Conference Program and Book of Abstracts

13th International Conference on Stochastic Programming

Bergamo, Italy

July 8-12, 2013
Organising Committee

- Prof. Marida Bertocchi - Chair
- Prof. Giorgio Consigli
- Prof. Vittorio Moriggia
- Prof. Sergio Ortobelli Lozza
- Prof. Rosella Giacometti
- Prof. Maria Teresa Vespucci
- Dr. Francesca Maggioni
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- Guido Perboli
- Alois Pichler
- Pavel Popela
- Rüdiger Schultz
- Asgeir Tomasgard
- Maarten van der Vlerk
- Andrés Weintraub
- Alex Weissensteiner
- Roger Wets
- David L. Woodruff
- William T. Ziemba
WELCOME FROM THE CHAIR

Dear participants,

It is a great pleasure to welcome you to the 13th International Conference on Stochastic programming in Bergamo. The conference gives you the opportunity to meet the SP community and the many researchers coming from every part of the world. It is the latest of a series of conferences that started in Oxford (1974) with subsequent meetings in Köszeg (1981) and Laxenbourg (1983) and have been held every three years since then: Prague (1986), Ann Arbor (1989), Udine (1992), Nahariyya (1995), Vancouver (1998), Berlin (2001), Tucson (2004), Vienna (2007), Halifax (2010).

Interest in stochastic programming is increasing leading us to a state-of-the-art in many problems, and applications. This is one of the reasons why we thought to arrange the present conference not only through the six important plenary talks, but also including special mini-Symposium (16) on different topics structured through an introductory lecture on that topics and a series of recent contributions (4 for each mini-symposium).

Other contributions (about 170) have been organized in parallel sessions.

The scientific programs looks very promising in widening one’s knowledge on many different topics.

In addition to the extensive scientific programme, we have prepared several social events: a welcome reception on Sunday late afternoon, a concert on Tuesday night at Teatro Sociale in the Old City, an exciting excursion to lake and monasteries with wine tasting on Wednesday afternoon and the conference banquet on Thursday evening.

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, first the University of Bergamo and its former Department of Mathematics, Statistics, Computer Science and Applications, followed by local banks as UBI and Fondazione Credito Bergamasco, other financial institutions like Pioneer Investments (IR) and Allianz (AU), Cambridge Systems Associates Ltd (UK), OptiRisk Systems (UK), the Centre for Sustainable Energy Studies at Thondheim (NO), and the RSE (Ricerca Sistema Energetico) SpA (Milan).

I cannot forget to thank also the generous help of many colleagues around the world in constructing the structure of the Conference: those who acted in the Advisory Program Committee as a reference point in making up the structure of the conference, all those that took care of organizing the mini-Symposium, a long list that you will find along the book, the organizer of tutorials, Prof. John Birge, the chairs of parallel sessions and all other colleagues that contacted us for many questions and suggestions.

The Local Organising Committee, with the help of staff from Bergamo University and the Conference Secretariat: BERGAMO CONVENTION BUREAU took over the planning and organizations of social events and the management of the on-site running of the conference. A special thanks to Giorgio Consigli for his enthusiastic and profound willingness to running this conference and in collecting sponsorship. An other special thank to Vittorio Moriggia for his competence and availability in running the website of the conference and in the preparation of the book of abstracts. His valuable experience in computing tools has given us the chance to safe time and money.

I am confident you will find this Conference stimulating, rewarding and pleasant and that you will enjoy your staying in Bergamo.

Marida Bertocchi
SPONSORS

Academic sponsors

University of Bergamo

Committee on Stochastic Programming (COSP)

Associazione per la Matematica Applicata alle Scienze Economiche e Sociali

Stochastic Programming Thematic Session

Department of Mathematics, Statistics, Computing and Applications "L. Mascheroni"

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FONDAZIONE CREDITO BERGAMASCO
OPENING CEREMONY

The opening ceremony takes place on Monday, July 8, at 08:30 at the Bergamo Conference Centre, Viale Papa Giovanni XXIII, 106, 24121.

Welcome addresses

- Marida Bertocchi - Conference Chair
- Franco Tentorio - Mayor of Bergamo
- Stefano Paleari - Chancellor of University

Awards

COSP Student Paper Prize

The student paper prize will be awarded at ICSP2013 on Thursday, July 11 at 18:00. The prize is kindly sponsored by the Italian Association of Applied Mathematics to Economic and Social Sciences (AMASES), by the Department of Mathematics, Statistics and Computer Science of the University of Bergamo and by the Euro Working Group on Stochastic Programming (EWGSP).

The award has been decided by a three-member jury formed by Prof. Georg Pflug (chair of the committee, University of Vienna), Prof. Suvrajeet Sen (University of Southern California) and Prof. Güzin Bayraksan (University of Arizona).

Reception

- Sunday, July 7th, from 17:00 at University of Bergamo.
OVERVIEW OF EVENTS

Registration
Since Saturday July 6, 14:00 at the University of Bergamo Registration desk.
For details go to page 8.

2 day PhD tutorials
The traditional PhD tutorials coordinated and organized by John Birge are held at the University of Bergamo on Saturday July 6 from 14:30 to 19:15 and on Sunday July 7 from 09:00 to 16:00. See page 11 for details.

Welcome Reception
Sunday July 7 from 17:00 to 20:00 in the University hall in Via Caniana, 2.

Plenary Lectures
Starting July 8 at 09:00 and then at the same time every day at the Bergamo Conference Centre.
Every Plenary Lecture lasts 50 minutes plus discussion.
Closing plenary on July 12 at 17:00 at the University of Bergamo.

Mini-Symposium (MS)
Every day from 14:00 to 16:25 at the University of Bergamo.
Each MS includes one 45 minute semi-plenary talk followed by four 25 minute talks.
We have organized the MS in four parallel streams with associated lecture rooms throughout the week:
- New Concepts for Stochastic Systems [room 5]
- New Approaches to Classical problems [room 4]
- Computation and Applications [room 3]
- Finance and Application [room Galeotti]

Special remark: we would like to mention that the MS on Dynamic Stochastic Optimization and Finance organized by Elena Medova on Monday July 8, intends to celebrate Michael A. H. Dempster’s 50 year scientific career and recent 75th birthday.

Parallel Sessions (PS)
Every day from 10:45 to 12:50 and from 16:55 to 19:00 at the University of Bergamo.
Each PS includes five 25 minute talks.
We ordered the PS into five parallel streams:
- Advances in stochastic programming and contiguous fields [room Galeotti]
- Problem formulation and solution algorithms [room 5]
- Energy [room 3]
- Finance [room 4]
- Operations Management and Software [room 10]

EWGSP Kick-off Meeting
The kick-off meeting of the newly established Euro Working Group of Stochastic Programming will be held from 16:30 to 17:00 on Friday July 12. Room Galeotti, University of Bergamo.

Conference Dinner
Thursday July 7, at 20:00 at the restaurant “Pianone” in the Old City. Special pick up services will be organized.

