modeling of 730 hourly intervals in each stage with the same computational effort as an aggregate model with five blocks; (b) representation of uncertainties in the parameter values of wind and inflow stochastic models (this problem became relevant due to the shorter historical records of modern renewables); (c) an integrated Markov chain-AR model framework for the joint representation of uncertainties of renewable production, load growth, fuel costs, macro-weather and spot prices; (d) generation expansion planning with a risk-averse SDDP (CVaR on either operating costs or supply reliability); and (e) an extension of SDDP to produce generation expansion strategies, in which the investment decisions depend on the system state, for example past load growth rates. This allows the correct valuation of technologies with different construction times (e.g. six years for hydro, three for a gas turbine and two for wind) when planning under uncertainty. The application of the above algorithms will be illustrated for actual planning and operation studies in Latin America and Asia.

TS: Computational Stochastic Optimization

Chair: David Morton

ICSP 2016

Búzios, Brazil
25 June – 1 July, 2016

A Class of Sequential Decision Problems with Stochastic Disruptions

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Abstract

We consider a special type of sequential decision problem under uncertainty. In contrast to typical multi-stage models, we assume that the uncertainty consists of a small number of disruptions, say at most k, relative to the number of overall time periods, T. In this way, both the timing of the disruption, and its magnitude, can be random. In the special case of a stochastic program with recourse under $k = 1$, we have a two-stage stochastic program in which the timing of the stage is random. Here, the first-stage decision corresponds to a policy from period 1 to period T when the disruption has yet to occur. More generally, under k disruptions we have a $(k + 1)$-stage problem in which the timing of these stages is random.

We begin by focusing on the case of $k = 1$ for a two-stage stochastic program with recourse, and we adapt the L-shaped method to deal with the random timing of the stage. We describe further extensions of the L-shaped method when $k > 1$. When T is large, and the stochastic parameters governing the magnitude of the disruption are continuous, approximations are required. We consider a sample average approximation with special purpose sampling schemes. We investigate the computational performance of our approach, and finally, we suggest that the modeling framework extends to other classes of problems, such as Markov decision processes.

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Nested Clustering on a Graph

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Abstract

We study a clustering problem defined on an undirected graph $G = (V, E)$ with weight function $c : E \to \mathbb{R}_+$, where c_e denotes the importance of the connection between vertices i and j where $e = (i, j) \in E$. We remove a set S of edges from E in order to produce clusters, or connected components, in the residual graph. We define a gain function $g(S)$, which denotes the number of connected components of $G' = (V, E \setminus S)$. We let $c(S) = \sum_{e \in S} c_e$ be the cost of deleting the edges in S. Then we formulate the following graph clustering problem:

$$\max_{S \subset E} \quad g(S) - \lambda c(S), \tag{1}$$

for $\lambda > 0$. Problem (1) can be solved in polynomial time via solving a sequence of maximum flow problems. Solving (1) for a range of values $\lambda > 0$ identifies the solutions that lie on the concave envelope of efficient frontier and the breakpoints on this envelope have a nested structure. Motivated by this important structural property, we study how to solve model (1) parametrically for all $\lambda > 0$. We propose to solve this parametric model in polynomial time by solving a sequence of parametric maximum flow problems, i.e., maximum flow problems parametric in $\lambda > 0$, which yields the family of nested clusters on the efficient frontier.

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Optimal transitions under uncertainty with applications to the mining industry

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Abstract

Mining operations may start at the surface in an open pit, and later proceed underground. Conventional industry wisdom suggests that we may currently wait too long to initiate this transition, but, to date, a principled technical case to initiate an earlier transition has not been made. We focus on optimizing the timing of the transition between open pit and underground mining. It is widely acknowledged in the industry that uncertainty is pervasive and important. The limited literature on stochastic mine planning addresses only ore *grade* and ore *prices*. However, mining operations also face uncertainty in *geotechnics*, including the strength of the host rock that encompasses the orebody. Geotechnical uncertainty can be a primary driver for timing the transition to underground mining.

Mine planning typically separates an orebody into notional, three-dimensional *blocks* on the surface and *activities* underground. Blocks are extracted if they are profitable in and of themselves, or if their extraction allows access to underlying, profitable blocks. Underground, activities may include not only the extraction of segments of ore, but also supplemental tasks such as backfilling a void. To increase tractability, we may consider horizontal *strata* of open pit and underground extraction, where a stratum would include all blocks (or extraction activities) on the same level.

We seek a block sequencing policy that hedges against the possibility that our system experiences a significant geotechnical disruption. In a typical multi-stage stochastic program, the corresponding stochastic process is indexed by time. Here, however, the stochastic process is indexed by the *phase* of the blocks which we mine and extraction activities in which we engage. Ore grade and geotechnical uncertainties are revealed once we reach the blocks (or activities) in a particular phase. We describe a family of stochastic longest-path problems on an acyclic network to optimize block sequencing in which the timing of the geotechnical uncertainty is random. A geotechnical disruption can require that recourse decisions revisit previous strata to "correct" now-violated precedence constraints to maintain safe slope requirements or can require that we abandon certain structurally compromised parts of the mine. The recourse model captures this by having an appropriate scenario-dependent network topology.

CS: Applications in Natural Resources

Chair: Hector Ramirez

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Búzios, Brazil
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Accounting for Climate Change in a Stochastic Optimization Model in Forest Planning

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Abstract

Climate change will impact severely forest production in Portugal. In this paper we consider the important problem of medium term forest planning considering harvesting decisions in the presence of uncertainty due to climate change. For each time period the forest planner must decide which areas to cut in order to maximize expected net profit. We present an application in a eucalypt forest located in central Portugal where 32 climate change scenarios are used. First, we considered a deterministic model using a single climate scenario which used average values for all the parameters of the 32 climate scenarios (deterministic approach). Then a multistage stochastic model using the whole set of scenarios was developed and solved to determine optimal harvesting decisions under uncertainty. For comparison purposes, the harvest scheduling plan obtained in the deterministic approach was simulated for each of the 32 scenarios and compared with the solutions of the stochastic approach. We demonstrate the usefulness of the stochastic approach as it enables the planner to make more robust decisions based on the range of climate scenarios used.

Policy gradient for water reservoir management

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Abstract

Direct Policy Search methods (DPS) have shown being efficient to solve the non linear stochastic optimization problem of water reservoir management [2] [1].
The DPS methods optimize directly into the policy parameter within a given family of functions. The actual parametrization is evaluated by simulating over an ensemble of scenarios. Thus, no model for the random process is needed and the stochastic process is implicitly represented through simulation.
In the field of water reservoir operation design, stochastic dynamic programming (SDP) has been extensively used. This method imposes a time decomposition of the stochastic process to build the value functions. Thus, achieving a good modeling of the complex spatio-temporal correlation of the streamflow is tricky.
So far, DPS is still slow to converge because it used with inefficient optimization methods such as evolutionary algorithms. We propose a method using a gradient estimation to perform the optimization step. The gradient is estimated using the Reinforce algorithm [3]. This method does not require the derivative of the objective function but only the derivative of the policy function. The policy function used in our case is a neural network. A regularization method is proposed to improve the generalization of the policy obtained. This ensure to obtain good performance on a different ensemble of scenarios that the one used to perform the optimization.
Results on the real case of Kemano (British-Colombia, Canada) are presented and a comparison to SDP is performed. Results show efficiency of the method and it overcomes the results obtained with SDP thanks to the better uncertainty modeling.

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Assessing Fishery Sustainable Management and Re-building Strategies through Viability Theory

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Abstract

Stochastic viability theory provides a theoretical framework that (1) assesses the sustainability of fishery management strategies and (2) develops recovery plans for overexploited fisheries. The framework is constructed to deal with multiple competing objectives frequently not considered. In the first application, stochastic viability ranks management strategies according to their probability to sustain economic and ecological outcomes over time in the face of potential climate change. This approach is then extended to build frontiers of stochastic sustainable production representing the trade-offs between sustainability objectives at any risk level, given the current state of the fishery. The viability of effort and quota strategies to achieve multiple objectives is evaluated when catch and biomass levels have to be sustained. In the second application, a suitable stochastic bioeconomic dynamic permits simulation of diverse recovery plans, and solving a related stochastic optimization problem results in a recovery plan which minimizes the total cost of rebuilding. Both approaches are illustrated with Chilean fisheries and compared to other strategies commonly used.

TS: Risk-Averse Dynamic Optimization

Chair: Andrzej Ruszczynski

DYNAMIC RISK MEASURES FOR PARTIALLY OBSERVABLE MARKOV DECISION PROBLEMS

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Abstract

The theory of dynamic risk measures in discrete time has been intensively developed in recent years. We provide theoretical foundations of the theory of *process-based dynamic risk measures* for controlled stochastic processes by introducing a new concept of *conditional stochastic time consistency*. In this talk, we focus on the applications to the *Partially Observable Markov Decision Problems*.

ALGORITHMS FOR RISK-AWARE MARKOV DECISION PROCESSES

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Abstract

We motivate the importance of risk management in sequential decision making, and put forward a general model for risk-aware Markov decision processes (MDPs). We then describe several solution algorithms for risk-aware MDPs, covering both the time consistent and time inconsistent cases. First, we develop the convex analytic approach and infer some key results on the optimal policies for risk-aware MDPs. Second, we consider simulation-based algorithms for MDPs with Markov risk measures. Finally, we derive minimax DP equations for time inconsistent risk-aware MDPs and comment on methods for their solution. The talk concludes with some initial numerical results.

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Risk Averse Control of Diffusion Process

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Abstract

We introduce the concept of continuous-time Markov risk measure for diffusion process. We use it to formulate risk-averse control problem where the costs are incurred by controlled forward stochastic differential equation. Relying on the Markovian Structure of decoupled forward backward stochastic system, we obtain the corresponding dynamic programming equation. We also derive and verify the risk-averse Hamilton-Jacobi-Bellman equation. Finally, we show piecewise constant control can well approximate the optimal control. As a result, we can solve the system in discrete time.

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TS: Chance Constrained Optimization

Chair: Abdel Lisser

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Distributionally Robust Optimization with Principal Component Analysis

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Abstract

Distributionally robust optimization (DRO) has gained increasing popularity because it offers a way to overcome the conservativeness of robust optimization without requiring the specificity of stochastic optimization. On the computational side, many practical DRO instances can be equivalently (or approximately) formulated as semidefinite programming (SDP) problems via conic duality of the moment problem. However, despite being theoretically solvable in polynomial time, SDP problems in practice is computationally challenging and quickly becomes intractable with increasing problem size. In this paper, we propose a new approximation method to solve DRO problems with moment-based ambiguity sets. Our approximation method relies on principal component analysis (PCA) for optimal representation of variability in random samples. We show that the PCA approximation yields a relaxation of the original problem and derive theoretical bounds on the gap between the original problem and its PCA approximation. Furthermore, an extensive numerical study shows the strength of the proposed approximation method in terms of solution quality and runtime. For certain classes of robust conditional value-at-risk (CVaR) problems, the proposed PCA approximation using only 50% of the principal components provides a near-optimal solution (within 1%) with a one to two order of magnitude reduction in computation time.

References

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Confidence sets and chance constraints

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Abstract

We consider uniform confidence sets for chance constrained programs. The confidence sets are based on outer and inner approximations in probability. Two kinds of such approximations will be investigated in different settings. Furthermore, an adaptive approach for the successive improvement of constraint sets and optimal values will be suggested.

Stochastic geometric optimization with joint probabilistic constraints

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Abstract

This talk discusses geometric programs with joint probabilistic constraints. When the stochastic parameters are normally distributed and independent of each other, we approximate the problem by using piecewise linear functions, and transform the approximation problem into a convex geometric program. We prove that this approximation method provides a lower bound. Then, we design a sequential convex optimization scheme to find an upper bound. Finally, numerical tests are carried out on a stochastic shape optimization problem.

TS: SDDP for nonconvex problems

Chair: Andy Philpott

SDDP: Dealing with non-concave value functions

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Abstract

The reasons for non-concave value functions in medium-term hydro power planning (MTHP) optimizations can be manifold. In principle, SDDP requires concavity so it can not be applied to such problems. However, different authors have proposed some work-arounds which allows SDDP to be used for some types of problems [1, 2, 3, 4].
In this talk, first, a brief overview will be given about such work-arounds. Then, a measure of non-concavity [5] is proposed which allows to decide which work-around to use. Finally, a short case study is presented to illustrate the idea.

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Hybrid SDDP / machine learning approach to represent nonconvexities in multistage stochastic scheduling of energy resources

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Abstract

Multistage stochastic scheduling of energy resources are complex optimization problems that can be solved using the Stochastic Dual Dynamic Programming (SDDP) approach. This method uses the dual problem information to approximate a future cost function, which can be applied to represent the subsequent stages cost uncertainly in the current stage problem. A main drawback to SDDP approach is that cost functions are approximated by convex surfaces formed by piecewise hyperplanes that cannot present good approximations for nonconvex functions. On the other hand, Support Vector Regression (SVR) is a well-established machine learning approach to approximate general functions, formulated as a quadratic programming problem, which has advantages over other regression methods in respect to typical stochastic scheduling cost functions such as data dimensionality independence. On this basis, this paper proposes a new approach in which SDDP and SVR methods are combined to produce a modified SDDP algorithm in which nonconvex future cost functions can be represented by a SVR model. Therefore, the proposed SVR model is an extension of the standard SVR, incorporating SDDP cuts as soft constraints into the SVR cost function fit optimization problem.

Tartaruga - Monday, June 27, 2016 - 12:05/12:30 (25min)

Mixed Integer Dynamic Approximation Scheme for Non-Convex Dynamic Programs

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We present a variant of Stochastic Dual Dynamic Programming for nonconvex dynamic programming problems for which the Bellman functions are known to be monotonic. The algorithm, which we call MIDAS (Mixed Integer Dynamic Approximation Scheme), approximates the stage problems using mixed integer programming models. We describe the algorithm and discuss its convergence properties, and illustrate it applied to some non-convex problems in hydroelectric generation scheduling.

TS: Brazil's Oil Industry

Chair: Silvio Hamacher

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A lagrangean decomposition strategy for nonconvex bilinear problems applied to the refinery operational planning

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Abstract

We propose a two-stage stochastic nonlinear model for the refinery operational planning problem. The uncertainties in the problem are the quantity and quality of oil available to be used as raw material. The first-stage decisions are oil quantities to be acquired in advanced by means of long-term contracts. Second-stage decisions concern oil amounts bought in spot market, stream volumes, stream properties, and storage volumes. Many of the constraints used to model stream property balances are bilinear, which results in a nonconvex nonlinear problem. To efficiently solve this problem, we rely on a primal-dual decomposition approach that is based on the Lagrangean relaxation of the non-anticipativity conditions and the use of method-of-multipliers-based iterative method. Attempting to obtain globally optimal solutions for the dual subproblems is not computationally feasible, due to their nonconvex nature. Thus, we replace these subproblems with a Mixed Integer Programming (MIP) relaxation, which is based on a new reformulation of the Normalized Multiparametric Disaggregation Technique (NMDT). We show that our reformulation can be made arbitrarily good while preserving a reduced number of binary and continuous variables and constraints when compared to traditional NMDT approaches. Moreover, primal feasible solutions can be obtained by adequately fixing the first-stage variables using the dual information from the subproblems, allowing us to decompose the primal problem scenario-wise as well. Each of these primal subproblem are then solved using a nonlinear commercial solvers and are warm-started with solutions obtained from linear relaxations applying McCormick Envelopes. Numerical results with cases based on a Brazilian refinery data have shown promising results.

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Capacity Planning Under Uncertain Demand

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Abstract

Infrastructure decisions are usually more difficult to be taken by its profile, its inflexibility and by the countless uncertainties on a long term horizon. Increase, or in some cases, reduce the capacity of a certain knot in a distribution network is a decision that must be made in advance, customarily transcending the horizon of fixed planning, exposing the decision maker to a range of uncomfortable possibilities.
In this work is studied, in a global level, a capacity expansion plan for an engineer-to-order company in order to solve an expected future capacity deficit in November 2016, based on demand projections and finite capacity calculations. It is proposed a mathematical model to handle, approximate, one million and six hundred thousand variables, and with the challenge to elucidate the main trade-offs inherent to production. In addition it will be conducted a second study to see how the mathematical model behaves against uncertainties in demand and if the initial solution is sensitive to this variation. It is proposed a scenario generation technique to capture the oscillations of demand, weighs them according to their respective probabilities of occurrence and optimizes them simultaneously in an environment that includes all the uncertainties that are proven to impact the strategic decision.
By dealing with an optimization problem in discrete uncertainty scenarios, the equivalent deterministic model, responsible for the decision to increase capacity at the current time - the first stage - and its allocation responses as soon as known the uncertainty response – second stage - is growing rapidly and soon becomes evident as computationally unsolvable. To deal with this adversity, in this study it is used the Benders decomposition method, known as L-Shaped, and an additional technique to accelerate the convergence to the optimal solution, known as Multicut, which perform cutting plans in different ways.
This study demonstrate how a proper technique application lever a business in a competitive advantage.

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Oil Rig Planning and scheduling under uncertainty

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Abstract

One of the most important activities in the oil and gas industry is the intervention in wells for maintenance services, which is necessary to ensure the constant production of oil. These interventions are carried out by rigs that are available to attend to a large number of wells according to a service schedule. The rigs are limited and scarce resources with high operational costs. The production loss due to the well wait time results in huge revenue losses, making it necessary to optimize the rig fleet and the schedule. Furthermore, due to the variations in the intervention times of the rigs [1] and other uncertainties in the operations , it is desirable to apply techniques that are able to address the uncertain characteristics. Thus, planning and scheduling oil rigs consists of sizing the rig fleet and of finding the best schedule to service the wells, while considering uncertain intervention times of the rigs with the objective of minimizing the rig operating costs and the total production loss due to the time spent by the wells waiting for maintenance service in a planning horizon. This work proposes a two-stage stochastic programming model capable of efficiently solving this problem. This mathematical model extends the mathematical model proposed by Costa and Ferreira Filho [2]. Computational experiments were carried out using instances based on real cases in Brazil to evaluate the performance of the proposed model.

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MS: G. Bayraksan – Data-driven Methods

Chair: Anton Kleywegt

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Distributionally Robust Stochastic Programs via ϕ-Divergences: Properties and Characterization of Scenarios

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Abstract

Most of classical stochastic programming assumes that the distribution of uncertain parameters are known, and this distribution is an input to the model. In many applications, however, the distribution of uncertain parameters is not known. Distributionally robust stochastic programs (DRSP) form an ambiguity set of distributions to hedge against the uncertainty in the input distributions. In this talk, we consider distributionally robust stochastic programs (DRSP) formed via ϕ-divergences and examine various model properties. We discuss a classification of ϕ-divergences to elucidate their use for models with different sources of data and decision makers with risk preferences. We examine data-driven properties of these models such as value of collecting additional data and convergence. Then, we define the notions of "effective" and "ineffective" scenarios by considering if removal of a scenario changes the optimal value/solution. For DRSP formed via the variation distance (a special ϕ-divergence), we present easy-to-check conditions to identify effectiveness of scenarios. We illustrate our results on several problems. Computational results show that effective scenarios provide useful insight on the underlying uncertainties of the problem.

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Distributionally Robust Stochastic Programming

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Abstract

We discuss distributionally robust stochastic programming in a setting where there is a specified reference probability measure and the uncertainty set of probability measures consists of measures in some sense close to the reference measure. We consider law invariance of the associated worst case functional and discuss two basic constructions of such uncertainty sets. Finally we illustrate some implications of the property of law invariance.

Data and generalization in scenario optimization

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Abstract

Scenario optimization is a well recognized methodology for data-driven constrained stochastic optimization, where uncertainty in the constraints is described probabilistically. One assumes that a sample of contraints is known from previous experience, and optimize so that these constraints are satisfied. One fundamental issue of scenario optimization is then the evaluation of the generalization properties of the so-obained solution. One says that the scenario solution generalizes well if it satisfies most of the other constraints besides the collected sample.

Over the past ten years, the main theoretical investigations on the scenario approach have related the generalization property of scenario solutions to the number of optimization variables, [1]. As is intuitive, the larger the size of the optimization domain, the more the degrees of freedom and the lesser the generalization ability.

This talk breaks into the new paradigm that the generalization level is a-posteriori evaluated after that the solution is computed and the actual number of so-called support constraints is assessed (wait-and-judge). We present a new theory which shows that a-posteriori observing k support constraints allows one to draw conclusions almost as strong as those obtainable when the problem is from the outset in dimension k. This permits one to draw evaluations that largely outperform those carried out based on the number of optimization variables.

In the talk, we shall also hint at the generality of this result whose cardinal elements extend as far as to cover non-convex problems in infinite dimensional spaces.

References

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Algorithms for stochastic optimization with expectation constraints

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Abstract

We present a new class of stochastic approximation (SA) algorithms to minimize different convex and structured nonconvex optimization problems subject to expectation constraints. We show that these algorithms exhibit optimal convergence behavior both in expectation and with high probability under different conditions. Some numerical results are provided for these algorithms for solving certain portfolio management and machine learning problems.

MS: D. Brown – Stochastic Dynamic Programming

Chair: David Morton

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Approximations to Stochastic Dynamic Programs via Information Relaxation Duality

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Abstract

In the analysis of complex stochastic dynamic programs (DPs), we often seek strong theoretical guarantees on the suboptimality of heuristic policies: a common technique for obtaining such guarantees is perfect information analysis. This approach provides bounds on the performance of an optimal policy by considering a decision maker who has access to the outcomes of all future uncertainties before making decisions, i.e., fully relaxed non-anticipativity constraints. A limitation of this approach is that in many problems perfect information conveys excessive power to the decision maker, which leads to weak bounds. In this paper we leverage the information relaxation duality approach of Brown, Smith, and Sun (2010) to show that by including a penalty that punishes violations of these non-anticipativity constraints, we can derive stronger bounds and *analytically characterize* the suboptimality of heuristic policies in stochastic dynamic programs that are too difficult to solve. We study three challenging problems: stochastic scheduling on parallel machines, a stochastic knapsack problem, and a stochastic project completion problem. For each problem, we use this approach to derive analytical bounds on the suboptimality gap of a simple policy. In each case, these bounds imply asymptotic optimality of the policy for a particular scaling that renders the problem increasingly difficult to solve. As we discuss, the penalty is crucial for obtaining good bounds, and must be chosen carefully in order to link the bounds to the performance of the policy in question. Finally, for the stochastic knapsack and stochastic project completion problems, we find in numerical examples that this approach performs strikingly well.

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Data-Driven Distributionally Robust Optimization Using the Wasserstein Metric

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Abstract

We consider stochastic programs where the distribution of the uncertain parameters is only observable through a finite training dataset. Using the Wasserstein metric, we construct a ball in the space of (multivariate and non-discrete) probability distributions centered at the uniform distribution on the training samples, and we seek decisions that perform best in view of the worst-case distribution within this Wasserstein ball. The state-of-the-art methods for solving the resulting distributionally robust optimization problems rely on global optimization techniques, which quickly become computationally excruciating. In this paper we demonstrate that, under mild assumptions, the distributionally robust optimization problems over Wasserstein balls can in fact be reformulated as finite convex programs—in many interesting cases even as tractable linear programs. Leveraging recent measure concentration results, we also show that their solutions enjoy powerful finite-sample performance guarantees. Our theoretical results are exemplified in mean-risk portfolio optimization, statistical learning and uncertainty quantification.

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A Polyhedral Approach to Online Bipartite Matching

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Abstract

We study the i.i.d. online bipartite matching problem, a dynamic version of the classical model where one side of the bipartition is fixed and known in advance, while nodes from the other side appear one at a time as i.i.d. realizations of an underlying distribution, and must immediately be matched or discarded. We consider various relaxations of the set of achievable matching probabilities, introduce star inequalities and their generalizations, and discuss when they are facet-defining. We also show how several of these relaxations correspond to ranking policies and their time-dependent generalizations, and discuss the empirical performance of the various bounds and policies implied by the relaxations.