COSP General Meeting
Thursday July 7, at 17:00 at the University of Bergamo. During the meeting the COSP Committee for the following three years will be elected and the next conference site presentations will take place. The COSP paper prize will be awarded by the appointed Jury.
**REGISTRATION AND GENERAL INFO**

**Registration**

Those who haven’t paid the registration fee before the conference are required to pay upon arrival to the conference at the ICSP2013 registration desk, namely at:

the University of Bergamo:
- Saturday July 6 and Sunday July 7, from 14:00 to 20:00
- From Monday July 8, until Friday July 12 every day from 10:30 to 12:30

the Bergamo Conference Centre:
- From Monday July 8, until Friday July 12 every day from 08:00 to 09:00

**Badges required for conference sessions**

Conference participants will collect the badge onsite upon registration and are required to carry it during the conference and to access the conference site.

**Conference dinner tickets**

For those who paid the conference dinner tickets will be included in the conference bag.

**Question and information**

All the people from the organization with orange badge’s lanyard will be available for any type of information.

**Getting around by public transport**

Tickets for transportation may be bought at square "Porta Nuova" close to Cappello D’Oro Hotel or from newspaper vendors or tobacconist. Cost of each ticket is 1.25€ (carnet 10 runs at 11€) and it lasts for 75 minutes.

**Messages**

Messages can be left at the registration desk.

**ICSP Bergamo Guide**

For accompanying persons a one-day special tour in the Old City is available for Tuesday July 9, at an extra cost of 40€ including lunch.

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**Internet access**

Each participant will have his own internet address.

Computer rooms (lab 7, lab 9 and lab 19) will be available

- **Monday**
  - Lab 7: 10:00 – 19:00
  - Lab 9: 14:00 – 19:00
  - Lab 19: 10:00 – 19:00

- **Tuesday**
  - Lab 7: 13:00 – 17:00
  - Lab 9: 14:30 – 17:00
  - Lab 19: 10:30 – 17:00

- **Wednesday**
  - Lab 7: 10:00 – 14:30
  - Lab 9: 10:00 – 14:30
  - Lab 19: 10:00 – 14:30

- **Thursday**
  - Lab 7: 10:30 – 15:00
  - Lab 9: not available
  - Lab 19: 10:30 – 19:00

- **Friday**
  - Lab 7: 10:30 – 19:00
  - Lab 9: not available
  - Lab 19: 10:30 – 19:00

**Snacks and coffee breaks**

Snacks, coffee and beverage are available at the dispenser machine. Coffee break will include coffee, tea, juice and some biscuits.

Bar are available outside the University.

**Food**

Food is available from 12:00 to 14:00 at the University cafeteria ("Mensa") or in nearby bars and restaurants:

- “Osteria Pane E Vino” - *special prices*
  Via San Bernardino, 51
  (Monday and Sunday closed)

- “La Fricca” - *special prices*
  Via Previtali, 18
  (Wednesday and Sunday closed)

- "Da Nasti"
  Via Zambonate, 25
  (Monday and Sunday closed)

- “Marechiaro”
  Via Borgo Palazzo, 2

- “Da Mimmo”
  Via Colleoni, 17 (Old City)

- “Da Franco”
  Via Colleoni, 8 (Old City)
SOCIAL PROGRAM

**Sunday, July 7, 17:00 – 20:00**
Welcome reception in the hall of the University of Bergamo in Via Caniana, 2 (drinks and snacks).

**Monday, July 8**
Free

**Tuesday, July 9, 21:00 – 23:00**
Concert at the theatre “Teatro Sociale”, in the Old City. A pick-up service will be organized by the Conference Bureau from “Porta Nuova” square.
For accompanying persons a special tour through Bergamo’s master pieces may be booked at the special price of 40€ included lunch.

**Wednesday, July 10, 14:00 – 19:00**
Trip to the Lake Iseo and Wine Tasting.

**Thursday, July 11, 20:00 – 22:00**
Social Dinner at restaurant “Il Pianone” in the Old City. Special pick-up services will be organized.

**Friday, July 12**
Free

**Saturday, July 13, 10:00 – 15:00**
Visit to “The Last Supper” and Castello Sforzesco in Milan, lunch and bye-bye.
SPEAKER AND CHAIR INFORMATION

Speaker guidelines

Audio-visual services
A laptop is available in each room and it is connected to a video beamer. White board is also available in each room.

Presentation guidelines
The Chair session must have available the presentations before the starting of the session. They have to keep on time to allow people to move from one session to another. Time your presentation to fit within the designated time schedule leaving enough time for audience questions and change of speaker. Student assistants will provide support for handling of the computer projectors.

Program information desk
An information desk is open during registration hours and a tableau will be available at registration desk for any news or program changes.

Assistance during your session
A person from the organizing committee will be available in each conference room.

Session Chair guidelines

The role of the Chair is to coordinate the smooth running of the session and introduce each speaker. The time available for each type of talk is the following:

- Plenary: 50 minute talks plus 10 minutes for questions
- Semi-plenary: 40 minute talks plus 5 minutes for questions
- Parallel and Mini-Symposium: 25 minute talks including questions
# PhD TUTORIAL SCHEDULE

## Saturday, July 6

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<tr>
<th>Time</th>
<th>Topic</th>
<th>Speaker</th>
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<td>14:30-16:00</td>
<td>Models and Overview</td>
<td>Stein W. Wallace</td>
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<tr>
<td>16:00-17:30</td>
<td>Risk-Averse Optimization</td>
<td>Andrzej Ruszczynski</td>
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<tr>
<td>17:45-19:15</td>
<td>Basic Theory</td>
<td>John Birge</td>
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## Sunday, July 7

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<tr>
<td>09:00-10:30</td>
<td>Scenario generation</td>
<td>Georg Ch. Pflug</td>
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<td>10:30-12:00</td>
<td>Stochastic integer programming</td>
<td>François Louveaux</td>
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<td>12:15-13:45</td>
<td>Computational methods</td>
<td>Jeff Linderoth</td>
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<td>14:30-16:00</td>
<td>Uncertainty quantification and data fusion</td>
<td>Johannes Royset</td>
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### SCIENTIFIC SCHEDULE