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Influence Diagrams and Information Relaxations

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Abstract

Influence diagrams are a popular approach for dynamic decision-making within the framework of graphical models. As is the case with dynamic programming (DP), influence diagrams suffer from the curse-of-dimensionality so that only relatively small problem sizes are exactly solvable. In this talk we will discuss how the recently developed information relaxation approach for DP can be used to evaluate sub-optimal policies for these problems.

MS: D. Woodruff – Applications of SP in Natural Resources

Chair: James Luedtke

Things that Make Applications of Stochastic Programming in Natural Resources Special

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Abstract

In this introductory talk, we will start from the viewpoint of decision makers in natural resource domains and examine the characteristics of the uncertainty they face and the decisions they make. Many of these problems naturally have uncertainty that should be modeled spatially as well as over time. The multi-stage aspects of the problem are central. For many applications there are forecasts, which should be included in the decision process. Finally, this is the area where so-called decision dependent random elements were first introduced and remain part of the landscape.

Probabilistically Constrained Stochastic Programming for Wildfire Initial Response Planning

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Abstract

We present an application of stochastic programming to strategic wildfire resource deployment planning for initial response for a given fire season. This approach combines fire behavior simulation, wildfire risk, probabilistically constrained stochastic integer programming, and the level of risk the fire manager is willing to take when making deployment plans. The methodology was applied to a study of Texas District 12, a part of the fire planning unit located in East Texas which is managed by the Texas A&M Forest Service. The study demonstrates the effect of the fire manager's level of risk on deployment decisions in terms of the firefighting resources positioned at each operations base, fires contained and their associated wildfire risk, and total containment cost. For example, the results show that the total number of fires contained and their associated total expected cost increase when the fire manager's level of risk is relatively high. In this case, relatively more firefighting resources are deployed to operations bases in areas with high wildfire risk and need for initial response.

A two-stage stochastic model for open pit mine planning under geological uncertainty

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Abstract

In open pit mining operations, planners must periodically prepare what is known as strategic mine plan. This is a production schedule for the remaining life of the mine that defines which area of a mining reserve will be extracted, in what years this extraction will take place, which resources will be used for the extraction, and how the extracted material will be treated or processed. These decision are based on the information of a discretized representation of the mining reserve, known as block models. Block models usually include a single estimation of the geological characteristics of the rock, particularly ore grades. However, most of these block-models are constructed by averaging conditional simulations of the mine, based on the information from drill-holes.

In this work, we present a two-stage stochastic model for this problem, that consider the different simulations of an ore body. In a first stage, the scheduling decision is taken, assigning an extraction period of each region of the mine. In a second stage, when the true ore grade is revealed, the model decides how to treat each individual block. Our proposed integer programming model can be reformulated as a large-scale precedence constrained knapsack problem, that can be (near-optimally) solved using decomposition techniques. This allow to solve real instances of the problem in a few hours.

We apply this model to a copper mine in Chile. We compare the resulting NPV from the deterministic solution (expected value solution), the best-possible plan for each scenario (wait-and-see solution), and our proposed model. Computational experiment shows that, in these data, the proposed two-stage stochastic model captures a 70% of the gap in between the wait-and-see and the deterministic solution, by providing more robust long-term mine plans.

Stochastic Unit Commitment: Scenario Generation, Scalable Computation, and Experimental Results

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Abstract

The objective in stochastic unit commitment is to optimize day-ahead and intra-day electricity generation schedules taking into account the uncertainty associated with both load and renewables production. The resulting large scale stochastic mixed-integer programming problems present serious computational challenges. We address these challenges using scenario-based decomposition techniques, in particular variants of progressive hedging, and modest parallel computing resources, achieving tractable run-times on moderate-scale instances. Our solver is embedded in a stochastic simulation environment, which is used to validate the model and to quantify cost savings relative to a standard deterministic unit commitment model. We describe experimental results on an ISO-NE test case, in addition to a smaller WECC-240 case. We also describe challenges and novel solutions to probabilistic scenario generation, required to represent the uncertainty associated with load and renewables production. to address more routine and commonly-occurring conditions.

TS: ALM and Long-Term Financial Optimization

Chair: Giorgio Consigli

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Asset Liability Management applied to a traditional open annuity plan

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Abstract

For insurance companies, building a sound annuity plan is a challenging problem, due to the need of stipulating the contractual terms with many years of anticipation. For this reason, such products must be managed according to the best practice in the market. When it comes to annuity plans, this best practice is called Asset Liability Management (ALM) which corresponds to the exercise of managing risks resulting from disruptions that affect differently the assets and the liabilities. This work presents an ALM model via stochastic optimization with chance constraints and dynamic induced by a rolling horizon. The model is applied to an annuity plan with minimum guarantee of future payment. Additionally, the proposed method is compared with its deterministic version and some further analysis are done.

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A Stochastic Optimization Model for the Life-Cycle Consumption-Investment Problem

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Abstract

We consider a life-cycle consumption-investment problem from the perspective of an individual. In such problems, the individual receives a monthly income and must decide how much to consume and how much to invest for the future. The benefits of the monthly consumption and of accumulating wealth at the time of retirement are measured by utility functions. Uncertainty arises both from the income stream as well as from the investment returns. This class of problems is well known in Economics, starting with the classical work by Merton (1971), and closed form solutions are available. However, these models often rely on some restrictive assumptions, without which the closed form expressions are not valid. Recents efforts such as Bick, Kraft and Munk (2013) have attempted to derive models that can deal with more general problems.

In this talk we formulate the life-cycle consumption-investment problem as a multi-stage stochastic program. Such a formulation allows us to consider the dynamic aspects of the problem without the simplifying assumptions typically made in the literature. To construct the scenario tree, we discretize the stochastic processes representing income stream and investment returns. As the number of stages in the problem is relatively large, we solve the problem using the Stochastic Dual Dynamic Programming algorithm. We discuss some modeling choices that are required to efficiently use that algorithm in this context.

We present numerical results for problems from the literature and use existing Economics models as benchmarks for comparison. We then present more complex models that cannot be tackled by standard tools, and show that the output of the multi-stage model yields policies that can be implemented.

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Scenario Tree Reduction Methods through Changing Node Values and Their Application in Asset Allocation

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Abstract

To develop practical and efficient scenario tree reduction methods, we introduce a new methodology which allows for changing the node values, and a simple and easy-to-calculate distance function to measure the difference between two scenario trees. Based on minimizing the new distance, we first construct a primitive scenario tree reduction model which also minimizes the Wasserstein distance between the reduced tree and the initial tree. To make it appropriate for the reduction of general multi-stage scenario trees, an improved model based on the primitive model is constructed which not only performs well for the multi-stage scenario tree reduction but also is supported theoretically by the stability results of stochastic programs. Depending on how to solve the improved model, we design a stage-wise algorithm which is superior to the simultaneous backward reduction method in terms of computational complexity. We further design a multi-stage scenario tree reduction algorithm with a pre-specified distance by utilizing the stability results of stochastic programs. Numerical experiments and solution of multi-period asset allocation problems demonstrate the practicality, efficiency and robustness of proposed reduction models and algorithms.

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Optimal dynamic pension fund liability replication via stochastic programming

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Abstract

Pension funds (PF) and life insurers (LI) acting as pension providers in complementary and individual pension schemes, face an asset-liability management problem in which funding conditions depend on the effectiveness of liability hedging strategy and the generation of sufficient return and liquidity surpluses. Specifically in the case of a defined benefit (DB) plan, a PF manager will be requested to maintain the market value of her asset portfolio at a level sufficient to replicate the future obligations, represented by pension payments which tipically will be inflation-adjusted and subject to different indexations rules. We present an approach based on dynamic stochastic programming where the PF will look for the minimal cost portfolio needed to replicate a long-term flow of pension payments. Liability hedging effectiveness in DB schemes implies portfolio immunization from inflation, interest rates and longevity risk.

TS: Bounds and Decomposition Methods

Chair: Francesca Maggioni

Decomposition methods for conic multistage stochastic programs, with applications to SDP/SOCP relaxations of non convex problems

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Abstract

We study decomposition algorithms for the conic multistage programs

$$\begin{array}{ll} min & c_1^\top x_1 + \mathbb{E}\left(h_2(x_1,\xi_2)\right) \\ s.t & \\ & P_1\, x_1 = p_1, \\ & A_1^1\, x_1 \succeq_{K_1^1} b_1^1, \\ & \dots \\ & A_1^m x_1 \succeq_{K_1^m} b_1^m, \end{array} \tag{1}$$

$h_T \equiv 0$ and for $t = T-1, ..., 2$

$$h_t(x_{t-1},\xi_t) = \begin{array}{ll} min & c_t^\top x_t + \mathbb{E}\left(h_{t+1}(x_t,\xi_t)\right) \\ s.t & \\ & P_t x_t = p_t - Q_t x_{t-1}, \\ & A_t^1\, x_t \succeq_{K_t^1} b_t^1 - B_t^1 x_{t-1}, \\ & \dots \\ & A_t^m x_t \succeq_{K_t^m} b_t^m - B_t^m x_{t-1}, \end{array} \tag{2}$$

where $K_t^1, ..., K_t^m$ are closed pointed convex cones for all $1 \le t \le T$, and $u \succeq_K v$ is a notational shorthand for $u - v \in K$.
The extensions discussed in this talk are motivated by the successful applications of semi-definite and second-order cone relaxations to difficult combinatorial and general non-convex problems. Moreover, many of those relaxations have been shown to be exact in some cases, and otherwise they serve as starting points for more complex techniques.
In contrast to the linear case, the future cost functions are not longer piecewise linear, but general convex functions. We provide necessary and sufficient conditions for the convergence of a concrete approximation algorithm based on (linear) Bender cuts. These cuts are obtained solving conic optimization problems, for most of which there exist efficient interior-point algorithms. We also discuss on the computational overhead introduced by the conic constraints.

Reduced cost based variable fixing in Stochastic Programming: a computational study

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Abstract

Stochastic programs, integer ones in particular, are usually hard to solve when applied to realistically-sized instances. A common approach is to consider the simpler deterministic version of the formulation, even if it well known that the solution quality could be arbitrarily bad. In this talk, we aim to identify meaningful information, which can be extracted from the solution of the deterministic problem, in order to reduce the size of the stochastic one. We show how and under which conditions the reduced costs associated to the variables in the deterministic formulation can be used as an indicator for excluding/retaining decision variables in the stochastic model. We introduce the *Loss* due *Variable Fixing* based on *Reduced Costs* (*LVFRC*), computed as the difference between the optimal values of the stochastic problem and its reduced version, called *Variable Fixing* based on *Reduced Costs*, obtained by fixing a certain number of variables. We relate the *LVFRC* with existing measures and show how to select the set of variables to fix. We then illustrate the accuracy of the new measure and procedure by applying them to problems taken from the literature, including the instances in the SIPLIB and some large-sized ones of stochastic TSP [1].

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Accelerating and automatic tuning for Progressive Hedging

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Abstract

Progressive Hedging (PH) is a scalable and effective approach for solving large stochastic programming problems through scenario-based decomposition. However, PH is not without its challenges: it is sensitive to the selection of key tuning parameters (notably ρ) and for many real-world problems can exhibit slow convergence. In this work we present new approaches for accelerating convergence and improving tuning of PH by propagating key information across the scenarios. Similar to Cross Decomposition [1], this extension to the standard PH algorithm evaluates solutions from the individual scenario subproblems in the context of each of the other subproblems to generate global information that can then be applied to all subproblems. Infeasible subproblems generate global Benders-like feasibility cuts. Solutions that are feasible for all scenarios yield valid upper bounds for the original stochastic program, which in turn lead to valid "no-good" cuts that greatly reduce cycling observed in PH applied to mixed-integer problems. Finally, we demonstrate how dual information gained from these subproblems can also be used to generate effective variable-specific values for the PH update parameter, ρ. This extension relies on additional subproblem solves that can be run in parallel and asynchronously from the main PH algorithm, providing significant benefit without significantly impeding the normal progress of the core PH algorithm.

We have implemented this extension as a plug-in to the PH algorithm implemented in the Pyomo open source optimization modeling environment, and will present the impact of the extension on stochastic mixed integer problems drawn from electric grid operations problems (stochastic unit commitment and contingency-constrained optimal power flow).

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Bounding Multistage Risk-averse Stochastic Programs

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Abstract

Multistage risk-averse stochastic programs, where the decision maker is very concerned about large losses, can be very hard to be solved in real-life decision problems. Approximations techniques can be useful in practice allowing to get quick information about the objective function even in the case the problem is not solvable.

In this talk new bounding approximations for two and multistage risk-averse convex stochastic programs are presented. Bounds in the two-stage case are based on convex order dominance and in the multi-stage case on multi-period convex order dominance. In particular lower bounds are obtained by approximating the continuous probability distribution with a barycentric approximation and upper bounds by dissecting the support of the probability into simplices. Different risk measures which satisfy the required properties are considered and discussed. Numerical results will be illustrated on a multistage risk-averse inventory problem.

TS: Applications of Stochastic Programming

Chair: James Luedtke

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On the Solution Quality Assessment in Multi-stage Stochastic Optimization Under Different Model Representations

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Abstract

Within the stochastic programming literature, sampling-based decomposition algorithms (SBDAs) have been successfully employed to approximately solve multi-stage stochastic optimization models [1], [2], [3]. In such contexts, SBDAs are generally applied to a sample average approximation (SAA) created from the original problem. When SBDAs are applied to SAAs it is important to assess the solution quality that can be obtained from the resulting policy applied to out-of-sample forward paths and scenario trees [4], [5]. In this work, we model a power generation scheduling problem using different aggregated system representations and solve them via a SBDA implementation [6]. We apply variance-reducing sampling methods to investigate solution quality as the model time horizon grows combined with different instance sizes and initial assumptions.

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Design Optimization in Multistage Stochastic Programming

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Abstract

We discuss two applications that involve both first stage design decisions and multistage operations decisions under uncertainty. The first application involves using autonomous underwater vehicles to help protect an arctic drilling platform from ice floes, where the arrival process governing the ice floes is stochastic. The second application involves designing a microgrid by choosing a combination of diesel generators, batteries, and photovoltaic systems, where the electric load that the microgrid serves and the solar irradiance that powers the photovoltaic systems are stochastic.

These two applications involve discrete decisions in both the first stage design and in the multi-stage operations. In both problems we describe how we compute optimistic bounds through coarser approximations in time and stochastics, and how we optimize and evaluate the performance of design decisions using simpler operations policies.

This talk includes joint work with John Hasenbein, Fang Lu, and Alex Zolan.

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Stochastic Dynamic Linear Programming: A Sequential Sampling Algorithm

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Abstract

To tackle high-dimensional multistage stochastic optimization problem, we will present a sequential sampling method which we refer to as the Stochastic Dynamic Linear Programming. This algorithm is a dynamic extension of regularized two-stage stochastic decomposition for stagewise independent multistage stochastic linear programs. The algorithm relies on empirical estimates of probability estimates, and thereby avoids the need for a-priori knowledge of probability distribution. We will present the convergence analysis of the algorithm and computational results on a short-term distributed storage control problem. In our computational experiments, we will compare our algorithm with the stochastic dual dynamic programming (SDDP) which has been effectively applied in planning power systems operations. These results show that our distribution-free approach provides prescriptive solutions and values which are statistically indistinguishable from those obtained from SDDP, while improving computational times significantly.

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Power Flow Models with Computationally Tractable Joint Chance Constraints

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Abstract

We present an economic dispatch model that incorporates uncertainty in power generation and demand and enforces a joint chance constraint to limit the probability of one or more line failures. A key feature of our model is that the chance constraint limits the probability of having a line fail, rather than limiting the probability that the flow on a line exceeds a fixed threshold as in [1], a condition that is used as a proxy for line failure. The model allows introducing a system-wide risk measure into power flow planning that has the potential to reduce the risk of line failures. With a limit on this system-wide risk measure enforced, one may also consider relaxing the line flow limits, and we demonstrate that doing so can lead to solutions that are simultaneously more reliable and cost-efficient compared to using a deterministic model or a model with chance constraints on line limits. With the assumption that the uncertain elements are normally distributed, we derive a computationally tractable method for solving the proposed model, and demonstrate that it can solve instances of the problem having thousands of lines and buses in seconds. We also extend the model and the algorithm to solve enforce the so-called $N-1$ reliability condition, which enables protecting against exogenously created component failures.

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TS: Mixed-Integer Stochastic Programming

Chair: Miguel Lejeune

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A new method for optimizing the non-anticipative Lagrangian dual of a stochastic mixed-integer program

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Abstract

We present a new primal-dual decomposition method for computing the value of the Lagrangian dual that arises from relaxation of the non-anticipativity constraints of a stochastic mixed-integer program (SMIP). The new method is based on an integration of the Progressive Hedging (PH) and the Frank-Wolfe (FW) methods, and is referred to as FW-PH. The deterministic equivalent (DE) form of a SMIP typically lacks convexity due to the integrality restrictions. The application of PH to SMIPs is, consequently, not theoretically supported. Thus, PH applied to a SMIP is understood as a heuristic approach without convergence guarantees. Although Lagrangian bounds may be computed after each PH iteration, these bounds often show limited improvement with increasing number of iterations, and the amount of improvement is highly sensitive to the value of the PH penalty parameter. Motivated by these observations, we integrate the PH method with FW, so that the generated sequence of Lagrangian bounds is guaranteed to converge to the optimal Lagrangian bound for any positive-valued PH penalty parameter. In the FW-PH method, approximate PH primal updates are carried out using a FW-based approach, with approximation errors measured by the so-called FW gap. The new method is shown to be theoretically supported, by integration of established theory for alternating direction method of multipliers (ADMM), of which PH can be viewed as a special case, and the FW method. It is also practically implementable due to its use of the FW gaps to quantify approximation errors. We present data from numerical experiments based on the application of FW-PH and the PH method to instances available from the SIPLIB library (www.isye.gatech.edu/∼sahmed/siplib/). Several penalty parameter values are considered for each problem, to allow a fair comparison of the two methods. In contrast with PH, the Lagrangian bounds generated with FW-PH improve consistently with an increasing number of iterations and over a wide range of penalty parameter values.

Envelope methods for stochastic mixed-integer programming problems.

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Abstract

Envelope methods are based on including a regularizing/stabilizing term in the objective function. We will discuss their use in the context of two types of Stochastic Mixed-Integer Programming (SMIP) algorithms: progressive hedging and stochastic decomposition. The former is a deterministic algorithm, whereas, the latter is a sampling-based algorithm. Both algorithms have proven to be successful for continuous SLP models, while their use for SMIP models have been based on heuristics. In this talk we will discuss the convergence of these methods for SMIP problems and present computational results as well.

Multistage Stochastic Mixed-Integer Linear Programming under Endogenous and Exogenous Uncertainties

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Abstract

We address the modeling and solution of multistage stochastic mixed-integer linear programming problems involving endogenous and exogenous uncertain parameters. We propose a composite scenario tree that contains both types of parameters. We then present new theoretical model-reduction properties to drastically reduce the number of non-anticipativity constraints. Lagrangean decomposition and a sequential scenario decomposition heuristic are used to solve large-scale problem instances.

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MINLP Models and Algorithms for Medical Evacuation Missions under Uncertainty

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Abstract

We propose MINLP optimization models with endogenous and/or exogenous uncertainty for the medical evacuation (MEDEVAC) of soldiers from the battlefield. The objective is to maximize the expected number of high-priority casualties that can be evacuated with air-ambulances within one hour. We propose a series of restriction and relaxation conic MINLP problems that provide lower and upper bounds, We also design a new spatial branch-and-bound algorithm. Computational results based on real-data are reported.

TS: SDDP - Risk Aversion

Chair: Luiz Carlos Costa Jr.

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On the solution variability reduction of stochastic dual dynamic programming applied to energy planning

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Abstract

In the hydrothermal energy operation planning of Brazil and other hydro-dependent countries, Stochastic Dual Dynamic Programming (SDDP) computes a risk-averse optimal policy that often considers river-inflow autoregressive models. In practical applications, these models induce an undesirable variability of primal (thermal generation) and dual (marginal cost and spot price) solutions that are highly sensitive to changes in current inflow conditions. This work proposes two differing approaches to stabilize SDDP solutions to the energy operation planning problem: the first approach regularizes primal variables by considering an additional penalty on thermal dispatch revisions over time, and the second approach indirectly reduces thermal generation and marginal cost variability by disregarding past inflow information in the cost-to-go function and compensates with an increase in risk aversion. For comparison purposes, we assess solution quality with a set of proposed indexes summarizing each important aspect of a hydrothermal operation planning policy. In conclusion, we show that it is possible to obtain high-quality solutions in comparison to current benchmarks with significantly reduced variability.

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A two-level SDDP solving strategy with risk-averse multivariate reservoir storage levels for long term power generation planning

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Abstract

Power generation planning in large-scale hydrothermal systems is a complex optimization task, specially due to the high uncertainty in the inflows to hydro plants. Since it is impossible to traverse the huge scenario tree of the multi-stage problem, stochastic dual dynamic programming (SDDP) is the leading optimization technique to solve it, originally from an expected-cost minimization perspective. However, there is a growing need to apply risk-averse formulations to protect the system from critical hydrological scenarios. This is particularly important for predominantly hydro systems, because environmental issues prevent the construction of new large reservoirs, thus reducing their water regulating capability. This work proposes a two-level SDDP / Benders decomposition approach to include risk-aversion in power generation planning. The upper level problem is a SDDP solving strategy with expected-cost minimization criterion, where recourse functions for each time step are built through forward/backward passes. The second level consists in multi-period deterministic optimization subproblems for each node of the scenario tree, which are solved to ensure a desired level of protection from a given critical scenario several months ahead. We apply an inner iterative procedure for each stage/scenario of the overall SDDP approach, where feasibility cuts for the feasible region of the second-level subproblems are included in the upper level problem. Such cuts yield the so-called risk-averse storage level surfaces, which are multidimensional rule curves for reservoir operation in order to ensure that the policy provided by the SDDP algorithm becomes risk-averse against such critical scenarios.

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Risk-constrained dynamic asset allocation via stochastic dual dynamic programming

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Abstract

Latest approaches in the literature of Stochastic Dynamic Dual Programming (SDDP) introduce risk aversion via time consistent dynamic risk measures. The objective function is defined as a recursive formulation of a one-period coherent risk measures, usually the convex combination of expectation and Conditional Value at Risk (CVaR). The recursive model ensures time consistent policies and has a suitable economic interpretation of a certainty equivalent, see [1]. In practical applications however, a decision maker must define the relative weights between expectation and CVaR to represent his risk aversion, which is non-intuitive user-defined risk aversion parameter.

In this work, we propose an asset allocation model motivated by the actual decision process in the financial market. Hedge funds hire managers to propose trading strategies that maximize expected returns while risk departments impose constraints to strategies with a high level of risk. We focus our developments on risk-constrained models arguing it is reasonable to assume that an investor knows how much he is willing to lose in a given period. Our approach assumes a Markov dependence of asset returns and imposes one-period CVaR constraints ensuring a relative complete recourse time consistent model. As opposed to recursive risk measures in the objective function, our model has a straightforward lower bound, considering maximization problem, and a direct way of representing the risk-reward trade-off in a time varying efficient frontier.

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Implementation and assessment of alternative risk aversion methodologies for large scale stochastic hydrothermal scheduling

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Abstract

This paper compares three analytical approaches to represent risk aversion in stochastic hydrothermal scheduling: (i) convex combination of expected value and CVaR of operation costs in the objective function; we show that this approach is a special case of importance sampling on the inflow probability distributions and, from that, we derive a practical procedure to calculate the exact upper bound of the CVaR-based SDDP recursion; (ii) representation of unserved energy costs as a piecewise linear function, where the first segment represents the "economic" value of energy shortage whereas the second segment ensures a CVaR-based reliability target; this is calculated by a iterative line search / SDDP procedure; and (iii) use of feasibility cuts to represent a "risk aversion surface" for storage values at each stage that ensures a given supply reliability target. The feasibility cuts are calculated with a hybrid stochastic/robust optimization scheme.

These approaches are compared in terms of execution time, ease of calibration and other indices for a configuration of the Brazilian power system.

TS: Unit Commitment under Uncertainty

Chair: Erlon Finardi

Eventual convexity for probabilistic constraints

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Abstract

Probabilistic constraints are an interesting modeling tool when dealing with uncertainty in decision making problems. Motivated by problems from unit-commitment, convexity of the feasible set of decisions is a welcome feature. In several situations this convexity can depend on the requested safety level. In this talk we will discuss several recent contributions that allow asserting convexity provided that the requested safety is above a given computable threshold.

Voltage-aware chance-constrained optimal power flow and unit commitment

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Abstract

We present new theoretical convexity results for nonlinear Gaussian chance constraints [1] which permit us to extend the standard DC power flow approximation to account for voltage and reactive power under the chance-constrained optimal power flow model proposed by Bienstock, Chertkov, and Harnett [2]. The resulting short-term planning model is computationally tractable via second-order cone programming and may incorporate discrete decisions such as unit commitment. We aim to present computational experiments on benchmark test systems.

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Stochastic Hydrothermal Unit Commitment via Multi-level Scenario Tree

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Abstract

In Energy Optimization, the stochastic hydrothermal unit commitment is a very practical and important problem, since for example, the Independent System Operator (ISO) needs to take decisions in advance regarding which units will be on or off. However, at the time a decision is taken, the ISO does not know the demand and wind generation levels, which affect directly the commitment of the units.

We propose a novel solution strategy based on a multi-level scenario tree approach, where decisions are separated into two groups, related to strategic and operational levels. Strategic decisions are the on/off units' status taking into account the startup costs and minimum up- and down-time constraints. Once the ISO decides which units will be on/off, operational decisions regarding the generation levels that minimize the operational costs can be taken. The overall approach, which relies on Benders decomposition, considers the reservoir inflows and wind generation as the random variables of the problem.

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Hydrothermal Unit Commitment Subject to Uncertain Demand and Water Inflows

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Abstract

We study stochastic Unit Commitment problems where uncertainty concerns water availability in reservoirs and demand (weather conditions), as in the highly hydro-dependent Brazilian system. We use the Lagrange Relaxation as decomposition strategy and recovery the primal solution by means of Lagrangian heuristics. Different strategies of decomposition schemes are assessed (space and scenario approaches) for these large-scale mixed-binary linear programming problems. The results are evaluated by means of the produced lower bound, quality of the solutions provided by Lagrangian heuristics and running time.

Plenary: Risk-Averse Dynamic Optimization and Control — Andrzej Ruszczynski

Chair: Rene Henrion

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Risk-Averse Dynamic Optimization and Control

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Abstract

We shall focus on modeling risk in multistage decision problems and discuss fundamental properties of dynamic measures of risk. Special attention will be paid to the local property and the property of time consistency. Next, we shall review solution methods for multistage risk-averse optimization and we shall discuss nested and scenario decomposition methods. Special attention will be paid to risk-averse control of Markov systems. We shall refine the concept of time consistency for such systems, introduce the class of Markovian risk measures, and derive their structure. This will allow us to derive a risk-averse couterpart of dynamic programming equations. Then we shall extend these ideas to partially-observable systems and continuous-time Markov chains and derive the structure of risk measures and dynamic programming equations in in these cases as well. In the last part of the talk, we shall discuss risk-averse control of diffusion processes and present a risk-averse counterpart of the Hamilton–Bellman–Jacobi equation. Finally, we shall discuss solution methods for risk-averse control problems.

CS: Applications in Finance

Chair: Frantisek Zapletal

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Galerkin's method applied to the optimal asset allocation problem

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Abstract

For financial institutions, to appropriately choose an investment portfolio is a challenging problem. In general, companies seek investments which offer acceptable returns while minimizing the risks associated with market fluctuations. Handling that choice in a tractable and efficient way often makes this problem nontrivial, especially when considering dynamically the uncertain nature of the assets. This work proposes a Galerkin approach to approximately solve the stochastic optimization portfolio problem. With this strategy exogenous information, available in the form of visions of the market experts, can be incorporated. When compared with the multistage formulation, the feasible set is smaller, but still realistic. Additionally, the proposed method is compared with its equivalent deterministic version by standard and AVaR deviation. The study finishes with considerations regarding the method and possible future work.

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Analysis of Intraday Data Effects on Two-Stage Risk-Averse Portfolio Optimization

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Abstract

This study examines the application of risk-averse optimization techniques to daily portfolio management. First, we develop efficient clustering methods for scenario tree construction. Then, we construct a two-stage stochastic programming problem with conditional measures of risk, which is used to re-balance the portfolio on a rolling horizon basis, with transaction costs included. Finally, we present an extensive simulation study on both interday and high-frequency intraday real-world data of the methodology.

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Decision of a Steel Company Trading with Emissions

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Abstract

We formulate a Mean-CVaR decision problem of a production company obliged to cover its CO2 emissions by allowances. Certain amount of the allowances is given to the company for free, the missing/redundant ones have to be bought/sold on a market. To manage their risk, the company can use futures and options, in addition to spot values of allowances. We solve the problem for the case of an existing Czech steel company for different levels of risk aversion and different scenarios of the demand. We show that the necessity of emissions trading generally, and the risk caused by the trading in particular, can influence the production significantly even when the risk is decreased by means of derivatives.

CS: Sampling Methods

Chair: Urmila Diwekar

Novel Sampling Technique for High dimensional stochastic optimization/Stochastic Programming problems.

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Abstract

Uncertainty is essence of real world optimization problem. Computational speed is critical in optimizing large scale stochastic problems. The major bottleneck in solving large scale stochastic optimization/stochastic programming problems is the computational intensity of scenarios or samples. To this end, this paper presents a novel sampling approach. There are two important properties for sampling randomness and uniformity. It is the uniformity that is important for accuracy of the sampling. Latin Hypercube sampling (LHS) provide good convergence rate as compared to random Monte Carlo simulations but LHS shows uniformity in single dimension only. For Multi Dimension it computes stratified sampling for each uncertainty but randomly pairs to form a K dimensional sample set. Due to this random combination; good uniformity for single dimension is lost for K dimension. Furthermore quasi random sequences like Hammersley, sobol, and Halton sequences show better uniformity in k-dimensions but are not one dimensionally uniform. For Quasi Monte Carlo sequence sampling pairings are done as per Hammersley or Sobol sequence points to form a sample set of K dimension. For higher dimension (more than 40) some of these quasi-random sequences like Hammersley and Halton show clustering and correlation pattern effects due to exponential increase in prime base. This pattern can be broken by coupling LHS with HSS. Similarly Sobol sequence sampling is not linked to the prime base so for dimension more than 40 there are no clustering or correlation patterns upto 100 variables. In this work, we combine one dimensional uniformity of LHS with k-dimensional uniformity of sobol to generate a new sampling called LHS-Sobol sampling. This sampling breaks the correlation patterns for sobol and shows superior convergence for larger dimensions. This sampling plays an important role in financial modeling .

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Stochastic methods for Data Analytics

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Abstract

In today's' dynamic environment, It is important for the decision makers to situate decision- making under uncertainty in the analytics space. A nalytics are often divided into three categories: descriptive, predictive and prescriptive. Descriptive analytics answers the question: "What has happened in the past?" Predictive analytics answers the question: "What is likely to happen in the future" or alternatively" What is the set of possible futures?" Finally, prescriptive analytics provides the business users with suggestions on "What should we do?" or "What is the set of possible decisions and their implications?" Decision-making under uncertainty includes all three categories. There are generally two methods to solve problems in analytics space i.e deterministic and uncertain. This talk will emphasize the stochastic methods used for uncertain problem solving in data analytic domain .

Student Prize Finalists Presentations

Chair: Suvrajeet Sen

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Time-consistent approximations of risk-averse multistage stochastic optimization problems

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Abstract

In this paper we study the concept of time consistency as it relates to multi-stage risk-averse stochastic optimization problems on finite scenario trees. We use dynamic time-consistent formulations to approximate problems having a single coherent risk measure applied to the aggregated costs over all time periods. The dual representation of coherent risk measures is used to create a time-consistent cutting plane algorithm. Additionally, we also develop methods for the construction of universal time-consistent upper bounds. The performance of the proposed techniques is tested using monthly return data for the components of the Dow Jones Industrial Average. Our numerical results indicate that the resulting dynamic formulations yield close approximations to the original problem.

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Scenario Min-Max Optimization and the Risk of Empirical Costs

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Abstract

Many decision problems can be formulated as the problem of minimising a convex cost function that also depends on an uncertain variable. In this talk, we take a data-based worst-case approach to deal with uncertainty, and we minimise the maximum of the cost functions corresponding to some previously observed instances of the uncertain variable. We call these instances *scenarios*, and the solution to this optimisation problem is the *scenario solution*. The empirical costs are defined as the cost values that the scenario solution incurs for the various scenarios that have been used in optimisation. The *risk* of an empirical cost is defined as the probability that the empirical cost will be exceeded "tomorrow", i.e., when a new instance of the uncertain variable will be experienced. In [1] it is proven that the vector of the risks of the empirical costs has an ordered Dirichlet distribution independently of the distribution of the uncertainty. By virtue of this result, one can construct a probability box for the distribution of tomorrow's cost, without making any assumption on the specific distribution of the uncertainty and without resorting to new observations.

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Error bounds for convex approximations of two-stage mixed-integer recourse models

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Abstract

We develop a convex approximation for two-stage mixed-integer recourse models and we derive an error bound for this approximation that depends on the total variations of the probability density functions of the random variables in the model. We show that the error bound converges to zero if all these total variations converge to zero. Our convex approximation is a generalization of the one in Romeijnders et al. [2] restricted to totally unimodular integer recourse models. For this special case it has the best worst-case error bound possible. As main building blocks in the derivation of the error bound we generalize the asymptotic periodicity results of Gomory [1] for pure integer programs to the mixed-integer case, and we use new total variation error bounds on the expectation of periodic functions.

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CS: Stochastic Vehicle Routing & TSP

Chair: Ricardo Fukasawa

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Solving Stochastic TSPs with a Hyper-heuristic Framework for Generic Construction Heuristics

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Abstract

The first attempts to address the stochastic versions of the well-known and challenging travelling salesman problem have led to a variety of heuristics, both construction methods and improvement methods. Whereas improvement methods received ample attention in recent years, only little research focused on construction heuristics. As a result, their significance and contribution to the quality of the final solution remains underexposed. We propose a framework that unifies a class of construction heuristics for the probabilistic travelling salesman problem [1], namely expected savings procedures [1, 2, 3], into a single generalised procedure. Its parameterised design allows for a great degree of flexibility, resulting in a set-up that embeds existing procedures as special instances and includes a wide array of new procedures. We refer to the proposed framework as the Generic Savings (GENS) procedure. In addition, we propose an adaptive implementation of GENS using a hyper-heuristic framework and refer to it as GENS-H. An attractive feature of GENS-H is its ability to unveil new expected savings-based construction heuristics based on its fit with the characteristics of the problem instance at hand. Finally, we empirically test the merits of GENS and GENS-H against other construction heuristics for the probabilistic travelling salesman problem, and investigate their relative performance. Our results suggest that GENS-H outperforms the best performing competitor heuristics in 75% of the tested cases, discovering new construction heuristics in over 90% of all tested instances.

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The Static and Stochastic Vehicle Routing Problem with Time Windows and both random Customers and Reveal Times

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Abstract

Unlike its deterministic counterpart, static and stochastic vehicle routing problems (SS-VRP) aim at modeling and solving real life operational problems whilst considering uncertainty on the data. We introduce a new two-stage stochastic combinatorial optimization problem, the SS-VRPTW-CR. Like the SS-VRP introduced by Bertsimas in [1], given a fleet of capacitated vehicles we are interested in optimal first stage routes to handle a set of customer demands, each having a known probability to be present. In addition to capacity constraints, customers are also constrained by time windows, just as in [2]. Our contribution is the following. Up to our knowledge, all SS-VRP variants make a strong assumption on the time at which a stochastic customer reveals its presence (e.g. when a vehicle arrives at the corresponding location). In the SS-VRPTW-CR however, the moment when a customer reveals its presence is stochastic as well. The later property clearly positions this new SS-VRP variant in a more realistic context, and provides new tools for online combinatorial optimization approaches to dynamic and stochastic VRP's. Finally, by assigning each vehicle a sequence of waiting locations, the objective minimizes the expected number of customers that cannot be satisfied in time. We provide closed-form expressions for computing the objective function under two different recourse strategies. We propose a stochastic integer formulation and a extended branch and cut algorithm that solves the problem to optimality.

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Exact Algorithms for the Chance-Constrained Vehicle Routing Problem

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Abstract

We study the chance-constrained vehicle routing problem (CCVRP), a version of the vehicle routing problem (VRP) with stochastic demands, where a limit is imposed on the probability that each vehicle's capacity is exceeded. A distinguishing feature of our proposed methodologies is that they allow correlation between random demands, whereas nearly all existing methods for the stochastic VRP require independent demands. We first study an edge-based formulation for the CCVRP, in particular addressing the challenge of how to determine a lower bound on the number of trucks required to serve a subset of customers. We then investigate the use of a branch-and-cut-and-price (BCP) algorithm. While BCP algorithms have been considered the state of the art in solving the deterministic VRP, few attempts have been made to extend this framework to the stochastic VRP.

CS: Applications in Oil & Gas

Chair: Jorge Rodríguez-Veiga

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A STOCHASTIC PROGRAMMING APPROACH TO LIQUIFIED NATURAL GAS PLANNING

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Abstract

This work reports on modeling and numerical experience in solving the liquefied natural gas (LNG) planning for an oil and gas company. We developed a model to optimize said purchase, optimizing the amount of LNG bought on the spot and on the long-term markets, based on the predicted demand for the planning horizon. A stochastic approach to address uncertainties related to the LNG demand and spot prices is presented. The expected cost of the operation is minimized, considering stock costs and the possibility to export the surplus gas. Numerical experiments in a real-life case are assessed.

References

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HYBRID ROBUST-STOCHASTIC OPTIMIZATION MODEL FOR PROJECT PORTFOLIO SELECTION IN OIL & GAS INDUSTRY

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Abstract

Oil companies must decide their project portfolio under differing sources of uncertainty including production and financial risk factors. In the literature, portfolio optimization models usually assume that joint probability distribution of those factors are available or well estimated by some stochastic model. In practice however, some factors are suitable for stochastic modeling while others are not well represented by a probability distribution due to lack of information. In this work, we propose a combination of robust and stochastic optimization that jointly deals with stochastic representation of financial risk factors and a worst-case analysis for production quantities whose conservatism level is an user-defined parameter. The resulting deterministic equivalent model is a mixed integer linear programming that is efficiently solved by commercial solvers and generates more reliable project portfolios than their pure stochastic counterparts.

References

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Refinery modelling under uncertainty

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Abstract

The aim of this talk is to show a stochastic optimization model designed to tackle a specific decision-making problem: short-term planning under uncertainty in a processing plant and, more specifically, an oil refinery. This work is part of an ongoing collaboration Repsol, a leading company in Spain in the energy industry.
A refinery is an industrial processing plant in which one has to make two types of decisions: i) choose, from a given portfolio of different types of crudes, the amount to buy of each of them and ii) decide how to operate the different units of the refinery to obtain some final products (mostly fuels). The final goal is to maximize the net profits obtained by selling the final products. Typically, the above choices have to be made under price and demand uncertainty, leading naturally to a multistage stochastic optimization problem. In this talk we will present the formal mathematical model and the latest results obtained in this ongoing collaboration.

CS: Theory and Practice

Chair: Robert Bassett

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Alternating Direction Method of Multipliers for Two-Stage Stochastic Problems with Convex Utility Functions.

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Abstract

The Alternate Direction Method of Multipliers (ADMM) has received significant attention recently as a powerful algorithm to solve convex separable problems of the form

$$\begin{aligned} \min_{x_1,x_2} \quad & f_1(x_1) + f_2(x_2) \\ \text{subject to} \quad & A_1x_1 + A_2x_2 = B. \end{aligned}$$

The ADMM is based on the augment Lagrangian and the k-th iteration of the ADMM consists in the following steps:

- **Step 1.** $x_1^{k+1} = \arg\min L_\rho(x_1, x_2^k, \lambda^k)$.
- **Step 2.** $x_2^{k+1} = \arg\min L_\rho(x_1^{k+1}, x_2, \lambda^k)$.
- **Step 3.** $\lambda^{k+1} = \lambda^k + \rho\left(A_1x_1^{k+1} + A_2x_2^{k+1} - B\right)$.

The vast majority of applications focus on deterministic problems. In this work we show that ADMM can be applied to solve two stage stochastic convex programming problems, and we propose an implementation in three blocks with proximal terms. The algorithm decomposes the problem by scenarios, and it can be easily parallelized across of them, and it has a low computational cost per iteration. For the particular cases where the second stage functions are linear or quadratic all the inner actualizations of the algorithm can be carried out without the need of a solver. We show numerical results for medium and large scale instances of stochastic linear problems from the literature, and extend our findings for risk averse formulations using utility functions.

ICSP 2016
Búzios, Brazil
25 June – 1 July, 2016

Assessment of Certainty Equivalence on Long-Term Hydropower Scheduling

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Abstract

The Certainty Equivalence Principle (CEP) states that deterministic and stochastic approaches are equivalent in the optimization of stochastic dynamic systems assuming linear dynamic, unbounded states and controls, quadratic cost, and Gaussian noise. Although long-term hydropower scheduling (LTHS) does not satisfy such assumptions it is possible to assess how close to certainty equivalence it is. In this work test case studies are conducted for a hypothetical single reservoir hydro-thermal system within the framework of dynamic programming. By adequately changing the original LTHS problem, CEP assumptions were initially imposed composing an ideal case on which, theoretically, all conditions are satisfied. Then, by gradually withdrawing each one of these conditions, the impacts of each assumption were evaluated both in optimization and in simulation. The case studies explicit the strategic differences between deterministic and stochastic operation policies, but overall results indicate that LTHS may be close enough to certainty equivalence to support the practical use of deterministic based approaches.

ICSP 2016
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25 June – 1 July, 2016

Estimation and Filtering with Monitoring Functions

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Abstract

Monitoring functions, first introduced in [1], are a class of functions of the form $\rho : \mathbb{R}^n \to \mathbb{R} \cup \{\infty\}$, with

$$\rho_{U,M}(x) = \sup_{u \in U}\{\langle u, x\rangle - \frac{1}{2}\langle u, Mu\rangle\}$$

where $U \subseteq \mathbb{R}^n$ is polyhedral and M is a positive semidefinite matrix. Monitoring functions are versatile in nature, and many common penalty functions, e.g. hard constraints, ℓ^1, ℓ^2, Huber, and others, can be expressed in this framework. They also have attractive computational properties for use in practice [2]. When a monitoring function is coercive, it can be used to define a density function $ce^{-\rho_{U,M}(x)}$, with some normalizing constant c. We consider the problem of estimating the state of a linear dynamical system with the information gained from a noisy, linear measurement process. The classical version of this problem assumes that the noise is gaussian. By showing that a dual problem is given by an instance of the Linear-Quadratic Regulator problem of optimal control, and noting that this system runs backwards in time, one can apply the principal of dynamic programming to derive the celebrated Kalman filter. The Kalman filter is ubiquitous in application because of its simplicity and powerful theoretical grounding.

We generalize the classical problem by allowing the measurement noise to be distributed according to a density generated by a monitoring function. We investigate the corresponding duality structure, and use it to design alternative computational approaches. This work has important applications in the areas of robotics and other engineering disciplines. In particular, it allows a practitioner to use data to derive assumptions about the model instead of being forced to rely on classical assumptions.

References

[1] R. T. Rockafellar, *Linear-Quadratic Programming and Optimal Control*, SIAM Journal on Control and Optimization 1987 25:3, 781-814

[2] Aravkin, Burke, Pillonetto. , *Sparse/robust estimation and kalman smoothing with nonsmooth log-concave densities: Modeling, computation, and theory.*, The Journal of Machine Learning Research 14.1 (2013): 2689-2728.

MS: A. Pichler – Applications of SP in Finance

Chair: Darinka Dentcheva

ICSP 2016

Búzios, Brazil
25 June – 1 July, 2016

Risk Measures and Ambiguity in Finance

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Abstract

In finance, the probability measure is typically not known in practice. The corresponding uncertainty with respect to the underlying probability measure is called *ambiguity*, and *distributionally robust* stochastic programs are occasionally used to handle this type of uncertainty.
We present stability results for these stochastic problems. The results are formulated in terms of Pompeiu–Hausdorff distances for general sets. Underlying distances metrisize weak* convergence on probability measures, the results on multistage stochastic optimization problems are based on the process distance.

ICSP 2016

Búzios, Brazil
25 June – 1 July, 2016

Solving stochastic programming problems with risk measures by the progressive hedging algorithm

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Abstract

The progressive hedging algorithm (Rockafellar/Wets 1991) can solve multistage stochastic programming problems by iteratively decomposing them into multistage deterministic problems, one for each scenario. Price vectors capturing the value of information are generated in this process. So far, however, only objectives of expectation form have been covered. This talk will demonstrate how the method can be extended to minimizing a measure of risk of the random cost instead of just an expectation.

Convex duality in optimal investment in illiquid markets

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Abstract

We study the problem of optimal investment by embedding it in the general conjugate duality framework of Rockafellar. This allows for various extensions to classical models of financial mathematics including nonlinear trading costs that are encountered e.g. in modern limit order markets. We derive an explicit dual problem and optimality conditions in terms of dual variables that extend martingale measures beyond classical perfectly liquid markets. The optimization problem is parameterized by a sequence of claims, which allows us to study general financial contracts that may involve payments at several points in time. Such contracts are common in practice due to the absence of a perfectly liquid bank account. In the special case of perfectly liquid markets or markets with proportional transaction costs, we recover well-known dual expressions in terms of martingale measures and consistent price systems. The talk is based on a joint work with Teemu Pennanen, King's College London.

Quasi-Monte Carlo methods for stochastic energy optimization models

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Abstract

We consider mixed-integer two-stage stochastic optimization models which are relevant for electricity production and trading and study the use of Quasi-Monte Carlo (QMC) methods for scenario generation. We provide conditions on the optimization model and the underlying probability distribution implying that QMC error analysis applies approximately to two-stage mixed-integer integrands. Hence, convergence rates close to the optimal O(1/n) may be achieved. Numerical results are presented for two particular randomized QMC methods that show their superiority to classical Monte Carlo.

MS: H. Xu– Stochastic MPECs

Chair: Andy Philpott

ICSP 2016 — Búzios, Brazil, 25 June – 1 July, 2016

Stochastic Mathematical Programs with Equilibrium Constraints

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Abstract

Mathematical Programs with Equilibrium Constraints (MPEC) is a class of optimization problems with two sets of variables: upper level variables and lower level variables, in which some or all of the constraints are defined by an equilibrium problem which is mathematically a parametric variational inequality or complementarity system with lower variables as its prime variables and upper level variables as the parameter vector. MPEC has found extensive applications in areas of decision analysis, structural engineering, network design, discrete transit planning etc and have developed as a new area in optimization over the past decade [1]. The underlying data in MPEC are all deterministic. However, in many practical applications such as network capcity expansion, the problem data may involve some random factors which reflect uncertainty in future demand. Replacing the random data with their mean value or a particular realization of the random variables may result in a wrong decision. A Stochastic version of MPEC is a natural way to address this challenge. SMPEC is initially studied by Patriksson and Wynter [2]. It has now developed into a new subject area in stochastic optimization. In this talk, we will give an overview of this relatively new topic from mathematical modeling to underlying theory of optimality and numerical methods with a particular focus on one stage, two stage SPMECs and robust SMPECs. Since SMPEC is intrincically nonconvex, we will also discuss convergence analysis of statistical estimators of stationary points when the well known sample average approximation method is applied to this class of problems and demonstrate how we may look into the issue more broaderly from stability analysis of stochastic generalized equations.

References

[1] Z.-Q. Luo, J.-S. Pang and D. Ralph, *Mathematical Programs with equilibrium constraints*, Cambridge University Press, 1996.

[2] M. Patriksson and L. Wynter, Stochastic mathematical programs with equilibrium constraints, Operations Research Letters, Vol. 25, 159-167, 1999.