**Monday, July 8, Morning**

**Chair: Giorgio Consigli**

#### Reflections on Dynamic Stochastic Programming: Theory, Computation and Applications

*Michael A. H. Dempster*

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<th>Problem formulation and solution algorithms</th>
<th>Energy</th>
<th>Finance</th>
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</thead>
</table>
| [Room Galeotti] **Bounds and SAA methods**  
  Chair: Francesca Maggioni | [Room 5] Approaches and Applications of Discrete Decisions in Stochastic Systems  
  Chair: Maarten van der Vlerk | [Room 3] Market evolution and pricing  
  Chair: Raimund Kovacevic | [Room 4] **Finance Optimization**  
  Chair: William T. Ziemba | [Room 10] Production and capacity planning for stochastic systems  
  Chair: Paolo Brandimarte |
| The impact of the spot price modelling on the electricity portfolio optimization problem  
  **Simone Sbrilli** | Multi-term Disjunctive Decomposition for Mixed-Integer Recourse in Stochastic Programming  
  **Suvrajeet Sen** | Medium-term planning for thermal electricity production  
  **Florentina Paraschiv** | A stochastic programming perspective on contingent claims  
  **Alan King** | Multi-period Supplier Selection under Price Uncertainty  
  **Hande Yaman** |
| VSS capture for the two-stage transportation problem with stochastic demand through scenario clustering  
  **Manuel Cepeda** | Fenchel Disjunctive Decomposition for Mean-Risk Stochastic Integer Programs  
  **Lewis Ntaimo** | A Risk Averse Multi-stage Stochastic Optimization Model for Power Generation Expansion Planning: Analysis of Multi-stage Consistency  
  **Paolo Pisciella** | Optimal Capital Growth With Shortfall Penalties  
  **Leonard MacLean** | Scenario-Based Stochastic Programming Approach to Capacity Planning Problem under Demand Uncertainty  
  **Serkan Kalay** |
| Bounds in Multistage Stochastic Programs  
  **Francesca Maggioni** | Optimization under uncertainty in reverse logistics  
  **Nadine Wollenberg** | Price dynamics in electricity spot markets  
  **Michael Schuerle** | Asset-Liability Management via Risk-Sensitive Control  
  **Sebastien Lleo** | Flow Balancing with Uncertain Demand for Package Sorting Facilities  
  **Luis Novoa** |
| Subgradient Bounds for Convex Dynamic Programs  
  **David Brown** | Total variation error bounds for convex approximations of two-stage mixed-integer recourse models  
  **Ward Romeijnders** | Price setting for energy swing options via stochastic bilevel problems  
  **Peter Gross** | Understanding and controlling high factor exposures of robust portfolios  
  **Min Jeong Kim** | Image modeling using energy optimization by stochastic programming  
  **Ben-Shung Chow** |
| Two-Stage Stochastic Mixed Integer Linear Programming  
  **Jian Cui** | Pricing of Energy Contracts - From Replication Pricing to Swing Option Pricing  
  **Raimund Kovacevic** | Applications in Finance - When to sell Apple and the NASDAQ100, the Nikkei and other bubble markets with a stochastic disorder model  
  **William T. Ziemba** | Dealing with end-of-horizon effects in stochastic lot sizing  
  **Paolo Brandimarte** |
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<td>Boolean Data Mining Method for Probabilistically Constrained Stochastic Programming Problems</td>
<td>Decomposition Methods for Two-stage Stochastic Linear Semidefinite Programs with Risk Aversion</td>
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<td>Automatic inference of decision rules for multistage stochastic programs</td>
<td>Optimization with multivariate stochastic dominance constraints</td>
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<td>Structure of Risk-Averse Multistage Stochastic Programs</td>
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<td>Statistical features in stochastic optimization programs</td>
<td>Learning policies from solutions of multistage programs, illustration on power system applications</td>
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<td>The value of local electricity storage in a smart grid: How important is intermittency?</td>
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<td>Hydrothermal Unit Commitment Subject to Uncertain Demand and Water Inflows</td>
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<td>A multistage stochastic program for production planning in the pig supply chain industry</td>
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<td>Robustness and bootstrap techniques in portfolio efficiency tests</td>
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<td>Andre Luiz Diniz</td>
<td>Valeria Caviezel</td>
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## Stochastic Programming with Probabilistic Constraints

**René Henrion**

### Advances in Stochastic Programming and Contiguous Fields

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<td>Room 4</td>
<td>Risk control for dynamic portfolios (Chair: Diana Barro)</td>
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<td>Room 10</td>
<td>Transportation and Logistic (Chairs: Francesca Maggioni, Guido Perboli)</td>
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### Problem formulation and solution algorithms

- **Energy**
  - Estimation of Pure Characteristics Demand Models with Pricing
    - Jong Shi Pang
  - A stochastic transmission planning model with dependent random variables; wind and load
    - Heejung Park
  - Distributed Algorithms for Nonlinear Multistage Stochastic Programs
    - Marc C. Steinbach
  - Benders Decomposition for solving multi-stage stochastic mixed complementarity problems.
    - Ruud Egging
  - Risk Averse Computational Stochastic Programming
    - Somayeh Moazeni
  - A Stochastic Trust Region Algorithm for Mixed Logit Type Problems
    - Anton J. Kleywegt
  - A diversification tabu search approach for the open-pit mine production scheduling problem with metal uncertainty
    - Amina Lamghari
  - Integrated planning of operations and spare parts logistics under uncertainty in the supply chain of maintenance service providers
    - Masoumeh Kazemi Zanjani

- **Finance**
  - Consistency and risk averse dynamic decision models: Definition, interpretation and practical consequences.
    - Alexandre Street
  - Accounting for Risk Measure Ambiguity when Optimizing Financial Positions
    - Erick Delage
  - Time Consistent Recursive Risk Measures Under Regime Switching and Factor Models and Their Application in Dynamic Portfolio Selection
    - Jia Liu
  - Optimal Liquidation Strategies for Portfolios under Stress Conditions
    - Jorge P. Zubelli
  - Controlling risk in dynamic asset allocation through stochastic optimization
    - Diana Barro

- **Operations Management and Software**
  - General Dynamic Programming
    - Vincent Leclere
  - Dynamic Time-Consistent Approximations of Risk Measures
    - Tsvetan Asamov
  - Risk aversion in multi-stage stochastic programming: a modeling and algorithmic perspective
    - Tito Homem-de-Mello
  - Nested Preprocessing for Multistage Stochastic Programming
    - Lijian Chen

- **Transportation and Logistic**
  - A diversified tabu search approach for the open-pit mine production scheduling problem with metal uncertainty
    - Amina Lamghari
  - Integrated planning of operations and spare parts logistics under uncertainty in the supply chain of maintenance service providers
    - Masoumeh Kazemi Zanjani
  - The Stochastic Generalized Bin Packing Problem
    - Mauro M. Baldi
  - The Stochastic Mixed Capacitated General Routing Problem: formulation and solution approaches
    - Maria Elena Bruni
  - The multi-path Traveling Salesman Problem with stochastic travel costs: a City Logistics computational study
    - Guido Perboli
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<th>Chair(s)</th>
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<td>The scenario approach to decision-making processes</td>
<td>Marco C. Campi</td>
<td>The fundamental theorems of the scenario approach.</td>
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<td>Chair: Bita Analui</td>
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<td>Capacity expansion using stochastic programming with decision dependent probabilities.</td>
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<td>Chair: Laureano F. Escudero</td>
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<td>On multistage mixed 0-1 optimization under a mixture of Exogenous and Endogenous Uncertainty in a riskaverse environment.</td>
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<td>Chair: Laureano F. Escudero</td>
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<td>A Scenario Based Approach to Robust Experiment Design.</td>
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<td>Chair: Laureano F. Escudero</td>
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<td>Equivalents and Algorithms for Programs with Stochastic Order Constraints Induced by Linear Recourse.</td>
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<td>A Generalized Benders' Algorithm for the Two-Stage Stochastic Optimization Problem with Mixed Integer Recourse.</td>
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<td>A Decomposition Approach to find the Nucleolus Share of a Renewable Hedge Pool.</td>
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<td>A stochastic programming model for hedging options in a market with transaction costs.</td>
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<td>Investing in complementary renewable sources using stochastic-robust optimization and real options.</td>
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<td>Management of Portfolio of Options With Two Expiration Dates.</td>
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<td>Using Malliavin derivative to price an American option under stochastic volatility.</td>
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**Tuesday, July 9, Afternoon**