ICSP 2016 Búzios, Brazil
25 June – 1 July, 2016

Confidence regions and intervals for the expected value formulation of stochastic variational inequalities

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Abstract

We consider the expected value formulation of a stochastic variational inequality (SVI) defined over a polyhedron, in which the function defining the variational inequality is an expectation function. A basic approach for solving the SVI is the sample average approximation (SAA) method, which replaces the expectation function by a sample average function. It is well known that under appropriate conditions the SAA solutions provide asymptotically consistent point estimators for the true solution to an SVI. We propose methods to compute confidence regions and confidence intervals for the true solution, when an SAA solution is known. In a general situation that we are interested in, a piecewise linear function appears in the expression of the asymptotic distribution of SAA solutions. We exploit the structure of normal maps of variational inequalities to obtain estimates about that piecewise linear function, to build asymptotically exact confidence regions and intervals for the true solution and its components that are computable from the SAA solution. We have applied these methods in the inference of sparse penalized regression.

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Extragradient method with variance reduction for stochastic variational inequalities

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Abstract

We propose an extragradient method with stepsizes bounded away from zero for stochastic variational inequalities requiring only pseudo-monotonicity. We provide convergence and complexity analysis, allowing for an unbounded feasible set, unbounded operator, non-uniform variance of the oracle and, also, we do not require any regularization. Alongside the stochastic approximation procedure, we iteratively reduce the variance of the stochastic error. Our method attains the optimal oracle complexity $\mathcal{O}(1/\epsilon^2)$ (up to a logarithmic term) and a faster rate $\mathcal{O}(1/K)$ in terms of the mean (quadratic) natural residual and the D-gap function, where K is the number of iterations required for a given tolerance $\epsilon > 0$. Such convergence rate represents an acceleration with respect to the stochastic error. The generated sequence also enjoys a new feature: the sequence is bounded in L^p if the stochastic error has finite p-moment. Explicit estimates for the convergence rate, the oracle complexity and the p-moments are given depending on problem parameters and distance of the initial iterate to the solution set. Moreover, sharper constants are possible if the variance is uniform over the solution set or the feasible set. Our results provide new classes of stochastic variational inequalities for which a convergence rate of $\mathcal{O}(1/K)$ holds in terms of the mean-squared distance to the solution set. Our analysis includes the distributed solution of pseudo-monotone Cartesian variational inequalities under partial coordination of parameters between users of a network.

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Incremental constraint projection methods for monotone stochastic variational inequalities

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Abstract

We consider stochastic variational inequalities with monotone operators defined as the expected value of a random operator. We also assume the feasible set is the intersection of a large family of convex sets. We propose a method that combines stochastic approximation with incremental constraint projections meaning that at each iteration, a step similar to some variant of a deterministic projection method is taken after the random operator is sampled and a component of the intersection defining the feasible set is chosen at random. Such sequential scheme is well suited for applications involving large data sets, online optimization and distributed learning. In the first part we assume the variational inequality is *weak sharp*. We provide convergence and complexity analysis and estimate the minimum number of iterations for any solution of a stochastic program with linear objective to solve the variational inequality. In a second part we introduce an explicit iterative Tykhonov regularization to the method and prove its convergence requiring just monotonicity. We consider Cartesian variational inequalities so as to encompass the distributed solution of monotone stochastic Nash games or multi-agent optimization problems under a limited coordination.

MS: W. Powell – Applications of Machine Learning

Chair: Giorgio Consigli

ICSP 2016
Búzios, Brazil
25 June – 1 July, 2016

Applications of Machine Learning in Stochastic Optimization

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Abstract

The problem of optimizing sequential decision problems under uncertainty span a variety of communities, with the best known including multistage stochastic programming, dynamic programming, and optimal control. These communities can be represented by four classes of policies, three of which involve the statistical estimation of some function, spanning functions for policy search, parametric cost function approximations, and value function approximations.

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Stochastic optimization using parametric cost function approximations

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Abstract

A widely used heuristic for solving stochastic optimization problems is to use a deterministic rolling horizon procedure which has been modified to handle uncertainty (e.g. buffer stocks, schedule slack). We formalize this strategy as a parametric cost function approximation where parameterized modifications of costs or constraints can be adaptively learned using the principles of policy search. We present stochastic algorithms for tuning the policy in a detailed simulator.

ICSP 2016 — Búzios, Brazil, 25 June – 1 July, 2016

Learning a Universal Policy

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Abstract

Sequential decision problems can be solved using any of four classes of policies, as well as hybrids of these classes. We describe experimental work with a simple energy storage problem where we demonstrate that each of the four classes of policies, plus a fifth hybrid policy, can work best depending on the data. We introduce the idea of a universal policy that is a weighted combination of the four classes. We present an online optimal learning algorithm that learns the weights from data.

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Forecasting in Policy Search

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Abstract

Policy search has been widely used in dynamic programming, but typically for stationary, low-dimensional policies. We demonstrate the power of support vector machines to create policies that work in a nonstationary environment with complex state variables including, for the first time, the forecast in the state variable. We demonstrate the effectiveness on a classical storage problem where standard algorithms from approximate dynamic programming have failed.

Due to the difficulty in training such complex policy forms, our algorithm decomposes the learning procedure to a passive and an active phase. In the passive phase, low-cost "informative" trajectories are sampled using a *guiding distribution* which is learnt through environmental interactions. These are then used to generate a good-enough initial policy. This policy is further improved during the active phase by minimizing total accumulated cost leading to high-accuracy performance. Our results show that this framework is capable of handling high-dimensional state variables even when including forecast as additional dimensions. We demonstrate successful behavior of the above framework on an energy storage problem with a variety of forecast qualities.

[1] Raymond T. Perkins III will present this talk as Haitham Bou Ammar could not be present due to unforeseen circumstances.

TS: Financial Engineering Applications

Chair: Giorgio Consigli

ICSP 2016 — Búzios, Brazil, 25 June – 1 July, 2016

Assessing performance of active funds: have active fund managers performed better than randomly constructed portfolios?

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Abstract

We compare the performance of active funds, including mutual funds and hedge funds, against the randomly constructed portfolios. To this end, we first analytically derive the closed form expression of performance distribution of randomly constructed portfolio, and then compare it with the historical performance distribution of active funds. We find that the active funds do not outperform the randomly constructed portfolio, and even significantly underperform in many occasions.

ICSP 2016 Búzios, Brazil
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Futures portfolio management based on stochastic programming

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Abstract

In the conference ICSP - 2013 our report "Management of Portfolio of Options With Two Expiration Dates" was presented. It told about an approach of option portfolio management in a risk-neutral world based on the stochastic program with approximated safety-first criterion. This criterion implies that some of the considered scenarios are not taken into account.

The portfolio started with options of one expiration. During portfolio management if the probability to reach the required return failed below some predefined level then options of the next expiration were included to the portfolio and the planning horizon was transferred to the next expiration date. If the probability of success was held over the predefined level all the time, then the options of the next expiration were not opted for and the portfolio expired on the nearest expiration date. The simulation showed that the developed program and the strategy ensured a quite high probability of the success of the portfolio. Among the ten simulated 1-year tracks none finished with a loss.

The contribution of the present work is as follows. *The approach described supra is applied for futures portfolio management. The according stochastic program has been developed. The real futures of Russian derivative market are considered. The portfolio can include futures of one or two different expirations. To formalize the dynamics of underlying asset prices ARIMA and GARCH models are used. The according scenario tree which presents one or two futures prices is constructed. The results of futures portfolio management simulations based on the historical prices of Moscow Exchange are provided in the report.*
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ICSP 2016 Búzios, Brazil
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Optimal hedging of the interest rate swap book

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Abstract

Most large banks trade interest rate swaps (IRS) with customers who wish to exchange a fixed interest rate payment stream to a floating rate payment stream or vice versa. All these positions make up the IRS book, which may contain tens of thousands of different swap contracts with different maturities. Banks make their earnings from the spread between bid and ask yields, and do not wish to be exposed to the interest rate risk this book carries. By identifying the risk factors arising from changes in the shape of the term structure of interest rates, the distribution of these risk factors can be determined. This enables us to generate scenarios for the interest rate market. In order to manage the risk of the IRS book in an optimal way, a stochastic programming model is proposed. Using performance attribution based on the previously identified risk factors, we analyze the outcome of our method compared to traditional hedging methods.

ICSP 2016
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Solving dynamic portfolio choice problems with transaction costs by approximate dynamic programming

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Abstract

We study dynamic portfolio choice problems with proportional transaction costs and many risky assets within the class of power utility functions by approximate dynamic programming. Motivated by concavity (in portfolio weights) and numerical studies with only two risky assets, we propose to approximate the value function in the no-trade region by quadratic functions using semi-definite programming. Outside the no-trade region the value function is evaluated by solving for the optimal trade to the boundary of the no-trade region. The resulting algorithm enables us to efficiently solve problems with many risky assets in the presence of transaction costs. We compare our results to several heuristic trading strategies and apply duality techniques to evaluate the performance of the proposed approach.

TS: Scenario Reduction, Partition, and Clustering

Chair: Yongjia Song

ICSP 2016
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25 June – 1 July, 2016

Clustering-Based Preconditioning for Stochastic Programs

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Abstract

We present a clustering-based preconditioning strategy for KKT systems arising in stochastic programming within an interior-point framework. The key idea is to perform adaptive clustering of scenarios (inside-the-solver) based on their influence on the problem as opposed to cluster scenarios based on problem data alone, as is done in existing (outside-the-solver) approaches. We derive spectral and error properties for the preconditioner and demonstrate that scenario compression rates of up to 87% can be obtained, leading to dramatic computational savings. In addition, we demonstrate that the proposed preconditioner can avoid scalability issues of Schur decomposition in problems with large first-stage dimensionality. .

ICSP 2016
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Parallel Scenario Decomposition of Risk Averse 0-1 Stochastic Programs

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Abstract

In this paper, we generalize a scenario decomposition algorithm proposed by [1] for 0-1 stochastic programs, which recovers an optimal solution by iteratively evaluating and cutting off candidate solutions discovered from scenario subproblems. We consider risk-averse 0-1 stochastic programs with objective functions based on coherent risk measures. Using a dual representation of a coherent risk measure, we derive an equivalent risk-neutral minimax reformulation of the considered problem. We develop scenario decomposition algorithms that relax the nonanticipativity constraints and refine solutions by cuts and bounds. We design three parallelization schemes for implementing the algorithms, to benchmark tradeoffs between communication time and computation time. We use conditional value-at-risk (CVaR) and mean-risk measures to design test instances of popular stochastic 0-1 programs from the SIPLIB test library, and demonstrate the speed advantage of our approaches particularly on instances with a large number of scenarios, and the good scalability of the proposed parallel schemes, which achieve near-linear or even super linear speedup.

References

[1] Ahmed, S. (2013). A scenario decomposition algorithm for 0-1 stochastic programs. *Operations Research Letters*, 41(6):565–569.

[1] replaces the original speaker, Siqian Shen, due to extraordinary circumstances.

ICSP 2016 — Búzios, Brazil, 25 June – 1 July, 2016

Moment-based Distributionally Robust Server Allocation and Scheduling Problems

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Abstract

In this paper, we investigate two classical problems as (i) server allocation and (ii) appointment scheduling, both under random service durations. The allocation problem decides which servers to operate and assigns jobs to operating servers. The scheduling problem obeys a fixed order of appointment arrivals on a single server, and assigns each an arrival time. In both problems, we employ chance constraints to restrict server overtime, while minimizing the operational cost in the allocation problem and the worst-case expected total waiting in the scheduling problem. We build distributionally robust (DR) models of the two problems using moment-based ambiguity sets. We reformulate the two problems as 0-1 and continuous semidefinite programs (SDP), respectively. For solving the 0-1 SDP for the DR allocation, we develop a cutting-plane algorithm with an SDP oracle, and also a second order cone programming (SOCP) relaxation. We demonstrate the efficacy of our approaches by testing instances of an outpatient treatment application.

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An adaptive partition-based inexact bundle method for solving two-stage stochastic programs

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Abstract

We present a computational study of several strategies to solve two-stage stochastic linear programming problems by integrating the adaptive partition-based approach with level decomposition. A partition-based formulation is a relaxation of the original stochastic program, obtained by aggregating variables and constraints according to a scenario partition. Partition refinements are guided by the optimal second-stage dual vectors computed at certain first-stage solutions. The proposed approaches rely on the level decomposition with on-demand accuracy to dynamically adjust partitions until an optimal solution is found. Numerical experiments on a large set of test problems including instances with up to one hundred thousand scenarios show the effectiveness of the proposed approaches.

TS: SP under Uncertain Probability Distributions

Chair: Anton Kleywegt

ICSP 2016

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Ambiguous Joint Chance Constraints under Mean and Dispersion Information

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Abstract

We study joint chance constraints where the distribution of the uncertain parameters is only known to belong to an ambiguity set characterized by the mean and support of the uncertainties and by an upper bound on their dispersion. This setting gives rise to pessimistic (optimistic) ambiguous chance constraints, which require the corresponding classical chance constraints to be satisfied for every (for at least one) distribution in the ambiguity set. We provide tight conditions under which pessimistic and optimistic joint chance constraints are computationally tractable, and we show numerical results that illustrate the power of our tractability results.

Distributionally Robust Shortest Path Problem

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Abstract

This talk considers a stochastic version of the shortest path problem, namely the Distributionally Robust Stochastic Shortest Path Problem on directed graphs. In this model, each arc has a deterministic cost and a random delay. The mean vector and the second-moment matrix of the uncertain data are assumed to be known, but the exact information of the distribution is unknown. A penalty occurs when the given delay constraint is not satisfied. The objective is to minimize the sum of the path cost and the expected path delay penalty. As this problem is NP-hard, we propose new reformulations and approximations using a sequence of semidefinite programming problems which provide tight lower bounds. Finally, numerical tests are given to illustrate the tightness of the bounds and the value of the proposed distributionally robust approach .

Distributionally Robust Stochastic Programming with Wasserstein Distance

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Abstract

We study distributionally robust stochastic programming in which the ambiguity set is defined by a Wasserstein ball centered at some reference distribution, such as empirical distribution obtained from data. We show that such a problem has a tractable reformulation with useful implications. More specifically, we derive a dual reformulation without the convexity assumption made in Esfahani and Kuhn [1]. The worst-case distribution and sensitivity analysis with respect to the radius of the Wasserstein ball are obtained from analysis of the dual reformulation. Using the concise form of the dual reformulation, we obtain further results for various special cases, such as (i) a reformulation of distributionally robust stochastic linear programs as affinely perturbed robust linear programs, which can be formulated as convex programs with conic quadratic constraints, and (ii) an efficiently solvable reformulation of distributionally robust chance-constrained problems with affinely perturbed chance constraints. Finally, we show that a Mirror-Prox algorithm can solve the reformulation at the optimal rate of convergence.

References

[1] P. M. Esfahani and D. Kuhn, Data-Driven Distributionally Robust Optimization Using the Wasserstein Metric: Performance Guarantees and Tractable Reformulations. *arXiv preprint*, 2015.

TS: Probabilistic Constraints: Applications and Theory

Chair: Wim van Ackooij

ICSP 2016 — Búzios, Brazil, 25 June – 1 July, 2016

Optimization in gas transport networks using nonlinear probabilistic constraints

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Abstract

We deal with optimization problems in gas transport networks under uncertainty. The problems are formulated in terms of stochastic programming models with probabilistic constraints, a major class in stochastic programming. Our approach for solving such models consists in applying nonlinear programming methods. Therefore, approximations for both values and gradients of the underlying probability functions must be provided. We introduce a sampling scheme based on the spheric-radial decomposition of Gaussian random vectors, which allows to compute values and gradients of such functions simultaneously. Theoretical and numerical studies for simple gas networks are provided, which are based on the characterization of feasible nominations in stationary gas networks with random load [1]. We consider relevant example problems like the validation of booked capacity and the optimization of certain network parameters as, for example, minimal installation cost of upper pressure bounds within the network.

References

[1] C. Gotzes, H. Heitsch, R. Henrion, R. Schultz, *Feasibility of nominations in stationary gas networks with random load*, WIAS Preprint Nr. 2158 (2015).

Theoretical and practical aspects of analytic approximation strategies for chance constrained optimization problems

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Abstract

Uncertainty is an inherent property of many scientific as well as industrial processes. Acknowledging these uncertainties explicitly can lead to improved solutions and better decisions when optimizing in those settings. One way of incorporating uncertainties in optimization problems is the use of the chance-constrained optimization formulation

$$(CCOPT) \min_{u\in\mathcal{U}} \quad E\left[f(y,u,\xi)\right] \tag{1}$$
$$s.t. \quad F(y,u,\xi)=0 \tag{2}$$
$$Pr\left\{g_i(y,u,\xi)\leq 0\right\}\geq \alpha_i, \quad i=1,\dots,q, \tag{3}$$

where $y\in\mathbb{R}^n$ is a vector of output variables, $u\in\mathcal{U}\subset\mathbb{R}^m$ is a vector of control variables, and ξ is a vector of Borel-measurable uncertain input variables from a probability space into $\mathbb{R}^p$. The function $f:\mathbb{R}^n\times\mathcal{U}\times\mathbb{R}^p\to\mathbb{R}$ is the objective function, $F:\mathbb{R}^n\times\mathcal{U}\times\mathbb{R}^p\to\mathbb{R}^n$ describes the model equations, and $g_i:\mathbb{R}^n\times\mathcal{U}\times\mathbb{R}^p\to\mathbb{R}$, $i=1,\dots,q$ are the constrained quantities. The chance constraints (3) are to be held with a probability level $\alpha_i\in[0.5,1]$. The main difficulty of solving problems of the type (CCOPT) usually lies in the computation of the probabilities (3). Analytic approximations (AAs) offer one possibility to overcome these obstacles. AAs are based on the fact that probability functions can be alternatively expressed using expectations, i.e., if $p_i(u)=Pr\left\{g_i(u,\xi)\leq 0\right\}$ then

$$1-p_i(u)=Pr\left\{g_i(u,\xi)>0\right\}=E\left[\mathcal{I}(g_i(u,\xi))\right], \text{ where } \mathcal{I}(x)=\begin{cases}1, & x>0,\\ 0, & x\leq 0.\end{cases}$$

The reformulation does not directly simplify the process of solution. This is due to the fact that the function $\mathcal{I}(\cdot)$ is discontinuous, which leads to difficulties in the numerical computation. Nonetheless, the functions $E\left[\mathcal{I}(g_i(y,u,\xi))\right]$ can be used to construct tractable approximations to the problem (CCOPT). More clearly, assume there exist continuous functions $\psi_i:\mathbb{R}_{++}\times\mathbb{R}^m\to\mathbb{R}_+$ and $\tau_{max}\in\mathbb{R}_{++}$ with the property $E\left[\mathcal{I}(g_i(y,u,\xi))\right]\leq\psi_i(\tau,u)$ for all $0<\tau<\tau_{max}$ and all $u\in\mathcal{U}$. Then any solution $u^*_{(CCOPT_\tau)}$ of

$$(CCOPT_\tau) \min_{u\in\mathcal{U}} \quad E\left[f(y,u,\xi)\right] \tag{4}$$
$$s.t. \quad F(y,u,\xi)=0 \tag{5}$$
$$\psi_i(\tau,u)\leq 1-\alpha_i, \quad i=1,\dots,q, \tag{6}$$

is also feasible for the original problem (CCOPT).
In this talk we will discuss several choices for the functions $\psi_i(\cdot,\cdot)$ and examine their theoretical and practical properties. The different approaches will be tested on case studies from the field of optimal power flow.

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Joint Probability Maximization for Gaussian Inequality Systems With Application to a Probabilistic Model for Portfolio Problems

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Abstract

We address the problem of determining a solution in a polyhedral set maximizing the joint probability to satisfy a system of m random linear inequalities -assumed to be stochastically independent- each specified as an n-variate gaussian coefficient vector. Applying standard maximization algorithms (feasible direction, projected gradient) does not guarantee global optimality because of the inherent nonconcavity of the joint probability function. First, we will recall and discuss a recent result [1] stating a necessary and sufficient condition for (local) concavity for a single gaussian inequality, leading to a characterization of concavity domains much larger than those arising from previously known sufficient conditions. Next, it will be shown how a global optimality certificate for a given solution can be derived, requiring the solution of Second Order Cone Programs. Finally, as a possible application, we deal with a probabilistic model of portfolio optimization where the parameters (anticipated means and variance/covariance matrices for the n assets) of each of the m random inequalities are supposed to represent the judgement of some expert, and the various experts are assumed to be independent. For each inequality, the right-hand side represents a target return to be obtained with maximum probability. Thus, a solution maximizing joint probability can be interpreted as a 'most robust' portfolio for achieving the required target return. Computational results on a series of test instances (up to $n = 250$ and m ranging from 10 to 150) show that the proposed global optimality test is computationally efficient and leads to guarantee global optimality for a significant proportion of the instances considered.

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(Sub-)Gradient formulae for Gaussian probability functions

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Abstract

Probability functions play a fundamental role in optimization problems dealing with reliability maximization or involving probabilistic constraints. Their differentiability may not be taken fro granted even if the probability density and the system of random constraints is smooth. The aim of the talk is to address the potential nonsmoothness of probability functions in the context of Gaussian distributions and to derive subgradient formulae in the sense of Clarke and Mordukhovich. The approach is based on the spheric-radial decomposition of Gaussian random vectors and allows one to compute both, values and subgradients (gradients under additional conditions), on the basis of efficient sampling schemes on the sphere (e.g. Quasi-Monte Carlo).

TS: Planning Problems in the Electric Power Systems

Chair: Francisco Munoz

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Co-optimizing Transmission and Generation Capacity Expansion

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Abstract

A pessimistic three-level equilibrium model for a market-based expansion of both transmission and generation is proposed here. The lower (third) level models the market outcome; the intermediate (second) level models the equilibrium in generation capacity expansion by taking into account the outcomes of the market equilibrium at the third level. The upper (first) level models the expansion of the transmission network. The second and third levels are modeled as an Equilibrium Problem with Equilibrium Constraints (EPEC) parameterized in terms of the optimal decisions of the transmission planner. At the first level, the transmission planner can take different positions with different impacts in the system because a manifold of equilibria is possible with different costs for the system. Unlike previously reported hierarchical problems approaches, which are implicitly formulated as optimistic, we solve the pessimistic solution of the problem.

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Investing in adaptable portfolios of generation technologies against energy policy uncertainty

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Abstract

The expansion planning for electricity generation is a complex problem, in which a strategy for the future construction of generation plants is designed, constrained to economical projections (e.g. costs prediction, risk exposures, uncertainty regarding future demands of energy) and operational issues (e.g. stability of the system and security supply). However, in recent years, expansion planning for electricity generation is facing new challenges due to a generalized environmental concern. Many plants of electricity generation, such as those based on fossil-fuels, can induce serious environmental damages including global warming, pollution, acid rain, and rising sea levels. In the last 10 years, an increasing number of countries are committed to reach progressively new renewable policy targets. For instance, the Renewables 2015 Global Status Report, from REN 21, shows that 164 countries have renewable policy targets by 2015 from only 55 countries by early 2005. These renewable policy targets has been (or they will be) implemented by each country through different mechanisms such as strict quotas for renewable generation (with the possibility of removing generation permissions) and economic incentives (e.g. penalties, carbon tax and subsidies) that are aimed to induce change in the technologies for electricity production.

In this context, we present a multi-stage model to design the expansion planning for electricity generation to incorporate future –although uncertain– new renewable policy targets. The model allows an expansion planning in multiple stages in which some decision can be taken today, and others postponed to the future, when the uncertainty of new potential policies are eliminated. The model is flexible enough to consider diverse 'potential' renewable policy measures which can be implemented by different mechanisms such as penalties, carbon taxes, subsidies, amongst others. The model is solved by a Benders decomposition algorithm to tackle large dimension problems for a country level planning of electricity generation. Through various examples based on the Chilean electricity system, we show that a multi-stage planning provide important economic benefits in term of costs and risks reductions.