**Advances in stochastic programming and contiguous fields - 1**
- Optimization under incomplete information
  - Chair: Guzin Bayraksan
- On Robust Multistage Stochastic Optimization with application in Energy
  - Bita Analui
- Two-stage Stochastic Linear Programs with Incomplete Information on Uncertainty
  - Jie Sun
- Risk-Averse Stochastic Optimization with Incomplete Information
  - Chaoxue Zhao
- Stochastic security constrained unit commitment with incomplete information
  - Ruwei Jiang
- On the Use of Phi-Divergences for a Class of Two-Stage Ambiguous Stochastic Programs
  - Guzin Bayraksan

**Advances in stochastic programming and contiguous fields - 2**
- Optimization under incomplete information
  - Chair: Ignacio E. Grossmann
- On Robust Multistage Stochastic Optimization with application in Energy
  - Bita Analui
- Two-stage Stochastic Linear Programs with Incomplete Information on Uncertainty
  - Jie Sun
- Risk-Averse Stochastic Optimization with Incomplete Information
  - Chaoxue Zhao
- Stochastic security constrained unit commitment with incomplete information
  - Ruwei Jiang
- On the Use of Phi-Divergences for a Class of Two-Stage Ambiguous Stochastic Programs
  - Guzin Bayraksan
The Decision Rule Approach to Stochastic Programming

Daniel Kuhn

Advances in stochastic programming and contiguous fields

Problem formulation and solution algorithms

Energy

Finance

Operations Management and Software

Minimax stochastic program with overlapping marginals

Xuan Vinh Doan

Robust combinatorial optimization with cost uncertainty

Michael Poss

Pricing of Multi-Product Monopolistic Cloud Computing Services with Service Level Agreements

Vladimir Roitch

Interdiction Games on Markovian PERT Networks

Eli Gutin

Solution of Probabilistic Constrained Problems with Compound Poisson Distributions

Anh Ninh

Conditional Value-at-risk Versus Multidimensional Rule Curves Within the Risk-averse SDP Approach

Debora Dias Jardim Penna

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

Murilo Pereira Soares

Representation of non-convexities in stochastic dual dynamic programming applied to hydrothermal operation problems

Fernanda S. Thome

Stochastic Dual Dynamic Programming with CVaR Risk Constraints Applied to Hydrothermal Scheduling

Luiz Carlos Da Costa Jr.

Risk-averse multistage stochastic programming

Vaclav Kozmik

Bidding in sequential electricity markets: The Nordic case

Trine Krogh Boomsma

Electricity Market Clearing With Improved Scheduling of Stochastic Production

Salvador Pineda Morente

Decomposition for day-ahead bidding of hydro power portfolios - experiences and challenges

Gro Klæboe

Model of Approximate Dynamic Programming Applied on Day-Ahead Trading of a Renewable Producer of Energy

Vadym Omelchenko

Bidding hydroelectric power via decision rules

Stein-Erik Fleten

Generalized quantiles as risk measures

Fabio Bellini

Fixed income management using Stochastic Programming

Jonas Ekblom

A Multistage Linear Stochastic Programming Model for Optimal Corporate Debt Management

Álvaro Veiga

Long-Term Bank Balance Sheet Management: Estimation and Simulation of Risk-Factors

Pedro Judice

Portfolio Selection with Objective Functions from Cumulative Prospect Theory

Janos Mayer

Stochastic Decomposition: Motivation, technology and the challenges that it presents.

Francis Ellison

A solver for problems with second-order stochastic dominance constraints

Victor Zverovich

A Randomized Metaheuristic for Stochastic Integer Programs with Binary First Stage Variables and Continuous Second Stage Variables

Cristiano Arbex

Valle A computational study of on-demand accuracy level decomposition for two-stage stochastic programs

Christian Wolf

An open-source solver system for stochastic programming

Horand Gassmann

Iseo Lake Tour

and

Wine Tasting
Chair: Anton J. Kleywegt

### The role of stochastic programming in revenue management

Huseyin Topaloglu

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<td>Multi-stage stochastic optimization: The distance between stochastic scenario processes Anna Timonina</td>
<td>Stochastic optimization of a gas plant with storage taking into account take-or-pay restrictions David Wozabal</td>
<td>Risk budgeting and portfolio optimization based on ARMA-GARCH non-Gaussian multivariate model Nima Nooshi</td>
<td>Stochastic programming applied to design and operation planning problems in the field of energy systems Michal Tous</td>
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<td>How to generate multi-stage scenario trees (if you have to) Ronald Hochreiter</td>
<td>Optimal capital planning with renewable-induced uncertainty using Markov decision processes Athena Wu</td>
<td>Application of skew t-distribution in the field of investors’ preferences visualization Ingrida Vaiciulyte</td>
<td>Recent Advances in Stochastic Quadratic Assignment Problems Radomil Matousek</td>
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<td>On k-sample homogeneity tests, when k is large Audrius Kabasinskas</td>
<td>On a Limited-Memory Damped-BFGS Method for Large Scale Optimization Mehiddin Al-Baali</td>
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<td>Chair: Roger Wets</td>
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<td>Chair: Alex Weissensteiner</td>
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<td>General economic equilibrium with incomplete markets</td>
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<td>Alejandro Jofré</td>
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**Thursday, July 11, Afternoon**

Mini-Symposium

Thu 14:00-16:25

COSP

Thu 17:00-19:00

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General Assembly

Student Paper Prize

Next Conference site proposals

EWGSP presentation

Triannual COSP election
### Risk-Constrained Multi-Stage Wind Power Investment

**Antonio J. Conejo**

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**Advances in stochastic programming and contiguous fields**  
**Chair:** Laureano F. Escudero

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<th>Joint dynamic chance constraints with projected linear decision rules for some multistage stochastic linear programs</th>
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| Energy Finance Operations Management and Software |
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<th>Bid Generation in Combinatorial Auctions for the Transportation Procurement under Stochastic Winning Prices</th>
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**Plenary**  
Fri 09:00-10:00

**Parallel**  
Fri 10:45-12:50
**New Concepts for Stochastic Systems**

**Information constraints and discretization puzzles in stochastic optimal control**  
Michel De Lara  

**Variational approaches in stochastic optimal control**  
Pierre Carpentier

**Dynamic Consistency for Stochastic Optimal Control Problems**  
Jean-Philippe Chancelier

**Decomposition-coordination methods in stochastic optimal control**  
Jean-Christophe Alais

**European energy equilibrium and decomposition**  
Anes Dallagi

---

**New Approaches to Classical Problems**

**Recent Advances for the Solution of Sample-Average Approximations of Chance-Constrained Stochastic Programs**  
James Luedtke