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Improving the Resilience of Electric Power Systems to Geomagnetic Disturbances

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Abstract

Resilience can be defined as the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from deliberate attacks, accidents, or naturally occurring threats or incidents. In this talk we demonstrate the use of stochastic non-linear programming to develop a resilience-aware dispatch tool that allows the system operator to modify their operating plan by changing generator set-points in order to reduce the potential negative consequences of an imminent geomagnetic disturbance (GMD). First, we create scenarios that describe the uncertainty in orientation and magnitude from the GMD. These are used to calculate the geomagnetic induced currents (GICs) in the electric system based on the geolocations of substations, transformer configuration, and transmission lines connecting those substations. Then, we use these GICs as additional inputs to a non-linear alternating current optimal power flow (ACOPF) which seeks to minimize the negative effects of those GICs. We use IPOPT – an interior point solver – to solve the resulting non-linear stochastic program. We also apply decomposition techniques in order to scale our approach to large size systems.

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A Scalable Solution Framework for Stochastic Transmission and Generation Planning Problems

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Abstract

Stochastic transmission and generation expansion planning models are receiving increasing attention among researchers today. They are being used to explicitly model uncertainties that result from the increasing penetration of renewable energy technologies, as well as from long-term market and regulatory conditions. However, existing commercial planning tools still lack stochastic capabilities.

We propose a two-stage investment-planning model that takes into account the aforementioned uncertainties, and we describe a scalable decomposition algorithm to solve real-sized problems. An application of our algorithm is illustrated using a 240-bus network representation of the Western Electricity Coordinating Council. We discuss its performance when implemented in both the Red Mesa/Sky supercomputer and a commodity multi-core workstation. .

TS: Brazil's Oil and Energy Industries

Chair: Welington de Oliveira

Investment strategies for renewable projects considering risk neutral and risk averse approaches

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Abstract

Despite recent trend for investment in renewable energy, potential investment is still hindered by the uncertainties associated with it. Usage of risk management tools, such as forwarding contracting, is essential even in Over The Counter (OTC) markets such as the Brazilian Free Trading Environment. While forward contracts allow reducing price uncertainty, it entails an obligation to deliver energy quantities at fixed prices. Since renewable sources still face the additional risk of uncertain generation, they are exposed to the price-quantity risk, when low generation periods occur during high spot prices. In this situation additional energy must be bought at spot price to cover contract quantities, and may represent huge losses for the firm. Proper investment strategies that apply risk management tools such as forward contracting, diversification and postponement options may foster the investment in such renewable projects. Existing approaches for determining optimal strategies are either based on stochastic programming, usually simplifying the dynamic aspects, or real options theory, that often simplify the uncertainty process. We present an approach that bridges the gap between these methods by developing a multistage stochastic programming framework that represents the main uncertainty sources, namely generation and price dynamics, and encompasses real options such as postponing, hedging with fixed (forward) contracts and diversification with seasonal complementary sources. The resulting multistage stochastic non-convex problem is solved by an heuristic based on the Stochastic Dual Dynamic Programming (SDDP) method. Integrality constraints are considered in the forward step, where policies are evaluated, and relaxed in the backward step, where policies are built, to ensure convexity of the recourse functions. Price dynamics is approximated by using a Markov Chain to model dependence structure

of the stages. Performance evaluation is carried out over a set of Monte Carlo simulated scenarios. We incorporate risk aversion with coherent measures of risk to obtain alternative strategies given a risk aversion parameter. A case study in investment in hydro and wind projects in the Brazilian market is used to illustrate the approach.

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OTIM-PBR: A Stochastic Programming Approach to Brazilian Oil Supply Chain Planning

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Abstract

Traditionally, the oil supply chain in Brazil has been planned using deterministic optimization models. The effect of uncertainty in the input data is currently evaluated by using sensibility analysis and specific studies.
This deterministic model, even after all possible simplifications are done in the tactical plan, results into a huge-scale optimization problem, with millions of variables and constraints. Therefore, the solving time is a relevant consideration.
The Brazilian oil supply chain is made up of dozens of different oil fields (mostly offshore); a lot of potential international suppliers and oil buyers; thirteen refineries; various international markets for buying and selling products; and dozens of distribution centers that supply throughout Brazil different oil derivatives.
It is important to say that each type of oil extracted from a different oil field has specific individual characteristics. In the same way, each refinery has a unique hardware, making it very challenging to perform tasks involving refinery shifts or the replacement of some crude oil.
Various uncertain sources impact strongly this supply chain: the accuracy of forecasted oil production and crude oil and derivative prices; deviations of the planned performance of refineries; and demand variations.
Nowadays, with the operation of low margins in the chain, to perform at optimum or near optimum levels represents a very big competitive advantage for Petrobras. In an industry that moves hundreds of billions of dollars a year, optimization through gains represents a significant economic contribution for the company.
The project *OPTIM-PBR*, an R&D collaboration between Petrobras and IMPA, was set to respond to the great challenge of defining a (mathematically sound and numerically tractable) stochastic programming model for the company supply oil chain. We analyze several key aspects in the proposed model and discuss expected gains that can be obtained when modelling uncertainty in the domestic supply of oil, as well in the prices of crude oil, gasoline and diesel.

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Fast Decomposition Schemes for Two-Stage Oil Supply-Chain Management Problems

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Abstract

The project *OPTIM-PBR*, an R&D collaboration between Petrobras and IMPA, was set to respond to the great challenge of defining a (mathematically sound and numerically tractable) stochastic programming model for the company supply oil chain.
Currently, the linear deterministic continuous model used to represent this chain contains more than 2 million variables and 1.5 million constraints. When introducing uncertainty, the optimization problem becomes untractable.
For the company, it is crucial to suitably manage both the *price risk* and the *volume risk*. The former is related to market fluctuations of the oil price as a commodity, and is represented in the model by scenarios for oil, diesel and gasoline. The latter depends on the domestic supply of oil and can be handled by probabilistic constraints.
For the resulting (huge-scale) two-stage stochastic linear program, we discuss state-of-the-art solution techniques that combine decomposition with on-demand-accuracy bundle methods.

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Primal-dual methods in stochastic programming with application to energy problems

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Abstract

We consider nonconvex stochastic optimization problems and a dual schema via generalized augmented Lagrangians. Primal and dual convergence results are obtained by employing specialized nonsmooth optimization algorithms to the dual problem. The main concepts are illustrated by examples on optimal power management.

Special Session in Honor of Jitka Dupacova

Chair: David Morton

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In Honor of Jitka Dupačová

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Abstract

As one of the founders of stochastic programming Jitka Dupačová made deep contributions, which continue to influence the state of the field today. Her contributions to stochastic programming include seminal work in distributional minimax optimization, robustness of solutions, contamination of a nominal probability distribution, stress testing, scenario generation and scenario reduction, and applications in finance. In this special session, we will: (i) provide an overview of her biography; (ii) have a technical presentation on minimax optimization and its impact; (iii) have a technical presentation on scenario reduction and its impact; and, (iv) have an open time for comments, memories, and thoughts from members of the audience.

Special Session: Roundtable

Chair: Suvrajeet Sen

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Are Stochastic Programs Solvable?

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Abstract

In connection with the 1991 ISMP Conference in Amsterdam, the organizers of that conference had compiled a book on various topics in Mathematical Programming. In it George Dantzig wrote: "In retrospect, it is interesting to note that the original problem that started my research is still outstanding – namely the problem of planning or scheduling dynamically over time, particularly planning dynamically under uncertainty. If such a problem could be successfully solved it could eventually through better planning contribute to the well-being and stability of the world." It has been 25 years since Dantzig's assessment. This special session is intended to revisit the question: "Are Stochastic Programs Solvable?" The speakers will address this issue from their unique perspectives.

Plenary: Quantifying Uncertainty using Epi-Splines — Johannes Royset

Chair: Alejandro Jofre

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Quantifying Uncertainty using Epi-Splines

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Abstract

Stochastic programming, optimization under uncertainty, and stochastic simulations require as input quantitative models of random phenomena usually in the form of ambiguity sets, probability densities, cumulative distribution functions, and descriptions of stochastic processes. Similar models synthesize and extrapolate output from physical and computational experiments. A challenge in these situations is how to best combine data, which might be noisy, with other information based on structural knowledge and experiences. We describe a framework for constructing quantitative models of random phenomena that relies on the formulation and solution of function identification problems. These problems consist of finding a semicontinuous function that minimizes some criterion and satisfies constraints. The presentation describes through examples how such problems can be formulated and layout out advantages that materialize from the formulations. We also develop a methodology for numerically solving the problems through approximation of semicontinuous functions by epi-splines. Case studies from the areas of electricity markets, traffic engineering, natural resources, capital budgeting, and uncertainty quantification of physical systems illustrate the framework.

CS: Equilibrium Problems

Chair: Leonidas Sakalauskas

ICSP 2016 | Búzios, Brazil
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General Bargaining Equilibrium for Stochastic Economies

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Abstract

This paper develops a general concept of bargaining equilibrium for stochastic economies with a small number of agents interacting (cooperating and competing), and who know each other. General (or Walrasian) equilibrium is an extremely useful concept for analyzing competitive economies with a large number of price taking agents. However, it is not a good concept for analyzing economies in which a small number of agents interact and in which prices and allocations are determined by negotiations among agents. This paper develops a new equilibrium concept that is general, tractable, and easily computable using standard numeric methods. The model extends previous multilateral negotiations models such as Gomes and Jehiel (2005), Gomes (2005, 2014), and Bloch and Gomes (2006) by allowing for uncertainty and transaction costs. Mathematically, solving for the equilibrium corresponds to solving a general complementarity problem or a variation inequality problem. The model can be applied, for example, to study spacial models of coalition government formation (where parties choose policy actions and coalitions) and mergers and acquisitions activity in an oligopolistic industry (where firms who know each other well choose mergers partners among other industry participants, negotiating the acquisition price heavily, in the presence of significant transaction costs and uncertain synergy gains). The methodology developed in this paper can be used to study the causes of inefficiencies in social and economic interactions. .

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Lopsided approximation for solving Equilibrum Problems

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Abstract

In this talk, a review of a new approach for studying equilibrium problems is presented. Particularly, the set of solutions of a multiagent equilibrium problem is characterized as the optimal points of an associated mathematical programming problem, corresponding to the *max-inf* optimization family. Given this setting, an approximation scheme is proposed through the application of the *lopsided convergence* theory. Finally, in order to provide a computational tool for numerical solutions, a constructive algorithm is discussed, based on a proposed application of the theory previously developed.

The family of the problems that can be modeled under this setting is appealingly large, ranging from Microeconomics up to Engineering applications. Three examples for this solution technique are presented: 1) a general equilibrium model for an exchange economy with uncertainty [1]; 2) a general equilibrium model with financial markets [3]; and 3) an infrastructure planning for fast EV-charging station problems [2]

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Bilevel Stochastic Programming by Monte Carlo Method

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Abstract

A great amount of new applied problems has recently arisen that can be efficiently solved only as stochastic bilevel programs (e.g., the pricing and resource allocation in telecommunication networks, natural gas cash-out problem, the deregulated electricity market equilibrium problem, and so forth). Bilevel models to describe migration processes are also in the list of the most popular new themes of bilevel programming, as well as allocation, information protection, and cybersecurity problems. Although a wide range of applications fit the bilevel programming framework, real-life implementations are scarce, due mainly to the lack of efficient algorithms for tackling medium- and large-scale bilevel programming problems. The survey of simulation-based optimization methods is given in the lecture focusing on the decomposition and the sequential Monte-Carlo search. The approach considered of sequential Monte-Carlo search is grounded by the stochastic termination procedure and the rule for iterative regulation of size of Monte-Carlo samples as well as taking into account the stochastic model risk, and allows us to solve stochastic bilevel problems rationally from the computational viewpoint and guarantees a.s. the convergence. The termination procedure is also proposed, which allows us to test the optimality hypothesis and to evaluate the confidence intervals of the objective and constraint functions in a statistical way. The numerical study and the practical example corroborate theoretical conclusions.

CS: Applications in Health Care

Chair: Tito Homem-de-Mello

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Appointment Scheduling under Slot Dependent No-Show Behavior

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Abstract

We analyze the problem of scheduling patients' appointments at a health facility while taking into account patients' no-show behavior. This is a problem in which the decision maker has to assign appointment times to a fixed set of patients during the working day assuming that three types of costs are involved: waiting time, idle time and overtime costs. Further, two main sources of uncertainty are considered — the service time and the no-show behavior of the patients. Patients' absences to appointments are a common problem and one of the primary concerns in medical facilities.

In some cases, real data have shown that the no-show probability depends on the time of the appointment. This implies that the probability of arrival of a patient depends on the time assigned to that patient, which is a decision variable of the problem. Problems with decision-dependent uncertainty are typically difficult to solve, and this one is no exception. Existing work for this problem in the literature only provide approximations.

In this talk, the schedule dependent problem is presented as a constrained non-convex stochastic optimization problem, and an algorithm based on the trust region methods is proposed to solve it. In particular, we present an extension of the STRONG algorithm (Chang et al., 2013), a method designed for unconstrained simulation optimization that is adapted to this constrained context. Some numerical results that illustrate the improvement of taking into consideration the variability of the no-show behavior are presented.

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A hierarchical solution approach for bed capacity planning under uncertainty

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Abstract

Effective capacity planning under uncertainty ensures robust and consistent plans in time. The health sector is a service system of great relevance to consider better methods for inter-temporal decisions, since poor planning affects directly the welfare of people. This work presents a hierarchical multistage model applied to beds planning. We propose a solution method based on the formulation and solved using stochastic optimization. The problem is to determine the availability of beds that minimizes overall patient welfare loss as a function of waiting time. From the solution we propose policies allowing better decisions in different planning horizons.

CS: Interfaces between Robust and Stochastic Optimization

Chair: Marida Bertocchi

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Robust and Stochastic Optimization to improve consistency in Intertemporal Decisions

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Abstract

Optimization models have been used since long to support operational planning in several areas. Typically, we model decisions that expand different time frames: long-term strategic decisions, mid term tactical decisions and short term operational decisions. In general, longer term decisions impose4 constraints to the decision process in shorter horizons and it would be expected that feasible and efficient shorter term decisions be obtained. However, many times there are incosistencies between these models, specially due to various sources of uncertainty, and also, due to the dynamics of the process. We explore the question of how to improve consistency and address this problem using various stochastic and robust optimization models. We show some results on how these methodologies could increase consistency, with an application to a planning model in the forest industry and also for a problem in the management of health systems. .

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Comparison of risk-averse stochastic programming and robust optimization for an energy producer

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Abstract

In this talk, we compare three optimization approaches to solve an operational and market involvement problem for a virtual power plant (VPP). The VPP generates electricity using a system involving a thermal plant, a hydro-pump unit, and a wind farm. The goal of the VPP is to maximize the profit through the optimal self-scheduling and selling or buying electricity in a market. In this decision-making problem, the parameters subject to uncertainty are the wind power and the electricity prices. We define this problem with a risk-averse stochastic programming formulation, with a robust optimization formulation, and with a new hybrid approach. The uncertainty is represented by a finite number of discrete scenarios in the stochastic programming approach, and by convex uncertainty sets in the robust optimization approach. Risk management is addressed using the conditional value at risk and a budget of uncertainty constraint. Each of the three formulations is solved with different methods, involving direct solution and decomposition methods. In the decomposition methods, we implement convergence acceleration techniques and parallelization to improve their convergence. We analyze the algorithmic implementation and computational performance of the decomposition methods to solve two case studies. Furthermore, we compare the impact of the risk measures and their parameterizations on the results obtained with the risk-averse stochastic programming, robust optimization and the new hybrid approach.

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A scenario-based framework for supply planning under uncertainty: stochastic programming versus robust optimization approaches

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Abstract

In this paper we analyze the effect of two modelling approaches for supply planning problems under uncertainty: stochastic programming (SP) and robust optimization (RO). The comparison between the two approaches is performed through a *scenario-based framework* methodology, which can be applied to any optimization problem affected by uncertainty. For SP we compute the minimum expected cost based on the specific probability distribution of the uncertain parameters based on a set of scenarios. For RO we consider static approaches where random parameters belong to box or ellipsoidal uncertainty sets in compliance with the data used to generate SP scenarios. Dynamic approaches for RO, via the concept of adjustable robust counterpart, are also considered.
The efficiency of the methodology has been illustrated for a supply planning problem to optimize vehicle-renting and procurement transportation activities involving uncertainty on demands and on buying costs for extra-vehicles. Numerical experiments through the scenario-based framework allow a fair comparison in real case instances. Advantages and disadvantages of RO and SP are discussed.

CS: Applications in Inventory and Logistics

Chair: Laureano Escudero

ICSP 2016
Búzios, Brazil
25 June – 1 July, 2016

Stochastic model for fuel procurement with commercial and logistic constraints

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Abstract

Fuels for thermal generation of electricity: liquified natural gas, diesel oil and fuel oil are purchased as discrete size cargos. Usually, purchase decision is made no less than two months before cargo arrival. After decision is taken, changes in thermal generation demand determine corrective actions such as cargo delay or cancelation due to minimum and maximum inventory capacity levels. Corrective actions must follow rules of commercial contracts. Each corrective action and its corresponding cost depend on how the unknown is revealed. The objective of the present work is to model a problem of minimization of the expected cost of fuel procurement. A multistage stochastic model is developed. It considers decisions on fuel procurement, fuel blending, delay and cancelation of cargos for a given time horizon, while satisfies the uncertain demand, the material balances, the commercial and logistic constraints. In order to achieve good results in an affordable time, a Relax and Fix heuristic is proposed and applied to determine the optimum decision. The methodology is applied for a specific case and results are compared with the solution of a Branch and Bound algorithm. It shows to be appropriate for decision-making.

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Optimization for the single-retailer location problem under uncertainty

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Abstract

We study the problem of a retailer facing uncertainty on the demand. His main objective is to optimize the inventory policy and to analyze the option to open a new selling point. We propose an integrated framework to jointly optimize the strategic and tactical decisions. First, we formulate a *deterministic optimization problem* (with demand known in advance) and we analyze its outcomes. The optimal solution is not satisfying because it suffers from being anticipative. Second, we formulate a *two-stage stochastic optimization problem*, as a step to take into account uncertainty on the demand in the decision problem. Third, we turn to *multi-stage stochastic optimization.* We formulate the problem in three different versions with increasing complexity. The first version considers a single retailer and ignores the strategic decision to open a new selling point. We solve it by *stochastic dynamic programming* and we discuss preliminary results. We are currently developing the second and third versions: a $N-$retailer case where transshipments between retailers is possible; a case where opening decisions of retailers might be made at any period of the time span, and not only at the beginning.

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On the strongest Lagrangean bound for multistage location-assignment problems under uncertainty

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Abstract

In this work we present an application of the multistage scenario Cluster Lagrangean Decomposition (CLD) approach that we have presented elsewhere for obtaining strong (lower in case of minimization) bounds on the solution value of large sized instances of the multi-period stochastic discrete location problem that sites facilities to locations and assigns customers to facilities under uncertainty, so-named *Multistage Stochastic Facility Location Problem* (MSFLP) under uncertainty. It is well known that the general static deterministic location problem is NP-hard and, so, it is the multi-period stochastic version. So, a decomposition methodology should be used. The DEM is formulated as a mixture of the splitting representation up to a given stage, so-named break stage, in the scenario tree, and the compact representation for the other stages along the time horizon. Then, independent scenario cluster submodels are generated from the original stochastic problem by dualizing the Nonanticipativity Constraints (NAC) in the original model that are related to the nodes that belong to the stages up to the break one. Those submodels lead to a (lower) bound on the solution value of the original model, where the Lagrange multipliers related to those NAC are appropriately updated a each iteration of the procedure. A broad computational experience is reported for large-scale instances, up to 15 facilities, 75 customers, 6 periods, over 260 scenarios and over 420 nodes in the scenario tree. The resulting stochastic model for the biggest instances has over 550,000 constraints and 480,000 (0-1) variables. Given those huge dimensions for a combinatorial optimization model, plain use of IP solvers, in our case, CPLEX v12.5, could not provide even a feasible solution before running out of memory for the biggest instances. By contrary, the CLD approach requires a very affordable elapsed time, it obtains the optimal solution for all of the instances but the largest ones. For those other instances, a Lagrangean heuristic provides solutions whose quasi-optimality gap that goes from 0.72 to 2.5%.

CS: Optimization of Dynamic Models

Chair: Nicolas Langrené

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Approximate Dynamic Programming in Parallel

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Abstract

Solving stochastic dynamic programming problems in practice can require large amounts of computational power. Over the last decade, CPU speeds have stagnated, although CPUs have offered increased computational power in other ways – most importantly by increasing the number of *cores*. Applications must therefore be able to execute in parallel in order to take advantage of recent increases in computational power. We develop an algorithm for (approximately) solving a stochastic dynamic programming problem in parallel, using the techniques of *approximate dynamic programming*. We then compare the computational performance of the algorithm on a large-scale stochastic simulation of the Brazilian Electric Power System to the performance of a corresponding serial implementation, in order to highlight the benefits of parallel execution. Most importantly, parallel processing can dramatically reduce the time required to obtain an acceptable solution.

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Approximate dynamic programming with endogenous state variable: the control randomization approach

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Abstract

A very popular algorithm to solve multi-stage stochastic optimization problems in the finance industry is the simulation-based Least-Squares Monte Carlo algorithm (LSMC). Initially designed for the pricing of American option ([1], [2]), it has subsequently been extended in various ways to encompass, for example, switching costs (gas storage valuation, investment in power plants, etc.), and chance-constraints (dam management, portfolio optimization, etc.), among others.
In addition to being very versatile when it comes to objective function design and dynamics of the stochastic state variables, the main strength of this algorithm is its scalability, with respect to both the number of scenarios and the number of decision times (with N decision times and M scenarios, the computational complexity is simply $\mathcal{O}(N \times M)$).
The purpose of this talk is to review a more recent extension, namely the possibility to include endogenous state variables (ie. state variables whose dynamics depends on the control) thanks to the so-called control randomization technique ([3]). This talk will describe the method and illustrate its potential on several applications (superhedging under uncertain volatility, portfolio selection under liquidity impact, mining operations, etc.) that are now within reach of the LSMC algorithm.

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CS: Modeling Languages and Computation Strategies for SP

Chair: Christian Valente

Updates to PIPS-SBB: Distributed-memory structure-aware presolve and cut generation

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Abstract

Deterministic equivalent formulations of stochastic MIPs from applications such as unit commitment (UC) can exceed available memory on a single workstation. To overcome this limitation, we have developed PIPS-SBB, a distributed memory parallel stochastic MIP solver based on the distributed memory parallel stochastic LP solver PIPS-S. Our initial work [1] focused on implementing a distributed-memory B&B algorithm that parallelizes LP solves, as well as a basic presolve and structure-aware branching. To further improve performance, we discuss implementing structure-aware variants of presolve methods and cuts, and how these methods improve performance. Based on these results, we discuss a path forward to solving large UC problem instances.

References

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New Solver Interface Approaches for Stochastic Programming in AMPL

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Abstract

There has been considerable interest in adding stochastic programming (SP) support to the AMPL modeling language and a number of stochastic extensions has been proposed including SAMPL [4], SML [2] and StAMPL [3]. These introduce various new language constructs to describe SP problems and either require a custom translator for the extended language or some kind of preprocessing to convert the code into the standard AMPL form. In this work we investigate an alternative approach to formulation of two- and multi-stage recourse problems as well as problems with second-order stochastic dominance constraints in AMPL. Our method does not require any extensions to the language or additional preprocessing. Instead we rely on existing extension mechanisms provided by AMPL such as suffixes and user-defined functions to describe an SP problem, and work on the solver interface level to convert it into the solver form or SMPS [1]. This allows using the standard AMPL translator providing better compatibility with existing code and diagnostics than alternative approaches. We describe the implementation of our method and present examples and test results.

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AMPL representation and solution of optimization models under uncertainty: an e-book

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Abstract

We describe the content and structure of an e-book which has a collection of models and generic methods of expressing and solving Stochastic Programming (SP) problems. Established paradigms, namely, SP problems with recourse, chance constrained, integrated chance constrained and robust optimization models are introduced and represented through use case exemplars. Our objective is to make these classes of models readily available to the industry based quantitative analysts as well as the academic research community. Through many years of applied research in this field and our close collaboration with AMPL LLC we have developed AMPL templates and frameworks whereby we can describe and solve this genre of models. Our use cases, however, extend beyond traditional applications. As an example, we consider the formulation of a long-short portfolio model which is based on the Second order Stochastic Dominance (SSD) method of portfolio construction with down side risk control. We describe the formulation as well as the use of dynamic cuts for its solution.