**A Decomposition Algorithm for a Chance-Constrained Program with Recourse**  
Simge Kucukyavuz

**Data-driven Chance Constrained Stochastic Program**  
Yongpei Guan

**Mixed-Integer Programming Models for Optimizing Risk Parameter in Chance Constraints**  
Siquian Shen

**Improved MIP models for chance-constrained problems with probabilistic right-hand sides**  
Ricardo Fukasawa

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**Computation and Applications**

**Progressive Hedging Applied to Mixed-Integer and Non-Linear Stochastic Programs**  
David L. Woodruff

**Progressive Hedging for Non-Linear Models that Arise in Parameter Estimation Problems**  
Yankai Cao

**Progressive Hedging for Stochastic Unit Commitment**  
Jean-Paul Watson

**Progressive Hedging for Stochastic Economic Dispatch with AC Power Flow**  
John D. Sirola

**A New Lower Bound from Progressive Hedging**  
Sarah M. Ryan

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**Finance and Applications**

**Improving Diversification in an Era of Contagion: Optimizing over a Set of Assets and Special Tactics**  
Woo Chang Kim

**Factor Models for Scenario Construction in Long Term Asset Allocation**  
Lorenzo Mercuri

**Practical Examples: Optimizing Dynamic Asset Allocation Strategies with Approximate Dynamic Programming**  
Thomas Bauerfeind

**Relevant short-medium-long term decision criteria for optimal Property & Casualty portfolio selection**  
Massimo di Tria

**Longevity Risk Management for Individual Investors using Multi-stage Stochastic Programming**  
Koray Deniz Simsek

---

**EWGSP Kick-off meeting**

**Chair: Marida Bertocchi**

**Recent computational advances in solving very large stochastic programs**  
Jacek Gondzio

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**Conference closing and See you at SP XIV!**
SOFTWARE DEMONSTRATIONS

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MODELLING SUPPORT
- AMPL Shell
- AMPL IDE
- AMPLDev SP* (IDE)
- AMPL API (Object library)

* Stochastic Programming and Robust Optimisation in AMPLDev SP are supported by: Stochastic AMPL: SAMPL

Stochastic Constructs include:
- Two/multi stage recourse
- Chance Constrained Programs
- Integrated Chance Constrained Programs

Robust Constructs include:
- Polyhedral Uncertainty Sets
- Ellipsoidal Uncertainty Sets

SOLVERS
- CPLEX:
  Full range with AMPL
- FortMP:
  SSX, IPM, MIP, QP, QMIP
- FortSP:
  Two/Multistage (integer) stochastic solver
- GUROBI

SERVICES
- MP Modelling
- MP Solver tuning
- Uncertainty and Risk Analysis/Modelling

TRAINING
- Linear & Integer Programming
- Stochastic Programming
- Quadratic Programming
- Portfolio Planning
- Asset & Liability Management

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Email: info@optirisk-systems.com
RELEVANT PLACES

University of Bergamo – Faculty of Economics, Via Caniana, 2, 24127 Bergamo

Bergamo Conference Center, Viale Papa Giovanni XXIII, 106, 24121 Bergamo

Casa della Lavoratrice, Via Autostrada, 2, 24126 Bergamo

Restaurant "Osteria Pane E Vino", Via San Bernardino, 51, 24122 Bergamo

Restaurant "La Fricca", Via Previtali, 18, 24122 Bergamo
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PLENARY SESSIONS

Monday 9.00-10.00 Plenary

Reflections on Dynamic Stochastic Programming: Theory, Computation and Applications

Michael A. H. Dempster

On the occasion of the 13th International Conference on Stochastic Programming, 39 years after I organized the first conference in Oxford in 1974, this talk will attempt to summarize and reflect upon the subsequent developments in the field of dynamic - multi-stage - stochastic programming (DSP). The former term is preferable to me, as it emphasizes that real time underlies the discrete decision points in practical applications of DSP strategic and tactical planning models over finite planning horizons in finance, telecommunications, logistics, energy and an ever growing number of other fields. Moreover, due to state space finite scenario sampling in tree form, DSP is the only one of the alternative approaches to the optimization of complex stochastic systems that can handle in an efficient manner a large number of stochastic processes and events - risk factors - as is required by these applications. With current advances in software and computing technology the accurate modelling capabilities of DSP can be greatly extended, for example in suppressing sampling error. The talk will illustrate the progress over four decades in theory, numerical methods and complex applications which has transpired since the first conference, whose proceedings, Stochastic Programming, were only published in 1980 - an embarrassing record for delay! I will stress problems which remain open in each area, with particular emphasis on my own experience and that of my students, colleagues and co-authors over the years.

Speaker Scientific Summary

Michael A H Dempster, Professor Emeritus and Founder, Centre for Financial Research, Department of Pure Mathematics and Statistics, University of Cambridge.

Educated at Toronto, Carnegie Mellon and Oxford, Michael Dempster has taught and researched in leading universities on both sides of the Atlantic, including Oxford, Cambridge, Stanford, California-Berkeley, Princeton, Toronto, Melbourne and Rome. He was the first Professor of Finance at the Cambridge Judge Business School and is currently founding Editor-in-Chief of Quantitative Finance and an Associate Editor of Stochastics, Computational Finance and the Journal of Risk Management in Financial Institutions. Michael is founding Editor-in-Chief of the Oxford Handbooks in Finance and founding Co-Editor of the Chapman & Hall /CRC Mathematical Finance Series. He has been consultant to a number of global financial institutions and corporations and several governments and is regularly involved in executive education in financial engineering and risk management around the world. Author of over 110 published research articles in leading international journals; his books include Introduction to Optimization Methods (with P R Adby), Stochastic Programming, Derivative Securities (with S R Pliska), Risk Management: Value at Risk and Beyond, Quantitative Fund Management (with G Mitra and G Pflug), Stochastic Optimization in Finance and Energy (with M Bertocchi and G Consigli) and The Euro in Danger (with J S Chadha and D S Pickford). His work has won several awards and he is an Honorary Fellow of the UK Institute of Actuaries and Managing Director of Cambridge Systems Associates Limited, a financial analytics consultancy and software company.
Tuesday 9.00-10.00 Plenary

Stochastic Programming with Probabilistic Constraints

René Henrion

Many optimization problems arising from engineering applications are affected by random parameters. In this case, the use of probabilistic constraints makes it possible to find optimal decisions which are robust against uncertainty at a specified probability level. From a formal point of view, probabilistic constraints are conventional inequalities restricting the domain of feasible decisions. The major difficulty in their numerical treatment consists in the absence of explicit formulae for function values and gradients. Recently a lot of alternative models or approximating strategies have emerged. In this talk we pursue the traditional approach of embedding (joint) probabilistic constraints into numerical schemes of nonlinear optimization. The motivation to do so is based on the one hand on the existence of efficient codes for the computation of multivariate Gaussian distribution functions (e.g. Genz) and on the other hand on the well-known fact that gradients of Gaussian distribution functions can be analytically reduced to function values. This reduction makes it possible to solve problems with separate probabilistic constraints in meaningful dimension. We will show in the first part of the talk, how the reduction can be generalized to probabilistic constraints with arbitrary (possibly singular) linear transformations of the separate Gaussian vector or with bilinear coupling of decision and Gaussian random vector. The second part will be devoted to models with Non-Gaussian distributions (log-normal, Student) and general nonlinear mappings of decision and random vector. In this latter case, our approach relies on the spherical-radial decomposition of Gaussian random vectors and - for the numerical realization - on Deak's sampling scheme of the unit sphere. The results are illustrated by means of applications to power management. In a third part of the talk, special topics like dynamic chance constraints or empirical approximations are addressed.

Speaker Scientific Summary

Professor René Henrion is recognised as a leading scholar on chance-constrained stochastic programming and a long-term member of the stochastic programming community. He graduated in mathematics in 1987 at Humboldt University in Berlin and completed his PhD in maths with a thesis on semi-infinite optimization in 1990. In 1995 he was appointed as research fellow of the German Research foundation and the year after Senior researcher at the Weierstrass Institute in Berlin, where he is still serving as at today. René is member of several Editorial boards, including SIOP, Set-values variational analysis, Optimization, Nonlinear analysis and he serves as editor of our electronic SP series SPEPS. From 2001 to 2004 he is been invited Professor at Martin-Luter University in Halle. He has some 60 publications in refereed journals on topics in stochastic programming, variational and set-valued analysis, nonsmooth and parametric optimization or chemometrics. In addition 2 monographs on multivariate data analysis (in German), one special issue of Set-Valued and Variational Analysis which he co-edited, and approx. 20 contributions to collections (book chapters, Springer Lecture note series, Proceedings).
The Decision Rule Approach to Stochastic Programming

Daniel Kuhn

Stochastic programming is a dominant approach to address practical optimization problems affected by uncertainty. Most of the existing solution techniques rely on some form of discretization of the underlying probability distribution or state space. While these discretization schemes theoretically achieve any desired level of accuracy, they may suffer from a curse of dimensionality that restricts their application to small and medium-sized problem instances. Recently, an alternative solution paradigm has gained popularity, which preserves the exact distribution of the uncertain parameters but restricts the set of feasible recourse decisions to those possessing a simple functional form, such as linear, piecewise linear or polynomial decision rules. Under this approximation, linear stochastic programs can be reformulated as standard conic optimization problems by using duality techniques. An attractive feature of this decision rule approach is that it typically leads to polynomial-time solution schemes. This talk surveys some of the main theoretical results on decision rules such as their scalability properties, worst-case (a priori) and instance-wise (a posteriori) bounds on their approximation quality as well as systematic techniques to improve their approximation quality by augmenting the dimension of the underlying probability space. Even though decision rule approximations have gained broader attention only since 2004, they have already found successful use in a variety of application areas ranging from operations management, portfolio optimization and automatic control to network design and energy planning. By taking a closer look at numerical results obtained in some of these application areas, we will showcase the potential of decision rule-based solution schemes to enable scalability to industry-sized problem instances.

Speaker Scientific Summary

Daniel Kuhn is a Senior Lecturer in the Department of Computing at Imperial College London. His current research interests are focused on the modeling of uncertainty, the development of efficient computational methods for the solution of stochastic and robust optimization problems and the design of approximation schemes which ensure their computational tractability. This theoretical work is primarily application-driven, the main application areas being energy systems, finance and engineering. Before joining Imperial College he was a postdoctoral research associate in the Department of Management Science and Engineering at Stanford University. He holds a PhD degree in Economics from University of St. Gallen and a MSc degree in Theoretical Physics from ETH Zurich. He serves on the editorial boards of several academic journals including Operations Research and Mathematical Programming.
Thursday 9.00-10.00 Plenary

The role of stochastic programming in revenue management

Huseyin Topaloglu

Revenue management refers to the set of activities pursued by a firm to make the most beneficial use of limited inventories by selling the products to the right customer segment, at the right price and at the right time. Many industries, including air transportation, hospitality and retail, benefit from revenue management models and algorithms. The common theme in these industries is that limited inventories are sold to customers from different segments that are willing to pay different prices. Problems are complicated by the fact that one needs to capture the stochastic and dynamic nature of the demand and inventories are consumed in bundles, which, for example, is the case when customers purchase airline seats on multiple connecting flights or hotel rooms on consecutive nights. We review the essential stochastic models in revenue management and describe solution methods for them. Often times, these models result in stochastic programs with high-dimensional recourse vectors. Some solution methods approximate the recourse functions, while others focus on a class of policies parameterized by a set of parameters and use simulation optimization to find a good policy within this class.

Speaker Scientific Summary

Huseyin Topaloglu is an Associate Professor in the School of Operations Research and Information Engineering at Cornell University.
He holds a B.Sc. in Industrial Engineering from Bogazici University in Turkey, and a Ph.D. in Operations Research and Financial Engineering from Princeton University. His research interests include stochastic programming and approximate dynamic programming with applications in transportation logistics, revenue management and supply chain management. His recent work focuses on constructing tractable solution methods for large-scale network revenue management problems and building approximation strategies for retail assortment planning. Huseyin Topaloglu is currently serving as associate editors for IIE Transactions, Mathematical Programming Computation, Operations Research and Transportation Science. He is the recipient of the INFORMS Revenue Management and Pricing Section Prize in 2010.
Risk-Constrained Multi-Stage Wind Power Investment
Antonio J. Conejo (with: Luis Baringo)

When investing in wind power facilities, three major issues arise: the uncertainty and variability in the production of wind power facilities, the eventual future decline in wind power investment costs, and the significant financial risk involved in such investment decisions. Recognizing these important issues, this presentation proposes a risk-constrained multi-stage stochastic programming model to make optimal investment decisions on wind power facilities along a multi-stage horizon. Such model includes complementarity conditions to represent market clearing under many operating conditions. The resulting large scale mixed-integer linear programming problem is efficiently solved using Benders’ decomposition. The proposed model is illustrated using a clarifying example and a case study.

Speaker Scientific Summary
Antonio J. Conejo, full professor at the Universidad de Castilla-La Mancha, Spain, received the M.S. from MIT and the Ph.D. from the Royal Institute of Technology, Sweden. He has published over 125 papers in SCI journals and is the author or coauthor of books published by Springer, John Wiley, McGraw-Hill and CRC. He has been the principal investigator of many research projects financed by public agencies and the power industry and has supervised 16 PhD theses. He is the Editor-in-Chief of the IEEE Transactions on Power Systems, an IEEE Fellow and the Chair of the IEEE PES Power System Operations Committee.
Recent computational advances in solving very large stochastic programs

Jacek Gondzio

Stochastic programming problems have always been a challenge for optimizers because the need to model the uncertainty with a sufficient accuracy may easily lead to creating intractably large problems. However, one may argue that the curse of dimensionality is actually a blessing for optimizers. Indeed, stochastic programming attracts considerable interest of researchers who wish to tackle these often huge problems. The ability to deal successfully with such problems is rewarding because any developments in stochastic programming impact on other optimization areas. In this talk, we will exploit different ideas of “decomposition” of stochastic programming problems. We will address a successful class of decomposition algorithms applicable in this context and compare them with a frontal approach which consists of applying interior point methods which rely on decomposing the underlying linear algebra steps. We will comment on the advantages and drawbacks of both approaches and we will review recent advances in both approaches.