TS: SP Models for Asset Allocation and Downside Risk Control

Chair: Cristiano Valle

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News enhanced trading strategy based on Kelly criterion

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Abstract

We define a metric of news impact on asset behaviour; the impact takes place as news (also micro-blogs and on line search information) arrive as information stream(s). By including these information streams in predictive models we achieve superior ex-ante prediction of volatility. Our daily trading strategy utilises enhanced volatility prediction and applies ubiquitous Kelly criterion. Kelly criterion as such exploits volatility (volatility pumping); we present empirical results which show superior fund performance of the news enhanced approach in contrast to the strategy which uses market data only in the predictive model.

Enhanced cutting-plane methods for two-stage stochastic programming problems

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Abstract

We deal with decompostion approaches for non-traditional two-stage problems, with a focus on risk-averse problems and on handling binary first-stage variables. Computational issues will be discussed and a study presented.

Asset Allocation using Particle Methods

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Abstract

Dynamic asset allocation probles are T-stage stochastic programs that suffer from the curse-of-dimensionality for dynamic programming based approaches and exponential growth in sample paths for direct optimization. The result is that most solution procedures either handle only limited dynamics or employ crude approximations of the value function. This talk will discuss an approach using a method based on particle filtering that maintains a constant number of states at each stage.

The basic idea of the approach is to branch forward from each of N particles in each stage and to update the probability of each particle using a conditional probability on all N states in the previous stage with re-sampling when the expected influence of a path becomes low. With sufficient mixing, the Markov chain of sample paths approaches a stationary distribution that achieves a consistent estimate of the multistage optimal value. Additional asymptotic properties (e.g., CLT-type results) and a large-deviation principle are also be available. .

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Novel Approaches for Portfolio Construction Using Second Order Stochastic Dominance

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Abstract

In the last decade, a few models of portfolio construction have been proposed which apply Second Order Stochastic Dominance (SSD) as a choice criterion. SSD approach requires the use of a reference distribution which acts as a benchmark. The return distribution of the computed portfolio dominates the benchmark by the SSD criterion. The benchmark distribution naturally plays an important role since different benchmarks lead to very different portfolio solutions. In this paper we describe a novel concept of reshaping the benchmark distribution with a view to obtaining portfolio solutions which have enhanced return distributions. The return distribution of the constructed portfolio is considered enhanced if the left tail is improved, the downside risk is reduced and the standard deviation remains within a specified range. We extend this approach from long only to long-short strategies which are used by many hedge fund and quant fund practitioners. We present computational results which illustrate (i) how this approach leads to superior portfolio performance (ii) how significantly better performance is achieved for portfolios that include shorting of assets.

TS: High-Performance Computing

Chair: Victor Zavala

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Adaptive Sparse Quadrature for Stochastic Optimization

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Abstract

Stochastic programing models became popular in recent years as most real-world optimization applications, such as those in energy, finance, and transportation, almost invariably involve uncertain parameters/inputs. These models typically presume that probability distributions for these parameters are known or can be estimated, and formulate objectives and/or constraints that are functions of summary statistics based on these inputs. Monte Carlo (MC) and Sample Average Approximation (SAA) techniques are commonly used to estimate statistics, *e.g.* expectations, that are employed in stochastic optimization models. While the MC approach is generally robust and scales well to high-dimensional problems, it exhibits poor convergence properties. This becomes especially evident in instances where the quantity of interest (QoI) exhibits significant variance due to the uncertainties in the input parameters. For these cases, a large number of samples (scenarios) is necessary to achieve accurate estimates for the desired statistics of the QoI. In this work, we consider an alternate approach that does not rely on random sampling. We model uncertain parameters as random variables, and employ functional representations for them in terms of sets of orthogonal basis functions of standard random variables, *e.g.* uniform or standard normal random variables. These representations, called Polynomial Chaos (PC) expansions, allow efficient propagation of uncertainties from inputs to output QoIs. The PC representations are built based on non-random sampling, using sparse quadrature methods, and are valid over the range of the input uncertainty. To alleviate the curse of dimensionality, we exploit the fact that in most applications of interest only a handful of parameters are dominant. Therefore, we construct the sparse quadrature adaptively, tailored to the specific dependence on the components of the input stochastic space. We explore several adaptive criteria and compare the adaptive sparse grid approach with results obtained via isotropic, non-adaptive, sparse grids, as well as with the classical MC approach.

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An Asynchronous Incremental Proximal Bundle Method for Dual Decomposition of Stochastic Mixed-Integer Programming

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Abstract

We present an incremental proximal bundle method applied for dual decomposition of stochastic mixed-integer programming (SMIP). The method uses a structural property that provides exact subgradients of the Lagrangian dual function even when the function is only approximately evaluated. The method and its asynchronous variant have been implemented in an open-source software package DSP [1] capable of solving the SMIP problems in high performance computing systems. Computational examples are given in this talk.

References

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Decomposition-based global optimization for optimal power flow problems under uncertainty

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Abstract

We discuss the development and application of a decomposition-based global optimization method, which is a variant of nonconvex generalized Benders decomposition (NGBD) [1]. NGBD was originally developed for a class of nonconvex mixed-integer nonlinear programming (MINLP) problems that can arise from power flow problems under uncertainty. As the performance of NGBD is highly dependent on the tightness of convex relaxations used, we propose to systematically integrate domain reduction techniques into the NGBD procedure, leading to progressively tightened variable bounds and improved convex relaxations. Domain reduction is achieved via construction of extra cutting planes from the solution of NGBD subproblems, and the reduction of variable ranges from solving bound contraction subproblems. These techniques not only can reduce the number of NGBD iterations, but also can speed up the solution of nonconvex NGBD subproblems. The computational advantage of the proposed method will be demonstrated through case study of some optimal power flow problems in the literature.

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Advances in tree traversing strategies and cut sharing for multistage Benders decomposition - application to the stochastic hydrothermal coordination problem in a parallel processing environment

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Abstract

Benders decomposition is a smart iterative strategy to solve optimization problems by decomposing the problem into small and easy-to-solve sub problems. It is commonly used to solve very large linear problems, generally associated to time-dependent probabilistic scenarios (scenarios trees), whose dimension becomes physically unmanageable for classical linear program algorithms.

Some weaknesses of this strategy may be: memory requirements and large CPU time due to its iterative nature, which may take a long time to converge. Besides that, decomposition may add an extra cost of information exchange, specially in a parallel processing environment. Efforts to improve Benders method efficiency have been made so far in the literature in two senses: 1) acceleration of the convergence process and 2) reduction of the CPU time per iteration.

We study and propose general smart tree traversing protocols, as well as cut sharing strategies in multistage Benders decomposition. The main idea is to explore the properties of Benders convergence in sub trees (local convergence) and also to make use of the information on the problem structure, which allows an additional level of cut sharing procedures. Such strategies enable an efficient guidance of the tree traversal, avoiding unnecessary and undesirable forward/backward steps.

Since the advances and accessibility of parallel technology have allowed huge processing time reduction and introduced new concepts of algorithm efficiency, we also assess the suitability of the algorithms to run in a parallel environment.

Stochastic hydrothermal coordination problems modeled as linear programming are known to have high dimensionality and are usually solved by Benders decomposition. Therefore we apply the proposed strategies to reduce the CPU time and improve the global Benders convergence process to this type of problems on a parallel environment.

TS: Risk-Averse Optimization

Chair: Darinka Dentcheva

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Multivariate Stochastic Orders in Radiation Therapy Design

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Abstract

Radiation therapy design optimizes the radiation dose delivery for the treatment of cancer. We propose a new design approach based on a probabilistic interpretation of the problem. We consider several stochastic orders for expressing the medical requirements regarding the dose distributions. In addition, we present results associated with a conditional multivariate stochastic order, which appears most suitable to this design problem. The problem formulation facilitates the application of convex optimization tools and methods while keeping close control on the dose delivery. We propose specialized decomposition methods for solving the resulting optimization problems and report on the numerical results.

This is a joint work with Darinka Dentcheva, Andrzej Ruszczyński, and Ning Yue.

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Learning with Dynamic Risk for Clinical Trial Design

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Abstract

We consider Markov decision processes (MDP) under uncertainty in both the system dynamics and costs. Such problems occur frequently, for example, with unknown model parameters or those estimated from empirical data, imperfect state information, or delayed costs. Industrial instances are diverse, ranging from machine learning applications to energy to healthcare. Much work in the literature has focused on construction of uncertainty sets of distributions and optimization with respect to the worst-case expectation over this set. In this talk, we take a Bayesian perspective and approach the problem by instead employing dynamic Markov risk measures to control the coupled uncertainties. We introduce the problem of optimal dose finding, arising in the design of early-stage clinical trials. We characterize the log-concavity of Bayesian posterior sequences in the problem. We then formulate the tractable two-stage problem with dynamic Markov risk measures, obtain a sub-optimal policy to the lookahead problem in each case, and compare to prominent policies in the literature. We then introduce an approximation schema for the full problem and solve the corresponding approximate DP (ADP) equations. We evaluate policy performance in *in distribution* and show that risk-averse lookahead policies are competitive with ADP solutions.

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Approximate Dynamic Programming for Dynamic Quantile-Based Risk Measures

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Abstract

In this paper, we consider a finite–horizon Markov decision process (MDP) for which the objective at each stage is to minimize a quantile–based risk measure (QBRM) of the sequence of future costs (we call the overall objective a dynamic quantile–based risk measure (DQBRM)). In particular, we consider optimizing dynamic risk measures constructed using one–step risk measures that are a convex combination of the expectation and a QBRM, a class of risk measures that includes the popular value at risk (VaR) and the conditional value at risk (CVaR). Although there is considerable theoretical development of risk–averse MDPs in the literature, the computational challenges have not been explored as thoroughly. We propose a simulation–based approximate dynamic programming (ADP) algorithm to solve the risk–averse sequential decision problem. In addition, we address the issue of inefficient sampling in risk applications and present a procedure, based on importance sampling, to direct samples toward the "risky region" as the ADP algorithm progresses. Finally, we show numerical results of applying our algorithms in the context of an energy storage and bidding application.

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Time-Consistent Risk Measures for Continuous-Time Markov Chains

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Abstract

We develop an approach to time-consistent risk evaluation of continuous-time processes in Markov systems. Our analysis is based on dual representation of coherent risk measures, differentiability concepts for multivalued mappings, and a refined concept of time consistency. We prove that the risk measures are defined by a family of risk evaluation functionals (transition risk mappings), which depend on state, time, and the transition function. Their dual representations are risk multikernels of the Markov system. We introduce the concept of a semi-derivative of a risk multikernel and use it to generalize the concept of a generator of a Markov process. Using these semi-derivatives, we derive a system of ordinary differential equations that the risk evaluation must satisfy, which generalize the classical backward Kolmogorov equations for Markov processes. Additionally, we construct convergent discrete-time approximations to the continuous-time risk measures.

TS: Stochastic VIs and Complementarity Models

Chair: Asgeir Tomasgard

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Variance-based stochastic extragradient methods with linear search for stochastic variational inequalities

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Abstract

We propose stochastic extragradient methods for stochastic variational inequalities with a linear search requiring only pseudo-monotonicity of the operator and no knowledge of the Lipschitz constant L. We provide convergence and complexity analysis, allowing for an unbounded feasible set, unbounded operator, non-uniform variance of the oracle and we do not require any regularization. We also prove the generated sequence is bounded in L^p. Alongside the stochastic approximation procedure, we iteratively reduce the variance of the stochastic error. Our methods cope with stepsizes bounded away from zero and attain the near-optimal oracle complexity $O(\log_{1/\theta} L) \cdot \epsilon^{-2} \cdot [\ln(\epsilon^{-1})]^{1+b}$ and an accelerated rate $O(1/K)$ in terms of the mean (quadratic) natural residual and the mean D-gap function, where K is the number of iterations required for a given tolerance $\epsilon > 0$ for arbitrary $\theta \in (0,1)$ and $b > 0$. Explicit estimates for the convergence rate, oracle complexity and the p-moments are given depending on problem parameters and the distance of initial iterates to the solution set.

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Mechanism design and allocation algorithms for network markets with piece-wise linear costs and quadratic externalities

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Abstract

Motivated by electricity markets we introduce in this paper a general network market model in which agents are located on the nodes of a graph. A traded good can travel from one place to another through edges considering quadratic losses. An independent operator has to match locally production and demand at the lowest expense. Producers types are random. As argued in our previous paper "Cost-minimizing regulations for a wholesale electricity market" this setting is relevant to describe some real electricity markets, pricing behavior and market power coming from the fact that generators can bid above their true value. In a general setting of many distributed generator agents connected by a transmission network, bidding piece-wise linear cost functions, we propose a pricing optimal mechanism model to reduce market power. Our main results are the expression of the optimal mechanism design, two algorithms for the allocation problem and market power estimations. To deduce these nice properties, we intensively use convex analysis and some monotone behaviors of the set-valued maps involved. Furthermore, these algorithms make it possible to numerically compute a Nash equilibrium for the procurement auction, which is important to compare the optimal mechanism and the standard auction setting. Finally, we also show some interesting examples.
In the continuation of this work, we introduce a class of biding games for which we prove the existence of a Nash equilibrium. We give a sufficient condition for uniqueness, propose a numerical scheme to compute the extreme Nash Equilibria and show that the equilibrium strategies are convex for a subclass of games. We apply this framework to electricity auctions.

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Benders Decomposition for Equilibrium Problems with Risk Aversion

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Abstract

In stochastic optimization problems, it is common that there is a natural decomposable structure along scenarios, that can be exploited by a family of methods known as Benders decomposition. In the case of stochastic equilibrium problems, the solution methods are different from that of optimization. One option is computing the equilibrium point by solving a variational inequality problem (VI). In this VI, the feasible set still has decomposable structure, and for the risk neutral case, Benders decomposition methods have been developed. However, these approaches still have some common drawbacks, as those related to the infeasibility of some subproblems and linearity assumptions on the VI operators. In a risk averse context, the decomposition can be even more difficult because of lack of linearity or even lack of differentiability. In this work we present a new algorithm that addresses these challenges, and in particular can be applied to risk averse models.

ICSP 2016 Búzios, Brazil
25 June – 1 July, 2016

A stochastic complementarity model for energy and climate policy

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Abstract

In this paper, we present a multi-stage multi-horizon stochastic equilibrium model of multifuel energy markets. The model is a one-level game, where market players simultaneously make their here-and-now strategies for a multi-stage investment taking into account short-term operations. It is assumed that market players have symmetric information on uncertainties from both long-term and short-term time scales. To facilitate the modeling, in this paper we propose a modified multi-horizon scenario tree modeling approach where both long-term and short-term decisions are made. In the original approach suggested in [1], there is no link between any short-term operational period within a long-term period and the next long-term period. In this paper, a modified approach allows passing the approximated value of any state variation tothe next long-term period. Specifically, two different approximation methods are suggested, i.e., passing the expected value of a state variation over a short-term scenario and passing the worst-case value.

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TS: SDDP: Computation and Theory

Chair: Vincent Guigues

ICSP 2016

Búzios, Brazil
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Regularized Decomposition of Multistage Stochastic Programs

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Abstract

We develop a quadratic regularization approach for the solution of high–dimensional multistage stochastic optimization problems characterized by a potentially large number of time periods/stages (e.g. hundreds), a high-dimensional resource state variable, and a Markov information process. The resulting algorithms are shown to converge to an optimal policy after a finite number of iterations under mild technical assumptions. Computational experiments are conducted using the setting of optimizing energy storage over a large transmission grid, which motivates both the spatial and temporal dimen- sions of our problem. Our numerical results indicate that the proposed methods exhibit significantly faster convergence than their classical counterparts, with greater gains observed for higher–dimensional problems.

Convergence Proofs of SDDP and Multi-stage Stochastic Decomposition

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Abstract

Stochastic Dual Dynamic Programming (SDDP) has become one of the main algorithmic forces for hydro-power scheduling as well as other applications of Multi-stage Stochastic Programming. One of the main arguments underlying the convergence of this algorithm is its use of fact that there can be only finitely many Benders' cuts that can be generated by these types of algorithms. This argument requires that the cuts use the probability distribution which used to state the optimization problem. In many applications of sampling-based algorithms, one may not have a prior description of scenarios, and their probabilities. For such cases, the traditional Benders' cuts in SDDP are no longer available, although some empirical estimates of the minorants can be calculated. We will discuss convergence of such algorithms, and show that convergence can be obtained even if one replaces the cuts used in SDDP with their empirical estimates. It turns out that the use of regularization becomes the key to convergence of such algorithms, which we refer to as Multi-stage Stochastic Decomposition.

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Proxy Strategies for SDDP Applied to High-Dimensional Multistage Stochastic Linear Program

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Abstract

Multistage linear programs solved by SDDP usually demand a computational effort that slows down the convergence process for high dimensional problems. To reduce the running time without losing in policy quality, we modify the backward pass to use a proxy in the cut computations. The strategy is assessed for the Brazilian Long-Term Hydrothermal Scheduling program, comparing its performance with a traditional SDDP approach, by means of the lower bound values provided by the algorithm and the operational decisions obtained in both out-of-sample and in-sample policy simulation forward pass.

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Multistage Stochastic Convex Programs with a Random Number of Stages: Modelling and Solution Methods

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Abstract

We show how to write dynamic programming equations for risk-averse multistage stochastic convex programs with a random number of stages. This formulation allows us to solve these problems using decomposition methods such as SDDP. We also propose an inexact variant of SDDP and study its convergence.

TS: Hydropower Reservoir Management

Chair: Stein-Erik Fleten

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Day-Ahead Bidding for Hydropower under Price and Inflow Uncertainty

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Abstract

In deregulated electricity markets, hydropower producers must bid their expected generation into the day-ahead market. At the time of bidding, future prices and inflows are two of the fundamental uncertainties. After market clearing, the submitted bids should result in physically feasible production schedules for the next day. Models for optimal bidding must thus adequately describe both the production system and the uncertainty faced by producers.

We present a new model for determination of optimal bid decisions to the day-ahead market based on stochastic successive linear programming. With this method, we are able to model the physical system with a high degree of detail and at the same time explicitly consider the stochastic nature of prices and inflow in the optimization of bids. The bid curves generated from the stochastic model are compared to separately calculated marginal cost curves from a deterministic model.

Our results show that the bid curve from the stochastic model follows the shifts in the marginal costs curves due to uncertain inflows. The fact that producers can give bids in terms of a supply function where the willingness to produce is dependent on the price will to some degree address the uncertainty of prices, but may not always give good results if inflow uncertainty is present. The stochastic model gives bid curves that see the total picture of uncertainty and generates bids that are robust enough to accommodate sound production schedules for a larger range of possible future states of the system.

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Blackbox optimization of inflow scenario trees

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Abstract

Short-term optimization models are utilized in the daily operations of a hydropower producer to determine turbines working, the amount of water they process, as well as the reservoir volumes. Uncertainty is present in the inflows of the reservoirs. In order to represent the underlying distribution of the inflows in a discrete fashion, multi-stage scenario-trees are used. The method to generate scenario-trees [1] from scenario fans of inflow prevision requires input parameters. More precisely, the user must determine the number of stages, the number of nodes per stage as well as the aggregation of each stage. We use blackbox optimization to determine the scenario-tree structure that maximizes energy produced. A rolling-horizon procedure of 30 days is used. The blackbox is the whole test-bed. A two phase multi-stage stochastic model is solved. The first phase is a stochastic nonlinear mixed integer problem and the second phase is a stochastic linear integer model [3]. NOMAD [2] is the blackbox optimization software used to compute results. The method is tested on three hydropower plants located in Saguenay, Canada. Numerical results are presented.

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Evaluating the costs of providing capacity reserves in a hybrid hydro-wind power system

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Abstract

This research concerns long-term power system scheduling models based on Stochastic Dual Dynamic Programming. In particular, we focus on how the traditional modelling framework can be extended to accommodate some of the expected changes in the future power system – and market structure. Increasing penetration of renewable generation, such as wind power, introduces additional uncertainty and leads to a higher need for balancing reserves. Moreover, the balancing markets may provide new profit opportunities for flexible hydropower producers. Some of the extensions we explore are to consider an additional market for providing capacity reserves, such as primary or secondary reserves for ancillary services, and to explicitly account for uncertainty in wind power generation. The purpose of the model is primarily to provide target values for short-term models. It could, however, also be useful for capacity expansion and investment planning (e.g. in new wind power projects).

Increasing amounts of intermittent energy generation in a power system is believed to increase the need and costs of balancing reserves. By performing several case studies with different levels of wind penetration in the system, we aim to evaluate the shape of this cost-curve and thereby quantifying the flexibility a certain hydropower producer may provide.

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Decomposition of Bidding in Reserves and Day Ahead Electricity Markets

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Abstract

Hydropower producers make short-term bidding decisions every day to maximize profit. We focus here on decomposition approaches for a stochastic programming model for bidding in spinning reserve markets and energy-only day ahead markets when markets are sequentially cleared. We use data from the Nordic electricity market. The spinning reserve market is cleared first, and we disregard activation of reserves. Marginal pricing applies to both markets. Bids are cleared assuming linear interpolation between bid points in both markets. We simplify the problem by viewing it as having two stages, where trading in subsequent markets and hydropower scheduling is aggregated into a single (second) stage. The first stage has continuous variables, and the second stage has binary variables. We report on computational experience from approaches such as progressive hedging [2], dual decomposition [1] and Dantzig-Wolfe decomposition.

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TS: Finance Applications

Chair: Leonard MacLean

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Extending the scope of ALM to social investment – investing in population growth to enhance sustainability of Korean National Pension Service

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Abstract

Currently, Koreas National Pension Plan has been hugely accumulated; in particular, it is the third largest public pension in the world. According to its financial projection from 2013, the accumulated amount of the National Pension is expected to reach as much as 50% of the nations GDP by 2043. However, many predict that this immense fund will become exhausted by 2060 due to the aging population and the low fertility rate. In this research, we develop an optimization model to calculate the effect of the investment for raising the fertility rate. In addition, by using the asset-liability management model, we examine whether the investment for raising the fertility rate improves the sustainability of the National Pension Fund. As a result, under some specific conditions, it is shown that the investment for raising the fertility rate enhances the sustainability of the Nation Pension Fund and postpones its exhaustion. Thus, we show that socially driven investment can also be a good investment asset in which the National Pension Fund should consider to invest.

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Moment-matching scenario generation using harmony search algorithm

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Abstract

Generating scenarios that represent uncertain random variables is an important issue in stochastic programming. As a methodology to make such scenarios, moment-matching scenario generation, which approximates the statistical moments of the target random variables, is suggested. Moment-matching scenario outcomes and probabilities are computed by solving an optimization problem as in [1]. However, the problem is non-linear and non-convex, and it is hard to find the globally optimum scenario tree, which is closest to the desired moments. To solve the non-convex moment matching scenario generation problem, we propose the usage of the recently developed efficient evolutionary search algorithm, Harmony search. Harmony search algorithm is a music-inspired heuristic optimization algorithm [2]. Using this algorithm, precise moment matching can be achieved in contrast to the previous researches, and CVaR minimization example is included.

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Optimization methods for Commodity Model Calibration

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Abstract

This work develops and implements several stochastic models, univariate and multivariate, representing the dynamics of commodity prices, such as oil derivatives. Those models depends of certain parameters (mean, variance, correlations), which are unknown and must be estimated so that the models can adhere to the reality and be used when simulating future prices in the industry. By the method of maximum likelihood approach, we write the models in a state space formulation, so that a calibration can use the Kalman filter, which is applied generate estimates of the state variables and the likelihood function. We use the feasible direction no linear and semidefinite programming algorithm will be employed to maximize this function..