This talk will have a light touch, appropriate for Friday afternoon and the closing of SP XIII.

Speaker Scientific Summary

Professor Jacek Gondzio holds an engineering degree (1983) and a PhD in Electronics (1989) both from the Department of Electronics, Warsaw University of Technology. Since October, 1998 he has been at the School of Mathematics, the University of Edinburgh. He is a member of Editorial Board of two leading optimization journals: Computational Optimization and Applications and Mathematical Programming Computation. His research interests include the theory and implementation of large-scale optimization methods. He has been involved in the development of the simplex, simplex-type and interior point methods for linear, quadratic and nonlinear programming and the cutting plane methods for convex optimization. He is best known for his contributions in the area of interior point methods. His joint work with Luca Bergamaschi and Giovanni Zilli on preconditioners for interior point methods received the 2004 COAP Best Paper Award. His joint work with Andreas Grothey led to a development of the Object Oriented Parallel Solver (OOPS) which was applied in 2005 to solve a very large multistage stochastic programming problem, a quadratic program with more than a billion decision variables. Recently he has developed a new matrix-free interior point method which avoids explicit access to the problem data and therefore is able to solve some very large optimization problems.
### PARALLEL SESSIONS AND MINI-SYMPOSIA

**Monday 10.45-12.50 Parallel Sessions**

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<td>The impact of the spot price modelling on the electricity portfolio optimization problem</td>
<td>Simone Sbrilli (with Gianluca Murgia)</td>
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<td>Manuel Cepeda (with Jose Aguero)</td>
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<td>Francesca Maggioni (with Elisabetta Allevi, Marida Bertocchi)</td>
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<td>Subgradient Bounds for Convex Dynamic Programs</td>
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<td>Suvrajeet Sen (with Yunwei Qi)</td>
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<td>Fenchel Disjunctive Decomposition for Mean-Risk Stochastic Integer Programs</td>
<td>Lewis Ntaimo (with Michelle M. Alvarado, Guglielmo Lulli)</td>
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<td>Total variation error bounds for convex approximations of two-stage mixed-integer recourse models</td>
<td>Ward Romeijnders (with Maarten H. van der Vlerk, Willem K. Klein Haneveld)</td>
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<td>Two-Stage Stochastic Mixed Integer Linear Programming</td>
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<td>A Risk Averse Multi-stage Stochastic Optimization Model for Power Generation Expansion Planning: Analysis of Multi-stage Consistency</td>
<td>Paolo Pisciella (with Maria Teresa Vespucci, Marida Bertocchi, Stefano Zigrino)</td>
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<td></td>
<td>Price dynamics in electricity spot markets</td>
<td>Michael Schürle (with Florentina Paraschiv)</td>
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Price setting for energy swing options via stochastic bilevel problems
Peter Gross (with Raimund Kovacevic, Georg Ch. Pflug)

Pricing of Energy Contracts - From Replication Pricing to Swing Option Pricing
Raimund Kovacevic (with Georg Ch. Pflug)

Finance

[Room 4] Finance Optimization [page 57]
Chair(s): William T. Ziemba

A stochastic programming perspective on contingent claims
Alan King

Optimal Capital Growth With Shortfall Penalties
Leonard MacLean (with Yonggan Zhao, William T. Ziemba)

Asset-Liability Management via Risk-Sensitive Control
Sebastien Lleo (with Mark Davis)

Understanding and controlling high factor exposures of robust portfolios
Min Jeong Kim (with Woo Chang Kim, Jang Ho Kim, Frank J. Fabozzi)

Applications in Finance - When to sell Apple and the NASDAQ100, the Nikkei and other bubble markets with a stochastic disorder model
William T. Ziemba (with A. N. Shiryaev, M. V. Zhitlukhin)

Operations Management and Software

[Room 10] Production and capacity planning for stochastic systems [page 58]
Chair(s): Paolo Brandimarte

Multi-period Supplier Selection under Price Uncertainty
Hande Yaman (with Alper Sen, Kemal Guler, Evren Korpeoglu)

Scenario-Based Stochastic Programming Approach to Capacity Planning Problem under Demand Uncertainty
Serkan Kalay (with Ali Tamer Ünal)

Flow Balancing with Uncertain Demand for Package Sorting Facilities
Luis Novoa (with Ahmad Jarrah, David Morton)

Image modeling using energy optimization by stochastic programming
Ben-Shung Chow

Dealing with end-of-horizon effects in stochastic lot sizing
Paolo Brandimarte
Monday 14.00-16.25 Minisymposia

**New Concepts for Stochastic Systems**

*Room 5* Approximation and stability for complex structural models [page 61]

*Chair(s): Petr Lachout*

- Rapidly Detecting an Anomaly Spreading Stochastically on a Network
  David Morton (with John Hasenbein, Jinho Lee)

- Stability of stochastic programming problems and mathematical statistics
  Silvia Vogel

- Structure of Risk-Averse Multistage Stochastic Programs
  Jitka Dupačová (with Vaclav Kozmik)

- Stability and Approximation in Stochastic Optimization via L1 Norm
  Vlasta Kaňková (with Michal Houda)

- Statistic features in stochastic optimization programs
  Petr Lachout

**New Approaches to Classical Problems**

*Room 4* Data mining methods for stochastic programming [page 62]

*Chair(s): Miguel A. Lejeune*

- Boolean Data Mining Method for Probabilistically Constrained Stochastic Programming Problems
  Miguel A. Lejeune

- Automatic inference of decision rules for multistage stochastic programs
  Boris Defourny (with Damien Ernst, Warren B. Powell, Louis Wehenkel)

- Clustering-Based Interior-Point Strategies for Stochastic Programs
  Victor M. Zavala

- Combinatorial Data Mining Method for Multi-Portfolio Stochastic Asset Allocation
  Ran Ji (with Miguel A. Lejeune)

- Learning policies from solutions of multi-stage programs, illustration on power system applications
  Bertrand Cornélusse (with Arnaud-Aymeric Gibault-Nowak, Damien Ernst, Louis Wehenkel)

**Computation and Applications**

*Room 3* Applications and solutions for non-convex SPs [page 63]

*Chair(s): Asgeir Tomasgard*

- MPECs with Energy Applications
  Steven A. Gabriel (with Sauleh Siddiqui, Chalida U-Tapao)

- A branch-and-bound method for discretely-constrained mathematical programs with equilibrium constraints
  Marte Fodstad (with Yohan Shim, Steven A. Gabriel, Asgeir Tomasgard)