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Endogenous Benchmarks in Stochastic Dynamic Investment

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February 2, 2016

In this paper we consider a dynamic stochastic model of optimal portfolio choice where exogenous benchmarks at the planning horizon are used in dynamically formulating endogenous intermediate benchmarks The intermediate benchmarks use available conditioning information A probabilistic constraint controls the rate of shortfalls with respect to the benchmarks and a convex penalty in the objective controls shortfall size We find that the rate and size of shortfalls of a trader subject to intermediate path constraints is lower than that of a horizon constrained trader

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TS: MicroGrid Management

Chair: Bernardo Pagnoncelli

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Energy Management Strategies for Energy Efficient Subway Stations

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Abstract

Urban railway stations are responsible for a significant amount of energy consumption of cities transportation facilities. Their efficiency could be significantly improved by harnessing different unexploited renewable or recoverable energy resources. Residual regenerative braking energy, geothermal or waste heat and local renewable energies represent each a potential we shouldn't neglect in subway stations. However, to fully exploit these energies potential we need energetic buffers in order to handle their intermittency. We present hereby a strategy relying on electrical storage systems as well as multi-physical building inertia to tackle the variability issue of such energetic potentials. It requires a proper electrical equipments control in a demand response fashion. At the crossroad between microgrids and smart buildings management, the aim of this work is to provide a methodology to control in real time the energetic characteristics of a subway station under different comfort and service constraints. Optimal control policies are calculated using approximate dynamic programming methods such as model predictive control, computational stochastic dynamic programming or stochastic dual dynamic programming. We apply the obtained policies to numerical simulations based on real historical sensors data and we present results to compare the quality of our methods. A discussion about models simplifications and the use of various heuristic methods to compute near-optimal policies online is carried out. The aim is to spark a debate about whether we should look for suboptimal policies adapted to highly detailed models or conversely optimal solutions to simplified optimization models.

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Redesigning electricity markets? New time-frames for local batteries facing wind uncertainty

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Abstract

The widespread deployment of renewable energy in combination with smart grid technologies is creating the opportunity for local electricity storage to play a critical role in energy systems and be a more prevalent technology in the near future. Since the economic viability of electricity storage depends on various short-term uncertainties (local renewable generation, demand and electricity prices), it is imperative to research smart grid oriented business models that provide arbitrage opportunities in electricity markets and takes into consideration renewable variability. Distributed electricity storage participation in electricity markets is, however, an open question; Would local electricity storage become economically viable if they are integrated into current market time-frames (day-ahead and intra-day markets)? By modelling a distributed generation system and local batteries under uncertainty realizations of wind power in a multi-stage stochastic programming problem, the research objective is to analyse time-frames options that will be dismissed in a deterministic formulation. The model is applied to distributed electricity storages in the Appenzell cantons in Switzerland. The study also considers the business case for aggregators (centralized vs. local based). Results note the need to revise current market time-frames structures to account for endogenous technology features of renewable-storage interactions and hence maximize the value of electricity storage.

Application of decomposition/coordination methods to the optimal control of a micro grid.

Franço s PACAUD

Apr 12, 2016

Most of european countries must produce more than 20 % of their e ectrica energy with renewab e energies by 2020 and smart and micro-grids are more and more put forward to achieve this goa   These new techno ogies a ow uti ity managers to contro in rea time the consumption of consumers and the production of different power p ants

Deterministic contro s such as Mode Predictive Contro (MPC) are the most used methods to manage a micro-grid But consumptions and renewab e energy productions are hard y foreseeab e and it is often difficu t to satisfy the adequation between demand and production in deterministic framework That is why we focus on stochastic optima management to contro a micro-grid

We consider here a domestic micro-grid composed of a smart home equipped with smart devices (thermostat contro er) and whose energy is produced by renewab e sources (micro-cogeneration so ar pane s) This system is mode ed with two state variab es and we wi   consider therma and e ectrica demands as stochastic variab es Stochastic optima contro wi   be used to manage the energy in this system and the contro wi   be tested upon a rea istic numerica mode   We wi   put emphasis on the a gorithms used (stochastic dynamic programming and stochastic dua dynamic programming) and the numerica resu ts obtained   A benchmark with other methods such as MPC and heurisitics wi   be presented

This work is part of a arger program aiming to contro a micro-grid where severa houses and decentra ized power sources are connected together through the oca network As the size of the prob em increases other methods must be investigated to tack e the curse of dimensiona ity Decomposition and coordination schemes have proved their effectiveness in deterministic settings and DADP (Dua Approximate Dynamic Programming) offers promising resu ts in the stochastic framework   We wi sketch some perspectives to app y such a gorithms to arge-sca e smart-grid prob ems

ICSP 2016 — Búzios, Brazil, 25 June – 1 July, 2016

Microgrid Energy Management with Renewables and Storage

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Abstract

We present a microgrid model consisting of a small community, or city, comprised of a photovoltaic panel (PV) and two types of storages: batteries and pumping. Demand will be deterministic, for example via contracts, but energy generated from the PV is stochastic. We frame the problem as a multistage stochastic programming problem in which the goal is to produce the schedule that minimizes average costs, while satisfying demand at every time period. We illustrate our methodology with an example of a one-week operation of such system.

TS: SP for Planning and Economics of Networks

Chair: Alexei Gaivoronski

ICSP 2016 — Búzios, Brazil, 25 June – 1 July, 2016

Modeling collaborative data service provision around an open source platform

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Abstract

We make use of concepts taken from coalitional game theory to model the incentives to join forces among a group of agents involved in collaborative provision of a data service. We model an open source system, where end users can freely pick a group of favorite basic services and bundle them into a composite service. Revenues resulting from the sale of the bundled service are shared amongst the providers, which contributed to the bundling of the service. No actor decides unilaterally how such revenues will be shared, but the sharing scheme is defined in a "fair" way, depending on the importance of the resources that each provider supplies to the bundle. .

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Stochastic Gradient Approach for Optimization of Pumping Schedules in Complex Water Supply System

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Abstract

Energy saving in operation of water pumping plants and the minimization of water deficit are important issues, which should be considered when optimizing multi-reservoirs and multi-users water supply systems. Undoubtedly, this problem is characterized by a high *uncertainty* level due to hydrologic variability and water demand behaviour.

The aim of this paper is to provide an efficient DSS (*Decision Support System*) through the optimization of emergency water pumping plants activation schedules. The obtained results allow the water system's authority to get a *robust decision policy*, minimizing the risk of wrong future decisions. A *cost-risk balancing problem* has been modelled to manage this problem, in order to balance the damages in terms of shortage water occurrences and energy-cost requirements. These problems are affected by a considerable uncertainty level in input data. Besides, decisions can be affected and modified in response to climatic trends. We develop here a simulation model for this problem, which is optimized using the *stochastic gradient methods*.

We have applied our model for optimization of water pumping in specific area in South-Sardinia (Italy) characterized by Mediterranean climate. The water supply system under consideration includes four pumping plants transferring water between five storage reservoirs serving different types of water demands. By applying our combined simulation and optimization procedure we obtained both the energy-costs saving and the reduction of water deficit to admissible level even during heavy drought periods.

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Activity Based Service Portfolio Optimization of Cloud Broker

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Abstract

This paper represents a model for managing the service portfolio of a cloud broker. More precisely, we presume a cloud broker that operates a platform for integrating, aggregating and sales of cloud services. The cloud broker faces a limited amount of human resources which are necessary to deal with the legal, technical and economic activities that are required for this kind of endeavor. Hence, the cloud broker needs to decide which services, service bundles and markets to focus on. For this situation we develop an optimization problem that can be used to select the service program with the highest profit potential. Moreover, sales numbers, service prices and resource usage cannot be estimated with certainty, which implies the risk of missing financial and operational targets. The model therefore allows for balancing the expected profit against this risk. The resulting model can be classified as a combined stochastic assignment and knapsack-problem with several capacity constraints. The paper points out the short comings of traditional activity based management for this kind of practical problem.

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Optimizing simulation parameters for stochastic empty container repositioning

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Abstract

In this work the stochastic empty container repositioning is faced by a discrete event simulation model, which is based on lower and upper inventory thresholds at each port. We look for the inventory thresholds optimizing the average system performance with respect to all observations of random parameters entering the system description in each period of the planning horizon. These random parameters are the net supply of empty containers at ports, ship loading and unloading times and transport capacities. The optimal values of these thresholds are determined by an optimization algorithm, which belongs to the family of stochastic gradient methods.

TS: Multi-Stage Models for Investment

Chair: David Wozabal

ICSP 2016

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Optimal capacity expansion planning with a CVaR-based stochastic scheduling model

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Abstract

SDDP implementations have long been used in hydrothermal systems to calculate optimal system scheduling and optimal expansion planning decisions in a deeply integrated way, in which Benders cuts resulting from the probabilistic operations module are used to solve the expansion MIP problem. In this paper, we study the modified SDDP formulation adopted by the Brazilian System Operator (ONS) since 2013, which introduces an intertemporal CVaR mechanism to incorporate risk aversion in the hydrothermal scheduling decisions. In particular, we show that using the expected marginal costs from the probabilistic simulations of CVaR policy directly would lead to inconsistencies between the investment decisions and the preferences implied by the objective function in the operations module, highlighting a need to extend the optimal system planning methodology. We propose an alternative implementation that calculates a weighted average of the Benders cut coefficients from the lower bound of the CVaR-SDDP scheme, showing that it results in consistent decisions for the two optimization problems. A contrast between planning studies carried out with and without risk-aversion is used to illustrate and discuss the implications of this methodology.

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Valuing strategic interactions in systemic urban infrastructure investments using option games: An approximate dynamic programming approach

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Abstract

Performances of investments in systemic urban infrastructures such as in energy, transport, water, waste and ICT are frequently influenced by enormous uncertainty surrounding both the investments' intrinsic risks and their highly volatile supply and demand patterns, but also by strategic interactions of multiple decision makers with often competing interests. As such, the application of option games, which combine real option analysis to investment under uncertainty and game theory to study decision makers' competing behaviours, appears to be a promising avenue for the analysis of such complex investment problems. However, existing option game models generally take a corporate perspective, use continuous-time models and aim at the provision of analytical solutions, which makes them both impractical and inadequate. This paper presents a new discrete-time, option games-based appraisal framework for selecting a portfolio of interdependent urban infrastructure investments. Representing the decision makers' flexibilities through influence diagrams and mathematically modelling their strategic interactions, we have used this framework to formulate a multi-stage stochastic optimisation model that combines Monte Carlo simulation for scenario generation with the approximation of the value functions through simple least-squares. Using the real-case of district heating network investments in London, we investigate the sensitivity of the optimal portfolio value to changes in both decision makers' strategic behaviour and demand and supply patterns. The numerical results demonstrate that our approach has enormous potential to enhance and support long-term, strategic investment decisions, particularly with regard to timing and scale, but also short-term, operational decisions, for example to switch between different modes of operation.

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Extension of the SDDP algorithm to determine an integrated stochastic investment & operations strategy

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Abstract

Many capacity planning models used today are based on a Benders decomposition scheme composed of: (i) a MIP-based "investment module" which determines a trial expansion plan; (ii) a SDDP-based "operations module" which calculates the expected operation costs for the trial plan; and (iii) Benders cuts from the operations to the investment module, whose coefficients are calculated from the expected marginal costs of the capacity constraints in the operations module.
Although this "traditional" planning model has been successfully applied in many countries, it has an inherent limitation, which has become more significant with the penetration of renewables with short construction times, such as solar: the optimal expansion plan is "static", i.e. investment decisions do not change as the system state evolves (e.g. load growth is lower than expected, a very rainy season occurs etc.). As a consequence, there is a growing interest in the calculation of an integrated stochastic investment & operations strategy.
This paper describes an extension of the SDDP algorithm that allows the calculation of this integrated strategy. The first (and obvious) step of this extension is to represent investment decisions that are conditioned to the system state vector in the SDDP recursion. The second step is to represent the construction time of each candidate project in the recursion; this requires an efficient modeling of time delays in the update of state variables. The final step is to represent the integrality of investment decisions in the multistage stochastic optimization scheme. This is done by applying a customized Lagrangian scheme to the scheduling/investment subproblem of each stage and scenario that produces the strongest possible convex cut to the previous stage's future cost function.
The application of the proposed algorithm will be illustrated in realistic capacity planning studies of the Central America system.

Gas Storage Valuation in Incomplete Markets using Approximate Dual Dynamic Programming

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Abstract

We calculate the value of a virtual gas storage. To this end, the gas market is modelled as an incomplete market and the valuation is performed using a Markov Decision Process (MDP) based on the physical process. Since risk neutral valuation is not possible, we explicitly incorporate the risk preferences of the investor using the nested CVaR. The MDP is solved using Approximate Dual Dynamic Programming and the resulting policy significantly outperforms the rolling intrinsic valuation, which is considered to be close to optimal in the extant literature.

TS: SDDP - Modeling Uncertainty and Hydro Plants

Chair: Vitor de Matos

ICSP 2016 — Búzios, Brazil, 25 June – 1 July, 2016

Representation of parameter uncertainty in probabilistic inflow and wind models of SDDP: a unified CVaR-Importance Sampling approach

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Abstract

The optimal scheduling of hydrothermal systems requires the representation of uncertainties in future streamflows to devise a cost-effective operations policy. Stochastic optimization has been widely used as a powerful tool to solve this problem but results will necessarily depend on the stochastic model used to generate future scenarios for streamflows. Periodic autoregressive (PAR) models have been widely used in this task. However, its parameters are typically unknown and must be estimated from historical data, incorporating a natural estimation error. Furthermore, the model is just a linear approximation of the real stochastic process. The consequence is that the operator will be uncertain about the correct linear model that should be used at each period.

With the increase of wind penetration in hydro dominated countries, such as Brazil, it is important to model the stochastic process of wind production, in order to optimize the water values. Since commonly the historical data size of wind is smaller than the data size of streamflows (30 versus 80 years), the uncertainty of wind stochastic model is higher.

The objective of this work is to assess the impacts of incorporating the uncertainty of the parameters of the PAR models and stochastic model for wind production into a stochastic hydrothermal scheduling model. It will be shown that when the uncertainty of the parameters is ignored, the policies given by the stochastic optimization tend to be too optimistic.

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25 June – 1 July, 2016

Inflow modelling for hydro-scheduling by SDDP

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Abstract

Hydropower scheduling problems often depend sensitively on the details of the stochastic process used to model natural inflows. The ideal inflow model for use with SDDP would *(i)* be representable within a linear-programming framework; *(ii)* naturally generate discrete scenarios without additional sampling or scenario selection steps; *(iii)* have as few scenarios as possible at each stage; *(iv)* realistically model serial dependence, including seasonally varying autocorrelation structure; *(v)* represent extremes well, including inflow events more extreme than any in the historical record; *(vi)* produce no negative inflows. I will discuss a class of autoregressive processes promising all these features. These processes have continuous state space, but the random innovation at each time step is discrete.

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Approximating stochastic processes as non-homogeneous Markov chains in stochastic dual dynamic programming

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Abstract

We consider the problem of long-term operational planning of the Brazilian interconnected power system. The problem can be modeled as a multistage stochastic optimization problem and solved using the stochastic dual dynamic programming approach (SDDP). Since the SDDP method requires the data process to be stagewise independent, a common modeling trick is to include linear state transition functions as additional equality constraints in the subproblems of each stage. The state of the stochastic process then adds an additional dimension to the Benders' cuts, which are used to approximate the value function of the stochastic-dynamic program.

An alternative approach is to approximate the continuous stochastic process by a scenario lattice. A lattice is a non-homogeneous Markov chain that approximates the unconditional continuous distributions by a small set of discrete states that minimize the distance between the two distributions. While this approach, also referred to as approximate dual dynamic programming (ADDP), can handle any Markovian data process, the guarantee that the algorithm converges to an optimal policy under the true model is lost.

We show that if the discrete random variables are stationary quantizers of the continuous random variables that, under certain conditions, the algorithm converges to a lower bound of the objective of the stochastic optimization problem. In a computational study, we compare the policies produced by SDDP and ADDP for the long-term operational planning problem. We find that the ADDP bounds close faster than the SDDP bounds and that ADDP produces a policy that is consistently better than the policy produced by SDDP.

ICSP 2016

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Modeling energy reservoirs and individual hydro plants in the long-term hydrothermal scheduling problem: A case study of the Brazilian energy planning in a rolling horizon framework

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Abstract

The Hydrothermal Scheduling (HS) plays an important role in power systems that rely heavily on hydroelectricity as its goal is to define a policy for the use of water. The Brazilian system has hundreds of hydro plants and some simplifications are made in their modeling in order to reduce the computational burden. However, these simplifications may affect their efficiency increasing the operational costs and the risks of load shedding.
In this work we are interested in assessing the consequences of aggregating the Hydro Power Plants (HPP) into Energy Equivalent Reservoir (EER), which are used in the official models used by the Independent System Operator (ISO). Although, in previous papers, we have already analyzed the benefits of reducing these simplifications by increasing the number of EERs, we believe that it is important to evaluate the pros and cons of avoiding the aggregation into EERs due to the importance of the HPP in the Brazilian Power Systems and the management of the reservoir levels to mitigate risks.
In order to compare the two approaches, we considered a rolling horizon procedure, as the ISO uses two official models (one with individual HPP and other with aggregation) which are used in sequence every month. This procedure was emulated by means of an application with EER aggregation (Plan4LHTS) coupled with the individual HPP implementation (SPARHTACUS). We show results for historical years with specific characteristics (average, wet, dry and start wet/finish dry) for a period of 12 months for the complete Brazilian Power System. The results indicate the new application provides lower cost over the 12 months and it ends with high storage levels, which implicates in lower future costs as well.

TS: Applications of SP in the Power Sector

Chair: Maria Teresa Vespucci

ICSP 2016 — Búzios, Brazil, 25 June – 1 July, 2016

Stopped AVaR: A multiperiod extension of the risk measure AVaR, with application in power optimization

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Abstract

Stochastic programming formulations of multiperiod risk measures are considered that can be applied in power optimization problems. In particular, a multiperiod extension of the coherent risk measure Average-Value-at-Risk (AVaR) is investigated that involves (random) stopping times. Basic properties are shown, and a linear re-formulation allows to integrate the risk measure in mean-risk optimization problems. The integration into long-term hydropower dispatch problems is discussed, and the resulting profit distributions are numerically compared to problems that use other, time-consistent extensions of AVaR [1].

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Energy Management in a Solar Microgrid Using Stochastic Programming and Data Clustering

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Abstract

The increasing interest in integrating intermittent renewable energy sources into the grid, like photovoltaic (PV) or wind based generation, presents several major challenges from the viewpoint of reliability and control. Energy storage enables large-scale integration of intermittent sources, allowing the penetration of distributed generation technologies to increase at a reasonable economic and environmental cost [1]. Despite its benefits, energy storage has not been fully utilized. Among the limiting factors is, besides the cost, the lack of appropriate control and management strategies, since now users need to decide when to store, consume and, if possible, inject that energy back to the grid [2].

In this work we present a novel approach for designing energy control policies for a PV microgrid, based on stochastic programming and data clustering to deal with the uncertainty of the generation. We use data clustering to determine the regimes in which the microgrid works around the year, and also to generate the scenarios used in the stochastic program. Next, we simplify the solutions obtained from the stochastic program to define rules that are easy to implement. The output of our procedure is a simple control policy that can be implemented in small microcomputers to control the flow of energy, with the objective of minimizing the total cost of consumption. Finally, our simulation based experimental results show that the resulting policy obtains costs that are very similar, in average, to the ones obtained by solving a multi-stage stochastic program.

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Transmission Expansion Planning under Uncertainty

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Abstract

It is foreseen that electricity grids will undergo large structural changes the coming years, driven by the goals for decarbonization of the power system towards 2050, improved security of supply and integration of markets between borders. Optimal transmission investment planning is extremely challenging due to the size of power systems, the time scales needed to assess the value of new assets, the gross market and regulatory uncertainties for the future, and the market structure in deregulated environments. Hence, it is of great interest to develop a thorough understanding of the benefits that adequate models might provide.

We present a two-stage stochastic formulation of a multinational transmission expansion planning model. Different decomposition methods will be used to evaluate which is the most applicable for this particular model characteristic. Metrics that indicate the value of a stochastic formulation will be presented for a North Sea offshore grid case study, incorporating scenarios for 2030.

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A Demand Side Management model for load scheduling in healthcare facilities

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Abstract

We propose a stochastic model for defining the optimal scheduling of electric powered devices with the aim of reducing energy expenditures in a healthcare facility. The model considers day-ahead electricity prices and scenarios for temperatures and rooms usage in order to define the amount of electricity to buy in the day-ahead market as well as the schedule for the air conditioning and ventilation settings for minimizing the total costs while maintaining minimum comfort conditions. A case study shows how the stochastic approach can lead to substantial savings compared to the deterministic approach.

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TS: (Un)Conventional SP Algorithms for Gas Networks

Chair: Ruediger Schultz

ICSP 2016

Búzios, Brazil
25 June – 1 July, 2016

Gas network planning under uncertainty: Modeling and implementation

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Abstract

In this talk we plan to present the results of an ongoing collaboration with a Spanish company in the gas industry, in which we have developed a software, GANESO, that can simulate and *optimize gas transmission networks*. A gas transmission network consists basically of supplier and consumer points joint with other controllable elements like compressors and valves that are connected via pipes. Thus, it is important to manage efficiently the network in order to satisfy all the required demands and reduce the operation costs. In particular, we will focus in a problem related to the *infrastructure planning under uncertainty*. We want to optimize, once we introduce some source of uncertainty on gas demands, decisions regarding network expansions and network design in order to guarantee the security of supply. This problem has been modeled as a *multistage stochastic nonlinear programming problem with integer variables* and the result is a parallel computing algorithm that builds upon *Lagrangian decomposition* ideas combined with a two stage approach based on sequential linear programming techniques.

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Steady-State and Transient Models of Gas Transport – A Comparison

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Abstract

The rise of renewable energy and the decreasing popularity of nuclear energy are in the center of public attention for the last years. Changes in the energy market led to the need of an efficient and affordable energy supply. In this context gas will play an important role for the next decades. It is sufficiently available, quickly obtainable, storable and can be traded.
The physical behavior of gas pressure and gas flow can be described by the Euler equations — a system of hyperbolic balance laws. The pipe friction coefficient is nonlinearly depending on the Reynolds number and the roughness factor. We compare the equilibrium state – where analytical solutions on networks have been developed for both ideal and real gas – with the transient behavior.

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DDSIP news

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Abstract

Starting with the ideas outlined in the joint paper of Carøe and Schultz [1] and the subsequent thesis of A. Märkert the software DDSIP for solving two-stage MIPs was developed over the years.
DDSIP is a **C** implementation of decomposition by scenarios:

- the first-stage variables are replaced by one copy per scenario and nonanticipativity is represented by a set of equations,
- Lagrangian relaxation of these nonanticipativity constraints yields independent problems for each scenario,
- the CPLEX Callable Library is used to solve the single scenario problems,
- an outer branch & bound procedure and C. Helmberg's conic bundle code [2] are used to re-establish nonanticipativity.

DDSIP comprises formulations and algorithms for mean-risk problems with different risk functions: expected excess of a target, excess probabilities, absolute semideviation, worst-case-costs, tail value-at-risk, value-at-risk, and standard deviation.
The decomposition algorithm works for problems with integer variables in both stages.
We report recent changes in the software inspired by cooperations.

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Computer algebra and stochastic programming encounter again

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Abstract

About twenty years ago, computer algebra, in particular Gröbner bases methods, inspired developments in integer programming that led to primal augmentation algorithms with test sets [2, 4]. In stochastic integer programming, the latter became useful for enumerative algorithms, [4], and methods relying on the decomposition of the test set rather the model itself, [3]. The catch then is in a finite set of vectors (building blocks) from where the full test set could be constructed, and augmentation as well as optimality check is possible at the building block level. Moreover, the building blocks stay the same after a threshold number of scenarios is passed. Aschenbrenner and Hemmecke [1] published the ultimate by extension to multi-stage linear stochastic integer programs. In the talk, the Gröbner past in stochastic integer programming is reviewed, followed by the basics of another exciting application, namely solving parametric polynomial equations by computing the Gröbner basis of the induced affine variety. Relevance for stochastic programming shows in speeding up nomination validation under uncertain inputs into gas networks.

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TS: Decomposition Methods

Chair: Vincent Leclère

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Decomposition-coordination methods for optimization under risk

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Abstract

In multi-stage stochastic optimization problems, solutions are indexed by time (discrete) and scenarios (discrete); as soon as the number of steps and scenarios is high, resolution becomes unfeasible. To make such problems numerically tractable, one can envisage to decompose them into optimization sub-problems; these sub-problems, of a smaller scale, should be easier to solve and their resolution parallelized. In most statements, the criterion to be optimized is the mathematical expectation of a random cost (or gain). As the expectation is a linear operator, this so-called risk-neutral formulation lends itself well to additive decomposition [1].

In this work, we examine the possibilities of decomposition when the expectation is replaced by a risk measure [3], not necessarily additive. For this purpose, we introduce classes of risk measures especially adapted for the two following decomposition methods:

- a method by nesting which corresponds to a time decomposition [2] (with time consistent dynamic risk measures),
- a method by dualizing non-anticipativity constraints, which corresponds to a scenario decomposition (with coherent risk measures).

Regarding applications, the management of energies with smart-grids offers interesting prospects. Indeed the new energy systems include more and more renewable energies, saptially scattered and subject to random weather conditions. This stochasticity leads to more risks of black-outs the handling of which can be mathematically expressed by a risk measure (e.g. AVAR). By decomposing, we expect to be able to handle smaller decentralized optimization problems on the nodes of the grid.

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Information relaxation and spatial decomposition of a stochastic optimal control problem

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Abstract

Multistage stochastic optimization problems give rise to large-scale models generally approximated by relaxing nonanticipativity constraints and decomposing w.r.t. stages and scenarios. When another level of coupling is present like in multizonal production planning, the natural decomposition into local stochastic subproblems is not straightforward as the dual variables generally needed for the coordination process are not decoupled in time. We propose here to introduce an adhoc relaxation of information to produce local subproblems solved by a dual decomposition dynamic programming technique. We show in particular that the application of specific operator-splitting methods (like the family of Douglas-Rachford splitting) to the spatial decomposition of the stochastic problem allows not only to solve approximately the problem for large instances and also to obtain convergence towards aggregate dual values associated with a limited number of local scenarios.

The method is applied to a complex stochastic optimization problem derived from a real-life long-term energy planning model.

We consider a set of geographical zones Z interconnected by a network of economic agreements to import or export electricity. Each arc $e = (z, z')$ carries the flow of imported energy denoted by f_{et} in each period of the time horizon $t \in [1, \ldots, T]$. We denote d_{zt} the total demand and i_{zt} the input of water resource for zone $z \in Z$ at step t (random information) . The variables are the local production levels p_{zt}, the control of hydroelectrical reserve u_{zt} and the interzonal flows f_{et}. The multistage stochastic program we face up is the following:

$$\begin{aligned} \min_{p,x,u \in L^2} \quad & I\!E\Big[\textstyle\sum_{t=0}^{T-1} \big(\sum_{z\in Z} c_z(p_{zt}) + \sum_{e\in E} l_e(f_{et})\big)\Big] \\ \text{s.t} \quad & p_t + u_t - Af_t = d_t \\ & x_{z,t+1} = x_{zt} - u_{zt} + i_{zt} \quad \forall z \in Z, \forall t \\ & + \text{ Zonal constraints on random variables } p_{zt}, u_{zt}, f_{et} \end{aligned}$$

We apply the Douglas-Rachford (or equ. Proximal Decomposition, see [1]) splitting method to the dynamic reformulated model. It consists in solving by a Dual Dynamic Programming technique the local subproblems, then update the dual variables and project back on a customized coupling subspace and its orthogonal (see details in [2] for the deterministic model).
Numerical results are presented on realistic instances with $|Z| = 12, T = 365$ and piecewise linear convex production costs that show the efficiency of the decomposition approach.

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DADP for large scale hydro valleys

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Abstract

Power systems are becoming more and more complex, so that optimizing energy systems becomes more and more difficult. As optimization is challenged by the complexity due to large size, dynamical aspects, and uncertainties, we claim that decomposition approaches may prove particularly adapted. This is why we present, in an unified framework, the main approaches to *decompose multistage stochastic optimization problems* for numerical resolution. This framework covers both Stochastic Programming (SP) (and scenario-based resolution methods) and Stochastic Optimal Control (SOC) (and state-based resolution methods like Stochastic Dynamic Programming), the two most well-known approaches and methods in multistage stochastic optimization.

This done, we go in more detail and outline the *Dual Approximate Dynamic Programming* (DADP) approach. DADP is a spatial decomposition method that solves an approximation of the original problem. The approximation consists in relaxing an almost sure coupling constraint into its conditional expectation. We discuss practical questions related to the implementation of the method and we illustrate DADP on the problem of managing a chain of hydroelectric dams. We finally discuss theoretical questions raised by the method.

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Theory and application of spatial decomposition method in Stochastic Optimization

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Abstract

Multistage stochastic optimization problem are hard to solve. This can be understood as the extensive formulation has a huge size. We claim that decomposition methods which allow to see this huge problem as a collection of coordinated smaller problems are an efficient way to address multistage stochastic optimization.
Decomposition methods can be done in at least three ways : by scenarios (e.g. Progressive Hedging approaches), by time (e.g. dynamic programming or SDDP approaches) or spatially by disconnecting subpart of the system. The Dual Approximate Dynamic Programming (DADP) algorithm we present fall in the last category and is motivated by the study of the optimal management of an hydroelectric valley composed of N linked dams. Dualizing the couling constraint, and fixing a multiplier allow to solve the problem as N independant dams. Unfortunately in a stochastic setting this approach fails. The DADP algorithm rely on an approximation of the multiplier allowing to efficiently solve the subproblems by dynamic programming.
We present theoretical results and interpretation of the DADP algorithm, encouraging numerical results being given in a following talk.

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TS: SDDP - Practical Applications

Chair: Raphael Chabbar

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Analytical representation of immediate cost functions in SDDP – an application to stochastic scheduling of renewable resources with yearly to hourly time resolutions

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Abstract

The increasing penetration of renewable generation plants in electric systems combined with the development of effective short-term energy storage batteries demand scheduling to be represented on an hourly basis or even in smaller time intervals. Multistage stochastic optimization in such time resolution would implicate in the increase of computational effort, which might result in the impossibility to solve such problems.

In this article, we present a method that is able to take into consideration such small time intervals while avoiding the considerable increase of computational times. This method consists in calculating the analytical representation of the immediate cost function that will be applied in the context of stochastic dual dynamic programming (SDDP). The function represents immediate operation costs as a function of the total hydroelectric generation optimal decision. As the immediate cost function is piecewise linear, it leads to a structure very similar to the one used to approximate the future cost function (cut set). Results of the application of the method in real electric systems are presented.

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On the cost and side effects of time inconsistency in long-term hydrothermal planning

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Abstract

The current state of the art method used for medium/long-term planning studies of hydrothermal power system operation is the Stochastic Dual Dynamic Programming (SDDP) algorithm. The computational savings provided by this method notwithstanding, it still relies on major system simplifications to achieve acceptable performances in practical applications. Simplifications in the planning stage in contrast to the actual implementation might induce time inconsistent policies and, consequently, a sub-optimality gap. In this talk, we present an extension to previous work on the subject of time inconsistency to measure the effects of modeling simplifications in the SDDP framework for hydrothermal operation planning. The sub-optimality gap provides an indicative measure of impact for a given inconsistency source in hydrothermal power system operation. We measure the sub-optimality gap due to time inconsistency by using a simplified model for planning the system, which is done by means of the assessment of the recourse (cost-to-go) function, and a detailed model for its operation (implementation of the policy).

Case studies involving simplifications in transmission lines modeling and in security criteria indicates that this source of time inconsistency might lead to unaccounted for reservoir depletion and spikes in energy market spot prices.Although one can argue that deviations fruit of this source of inconsistency are small and day by day readjusted by means of the rolling-horizon inconsistent procedure, the comparison with the consistent policy reveals that the composite effect can be relevant. Motivated by this, we studied the incorporation of security criteria as a second source of inconsistency and discuss ways for achieving computational tractability for its consistent counterpart in the long-term planning. We propose a multi period and scenario based extension of Adjustable Robust Optimization models already discussed in recent literature. The proposed methodology merges the Column-and-Constraint Generation algorithm and the SDDP algorithm. Case studies show that we are able to sustain quality of the policy built by the algorithm whilst achieving reasonable computational time.

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Modeling power markets with multistage stochastic Nash equilibria

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Abstract

The modelling of modern power markets requires the representation of the following main features: (i) a stochastic dynamic decision process, with uncertainties related to renewable production and fuel costs, among others; and (ii) a game-theoretic framework that represents the strategic behavior of multiple agents, for example in daily price bids.
These features can be in theory represented as a stochastic dynamic programming recursion, where for each stage and state we have a Nash equilibrium. However, the resulting problem is very challenging to solve.
This paper presents an iterative process to solve the above problem for realistic power systems. The proposed algorithm is composed of forward and backward steps. The forward step is a stochastic multistage Nash equilibrium simulation with approximate future benefit functions for each agent, and solved by a customized MIP algorithm. The resulting bidding strategies and equilibrium prices for each stage and stochastic scenario are then passed to the backward stage, where the objective is to improve the future benefit functions of each agent. This is done by representing the strategic bidding of each agent as a separate multistage SDDP recursion, where the bidding strategies of the other agents are "frozen".
The application and computational effort of the proposed algorithm are illustrated in case studies with realistic South American power systems.

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Representation of uncertainties in fuel cost and load growth in SDDP-based hydrothermal scheduling

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Abstract

One of the attractive characteristics in the application of SDDP to stochastic hydrothermal scheduling has been the ability to represent inflow uncertainty analytically as a multivariate autoregressive model, for example, AR-3. This analytical representation was later extended to other renewables such as wind and to random fluctuations in hourly load. However, two other important sources of uncertainty, which are fuel costs and annual load, were usually represented as a scenario tree with (weekly or monthly) stages and annual "splitting" of scenarios. In this approach, a separate SDDP backward recursion is carried out for the intra-year stages in each branch of the tree, followed by the construction of a combined future cost function in the yearly joining nodes. In this paper, we describe an alternative Markov/AR modeling of these uncertainties, where the Markov states represent the incremental rates with respect to the previous year values (for example, a 3% load growth and a 5% decrease in fuel cost), and the autoregressive models represent variations along the stages. In the case of fuel costs, there is an additional dualization/McCormick step that allows their representation in the problem RHS instead of the objective function. This approach is illustrated with a case study of a realistic Asian power system.

TS: Structures of SP Models

Chair: Kai Spurkel

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Problem-driven Scenario Generation

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Abstract

Scenario generation is the construction of a discrete random variable to use as input to a stochastic program. Standard approaches to scenario generation are distribution-driven, that is, they do not take into account the underlying problem. In this talk we promote the idea of problem-driven scenario generation. By exploiting the underlying structure of a problem, it may be possible to construct a more parsimonious representation of the uncertainty. This may mean generating scenario sets which, in a probabilistic sense, do not accurately represent the distribution of future possibilities, but which do yield near-optimal solutions to the problem.

Although a few problem-driven approaches have been proposed, these have been heuristic in nature. We present here two approches which are mathematically adapted to a particular class of stochastic programs and demonstrate their effectiveness in comparison to distribution-driven methods. The first of our approaches applies to stochastic programs with tail risk measures (such as conditional value-at-risk) and the second to simple recourse problems. Both of these approaches exploit "inactive regions" of the support of the distribution which need only be represented by a single scenarios. The performance of both methodologies improves as the problem becomes more constrained and as the probability of these inactive components increases.

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On a class of stochastic programs with exponentially many scenarios

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Abstract

In stochastic programming, it is usually assumed that the random data of the problem follows a known distribution $\mathbb{P}$. When $\mathbb{P}$ is either continuous or finite with a large number of atoms, sampling methods can be used to approximate the true problem with a model involving a reasonable number of scenarios. But what happens when $\mathbb{P}$ is "easy" to describe and still involves an enormous number of possible outcomes? A natural question to ask is whether we can solve the true problem without relying on sampling.
In this work, we propose a model where scenarios are affinely parametrized by the vertices or integral vectors within a given polytope Q. For instance, with Q being the n-dimensional unit cube, a vertex is a binary vector that might represent the availability of a set of resources in a particular scenario. Given that in general the number of vertices is exponential with respect to the size of the description of Q, a natural integer programming formulation that includes binary variables to choose which scenarios are satisfied is simply impractical. For this reason, we present a formulation that implicitly discards the k worst scenarios for a given vector x without including variables for each scenario, leading to a mixed-binary program of moderate size. We also study a model where the average cost of the k worst scenarios is considered, for which we present a compact linear formulation. These models can be interpreted in the context of VaR- and CVaR-constrained problems, respectively, exhibiting similar relationships. A key tool we exploit is a dynamic program to optimize a linear function over a set of integral matrices with lexicographically ordered rows, which might be of independent interest.

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A transportation distance based stability results for linear Markov decision processes

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Abstract

The approximation of stochastic processes is an important topic in multistage stochastic optimization. In this paper we focus on the approximation of Markov process by lattices. We measure the quality of the approximation by a distance between Markov processes.

To this end, we introduce a distance between Markov processes, which is transportation distance arising from a generalization of the Wasserstein distance. We take into account the effect of the information, which, in contrast to similar approaches for general stochastic processes, includes only the last state and not the whole history of the process. We apply the obtained results for lattices and compare with approach presented in [1], where the distance between trees was considered. Our main result states that the difference of the optimal values of linear multistage stochastic problems, which differ only in the underlying Markov processes, can be bounded by the distance between these processes. We show several properties of the distance such as a dual representation and apply our results to realistic problem instances of stochastic optimization problems in the field of energy planning.

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Partially Random Data in Linear Two-Stage Stochastic Programming

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Abstract

There is a fairly rich theory on the structure of stochastic linear recourse problems (with or without integer variables). Often, assumptions involve the existence of a density for a suitable data vector, with the prominent example of continuous differentiability of the expected recourse function in models with continuous variables. This rests on the tacit assumption that all components are "truly random" with continuous probability distributions. The talk addresses partial randomness of input data in two-stage stochastic linear programming which is much more realistic in real-life applications. With emphasis on improved convexity properties of expected recourse functions, we present counterparts of results on structure and stability.

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TS: SP for Real Hydrothermal Power Generation

Chair: Andre Diniz

An SDP/SDDP model for Medium-Term Hydropower Scheduling Considering Energy and Reserve Capacity Markets

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Abstract

Long- and medium term hydropower scheduling models normally consider sales of energy as the only opportunity for the producer to earn money. However, as the future (European) energy mix will have a growing share of renewable intermittent generation, the revenue potential from delivering reserve capacity can be significant for flexible hydropower facilities.

We describe a method for optimal scheduling of hydropower systems for a profit maximizing, price-taking and risk neutral producer selling energy and reserve capacity to separate and sequentially cleared markets. In line with the practice in many European countries, the method allows selling reserve capacity prior to energy. The method is based on a combination of stochastic dynamic programming (SDP) and stochastic dual dynamic programming (SDDP), and treats inflow to reservoirs and prices for energy and capacity as stochastic variables.

We apply the method in a case study for a Norwegian watercourse, and quantify the expected changes in operational schedules when incorporating sales of reserve capacity.

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Binary and linear security constraints in SDDP: modeling Ralco reservoir operation to avoid landslide events

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Abstract

Construction and operation of large reservoirs sometimes requires to consider safety constraints, due to soil dynamics that may lead to landslide events, as a result of fast water level changes. These events may be highly dangerous, leading even to water dam overtopping incidents [1], and/or may affect the lifespan of the dam. Therefore, when the nature of the reservoir is such, and given the possibility of catastrophic scenarios, safety constraints should be directly included in the dam's operational and optimization guidelines and modeling tools. In this work we present the case of Ralco reservoir, one of the largest reservoirs in the hydrothermal Chilean system, and how its landslide constraints are explicitly included in the SDDP based model used by the Chilean System Operator (CDEC-SIC). We use a similar modeling approach to [2], since the nature of the rules to avoid landslide events and provide safe operation of Ralco has an integer behavior as well. The explicit inclusion of Ralco's landslide constraints in the hydrothermal coordination tool changes the water value and its usage policy, specially when the reservoir level is below a critical value. While this work was specifically developed for Ralco, the proposed modeling approach might be applicable to other reservoir systems.

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Two-stage recombinatory Benders decomposition

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Abstract

The main goal of the power systems planning is the optimal management of the energy resources in order to ensure a safe and reliable operation. Otherwise, the system operation and reliability will be compromised, as happened in Colombian between 1992 and 1993 due to a high dry period. The planning process must be anticipative to the uncertainty, obtaining a solution accounting for multiple future scenarios. This uncertainty is commonly represented by scenario trees [?]. The simultaneous consideration of all the future scenarios usually leads to apply mathematical decomposition techniques due to computational burdensome. The main decomposition techniques are the Benders' decomposition, [?], and the Stochastic Dual Dynamic Programming, [?]. Real applications of these methods have as main disadvantage the strong dependence of the solution on random processes, requiring to reduce the number of scenarios. As a consequence, the robustness of the solution is not guaranteed, especially when draws are made in the early stages of the optimization horizon. The approach presented here has two main characteristics. Firstly, when the forward pass needs draws due to the tree size, they are made as far as possible to the star of the horizon. This decreases the number of stages for the decomposition algorithm, improving the runtimes. Secondly, recombining trees are applied for the uncertainty representation. This improves the backward pass by obtaining more future information to be considered in the previous stages, helping to the convergence speed. This approach is being used for planning the Colombian electric system, showing results consistent with other commercial tools, but with much lower execution times.

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An embedded chance constrained approach for risk averse long term power generation planning within Stochastic Dual Dynamic Programming

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Abstract

We discuss the inclusion of chance constrained programming as a tool to enforce more risk averse operation policies for long term power generation planning problem for hydrothermal systems (LTHTP), solved by stochastic dual dynamic programming (SDDP) [1]. We propose a more robust and less restrictive approach as compared to the use of rule curves or minimum level surfaces, which have been presented so far in the literature. We define a lower level subproblem for each node of the scenario tree of the SDDP approach, in order to test whether the SDDP solution yields system conditions so to ensure a given security criteria several months ahead, taking into account a continuous multivariate Gaussian distribution for the energy inflows to the reservoirs. The feasible region for this chance constrained subproblem is outer approximated by linear cuts, which are derived by computing probabilities levels and corresponding derivatives by using Genz' code [2]. An iterative approach is proposed to solve the overall problem, which comprises three modules: (i) the upper level LTHTP subproblem; (ii) a deterministic multi-stage subproblem for each node, with linear cuts that approximate the feasible region for the chance constraints; (iii) and the Genz's code itself to compute these cuts. We present preliminary results for a simplified formulation of the LTHTP problem

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TS: SP for Planning in the Energy Sector

Chair: Asgeir Tomasgard

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On large-scale power system planning using nested decomposition algorithms

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Abstract

A nested decomposition algorithm is presented to solve a large-scale dynamic generation and transmission expansion planning model for the European power system. Rather than resorting to continuous variables to model the capacity expansion, investments in significant infrastructure and generator projects are represented using first-stage binary variables. The corresponding stochastic two-stage mixed integer (binary) problem is solved by the Branch-and-Fix Coordination (BFC) algorithm, in which the original model is decomposed into submodels using break-stage scenario clustering. In this work, we present several nested decomposition schemes for solving the full size LP problem that guarantees non-anticipativity in the continuous variables of the BFC master problem. An analysis of using parallel computing for solving larger scale problems is also discussed.

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Risk Management and Project Portfolio Optimization in the Oil & Gas Industry

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Abstract

Oil & gas companies are constantly required to determine how to best allocate their budgets given a potentially vast number of investment opportunities across the globe. Adding to the pressure from volatile market conditions, falling prices and declining reserve replacement ratios, challenges include the varying degree of available information on each candidate asset – ranging from mature fields for which reservoir behavior can be relatively well characterized to new prospects with limited data in new exploration frontiers – as well as uncertainty regarding the future evolution of prices and demand.

Difficulties associated with this complex process are also compounded by the decision-dependent nature of the gradual resolution of uncertainties regarding the performance of different assets. The acquisition of seismic data, drilling of exploration wells and implementation of a field development plan are all components of the decision process through the different stages of the lifecycle of each asset, each progressively revealing additional information used by geologists and reservoir engineers to refine their forecasts and, possibly, update their strategies.

In this work, we study a stochastic programming approach to tackle such problem, discuss obstacles faced along with strategies to circumvent them and, finally, provide illustrative computational results. .

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Handling hydro uncertainty in electric power systems investment planning through stochastic mixed-integer programming

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Abstract

This study explores the Capacity Expansion Planning (CEP) problem under hydro uncertainty. CEP deals with optimally deciding the new investments to make (what, where, and when to build new generation and transmission) in order to minimize the total investment plus future operation costs for a power system. As CEP involves long decision horizons (usually 10 to 20 years), forecasting of parameters such as demand, fuel prices, and primary energy availability adds uncertainty the problem. Although remarkable advances have been made in optimization techniques, finding an optimal solution to CEP considering uncertainty can still be extremely challenging. The mathematical formulation of the problem corresponds to a large-scale, mixed-integer, non-linear programming problem over which a number of approximations and simplifications need to be made in order to solve it in a reasonable time. In this study, the uncertainty of the hydro variable in the stochastic CEP problem is represented through a finite set of differently-weighted scenarios selected from historical data (each scenario corresponding to a year of hydrological data for the different inflows). The selection of scenarios and adjustment of weights is conducted using clustering techniques and trying to preserve the statistical properties (statistical moments and covariance structure) of the multi-dimensional time series. Although this study only explores hydro uncertainty, the same ideas can be applied to other uncertain parameters such as demand or renewable generation. The proposed stochastic CEP model considers the co-optimization of generation and transmission investment decisions, and the electric network model uses a DC power flow formulation with linearized losses. The mathematical problem is formulated using 2-stage stochastic mixed-integer linear programming. As the stochastic problem is very challenging to solve in its extended form without recurring to further approximations and simplifications, a lagrangian relaxation approach was used to decompose the optimization problem by scenarios. A case study for the Chilean Central Interconnected System is presented, where hydro generation can annually change from 40% to 70% of the total generation. Numerical results concerning the benefits of the stochastic solution (in terms of expected costs and robustness of the solution) are presented, along with insights regarding the computational performance of the optimization and the decomposition approach.

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Large scale power system investment planning using multi-horizon stochastic programming

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Abstract

Managing the power system transition from a supply side based mainly on fossil fuel thermal generating technologies to one with significant shares of intermittent renewable generation requires the ability to handle short-term uncertainty and short-term dynamics in the planing process. This talk will present a stochastic programming investment model for the European power system where the multi-horizon formulation of [1] is used. Investments in generation capacities for different technologies, interconnector capacities for cross-border exchange and storage capacities are made subject to uncertainty about load and intermittent generation profiles. Short-term operational decisions are considered not to affect future investment decisions and operational decisions, which allows for a significant reduction of the scenario tree used to model the decision process. Thereby long-term dynamics, short-term dynamics and short-term uncertainty can be simultaneously be considered in a large-scale power system investment model without the curse of dimensionality issues. Computational results will be discussed.

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Plenary: Blessings of Binary in Stochastic Integer Programming — Shabbir Ahmed

Chair: Tito Homem-de-Mello

Blessings of Binary in Stochastic Integer Programming

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Abstract

Stochastic integer programming (SIP) combines the triple difficulties of uncertainty, dynamics and nonconvexity, and therefore constitutes an extremely challenging class of problems. SIP problems require carefully embedding a stochastic process within a mixed integer program while preserving the decision dynamics. A common formulation involves approximating the stochastic process by a scenario tree and exploding the underlying optimization problem into a very large-scale mixed integer program. The absence of a computationally convenient duality theory for integer programming poses severe difficulties for effective decomposition approaches for such large-scale problems. In this talk we focus on SIP problems with *binary state variables*. Under mild conditions any SIP problem can be approximated as such. We discuss how the binary nature of state variables can be exploited to develop valid decomposition approaches for SIP problems. In particular, we present an exact scenario decomposition algorithm for two-stage SIP, as well as a nested stage-wise decomposition approach and its stochastic variant – the stochastic dual dynamic programming (SDDP) algorithm – for multi-stage SIP when the state variables are binary.

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