- Emergency Shelter Design for Geographic and Building Environments using Stochastic and Robust Optimization
  Elise Miller-Hooks (with Reza Faturechi, Lei Feng, Shabtai Isaac)
Nonconvex Generalized Benders Decomposition
Paul I. Barton (with Xiang Li, Asgeir Tomasgard)

Enhancing Nonconvex Generalized Benders Decomposition With Piecewise Relaxation and Adaptive Parallelization
Xiang Li (with Yang Chen, Paul I. Barton)

Finance and Applications
[Room Galeotti] Dynamic stochastic optimization and Finance [page 64]
Chair(s): Elena Medova

The Values of Information and Solution in Stochastic Programming
John Birge

Estimating Animal Spirits
Mark Davis (with Grzegorz Andruszkiewicz, Sebastien Lleo)

Optimal capital allocation and strategic portfolio selection for a large property/casualty insurer
Giorgio Consigli (with Vittorio Moriggia, Massimo di Tria, Lorenzo Mercuri)

Risk management and contingent claim valuation in illiquid markets
Teemu Pennanen

ALM Analysis for Pensionskasse: Asset Liability Management Study
Francesco Sandrini (with Matteo Germano)
Monday 16.55-19.00 Parallel Sessions

**Advances in stochastic programming and contiguous fields**
[Room Galeotti] Risk aversion and stochastic dominance [page 66]

*Chair(s): Darinka Dentcheva*

Decomposition Methods for Two-stage Stochastic Linear Semidefinite Programs with Risk Aversion
Tobias Wollenberg (with Rüdiger Schultz)

Optimization with multivariate stochastic dominance constraints
Eli Wolfhagen (with Darinka Dentcheva)

Optimization with Multivariate Conditional Value-at-Risk Constraints
Nilay Noyan (with Gabor Rudolf)

Regularization Methods for Stochastic Order Constrained Problems
Gabriela Martinez (with Darinka Dentcheva)

Robustness and bootstrap techniques in portfolio efficiency tests
Milos Kopa

**Problem formulation and solution algorithms**

[Room 5] Multistage mixed-integer stochastic programming [page 67]

*Chair(s): Suvrajeet Sen*

BFC Parallel Implementation
Gerardo A. Pérez-Valdés (with Adela Pagès-Bernaus, Asgeir Tomasgard)

Parallelized Branch-and-Fix Coordination (P-BFC) for solving large-scale multistage mixed 0-1 problems
Gloria Pérez (with Unai Aldasoro, Laureano F. Escudero, María Merino)

The integer L-shaped method for multiple objective stochastic integer linear programs.
Salima Amrouche (with Mustapha Moulaï)

Decomposition method for linear stochastic bilevel problems
Charlotte Henkel

A matheuristic for a class of multi-stage mixed-integer stochastic programs: application to the maritime fleet renewal problem
Giovanni Pantuso (with Kjetil Fagerholt, Stein W. Wallace)

**Energy**

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*Chair(s): Bita Analui*

The value of local electricity storage in a smart grid: How important is intermittency?
Pedro Crespo Del Granado (with Stein W. Wallace, Zhan Pang)

Hydrothermal Unit Commitment Subject to Uncertain Demand and Water Inflows
Murilo Reolon Scuzziato (with Erlon Cristian Finardi)

Determining the variable cost of pumped-storage stations for use in the real-time market
Goran Vojvodic
Combining Sampling-based and Scenario-based Nested Benders’ Decomposition Methods: Application to Stochastic Dual Dynamic Programming
Steffen Rebennack

An Efficient Parallel Decomposition Approach for Stochastic Dual Dynamic Programming
Andre Luiz Diniz (with Tiago Norbiato dos Santos)

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Optimization and performance evaluation in the portfolio selection problem
Cristinca Fulga

Comparison of back-testing results for various VaR estimation methods
Ales Kresta

Portfolio selection with European call and put options
Marco Cassader (with Sergio Ortobelli Lozza, Valeria Caviezel)

International portfolio selection with Markov processes and liquidity constrains
Sergio Ortobelli Lozza (with Daniele Toninelli, Enrico Angelelli, Tomas Tichy)

Risk profile versus portfolio selection
Valeria Caviezel (with Sergio Ortobelli Lozza, Lucio Bertoli Barsotti)

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Design of Resilient Supply Chains using Sample Average Approximation (SSA)
Pablo Garcia-Herreros (with John Wassick, Ignacio E. Grossmann)

The Design of Robust Value-Creating Supply Chain Networks
Walid Klibi (with Alain Martel)

A multistage stochastic program for production planning in the pig supply chain industry
Victor M. Albornoz (with Esteve Nadal, Lluis M. Plà)

Scenario Bundling for a Pre-Disaster Planning Problem
Steven Prestwich (with Marco Laumanns, Ban Kawas)

Supply Planning for the Material Use of Renewable Resources
Susanne Wiedenmann (with Jutta Geldermann)
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*Chair(s): Tito Homem-de-Mello*  
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Vincent Leclere (with Michel De Lara)  
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**Dynamic Time-Consistent Approximations of Risk Measures**  
Tsvetan Asamov (with Andrzej Ruszczynski)  
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Consistency and risk averse dynamic decision models: Definition, interpretation and practical consequences.  
*Alexandre Street (with Davi Michel Valladão, Birgit Rudloff)*  
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Risk aversion in multi-stage stochastic programming: a modeling and algorithmic perspective  
*Tito Homem-de-Mello (with Bernardo K. Pagnoncelli)*  
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**Nested Preprocessing for Multi-stage Stochastic Programming**  
Lijian Chen  

| **Problem formulation and solution algorithms** | [Room 5] Non-Linear and Monte Carlo algorithms [page 74]  
*Chair(s): Anton J. Kleywegt*  
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**Estimation of Pure Characteristics Demand Models with Pricing**  
Jong-Shi Pang (with Che-Lin Su, Yu-Ching Lee)  
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**Worst-case-expectation approach to optimization under uncertainty**  
Wajdi Tekaya (with Alexander Shapiro, Murilo Pereira Soares, Joari Paulo da Costa)  
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**Distributed Algorithms for Nonlinear Multistage Stochastic Programs**  
Marc C. Steinbach (with Jens Hübner)  
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**Hierarchical Bayesian Learning in Neural Networks using Genetic Algorithms**  
Ozan Kocadağlı  
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**A Stochastic Trust Region Algorithm for Mixed Logit Type Problems**  
Anton J. Kleywegt (with Xinchang Wang)  

| **Energy** | [Room 3] Stochastic models in energy planning [page 75]  
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Heejung Park (with Ross Baldick)  
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**A L-shaped method for mid-term hydro scheduling under uncertainty**  
Fabian Bastin (with Pierre-Luc Carpentier, Michel Gendreau)  
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**Benders Decomposition for solving multi-stage stochastic mixed complementarity problems.**  
Ruud Egging  

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Risk Averse Computational Stochastic Programming  
Somayeh Moazeni (with Warren B. Powell)

**Finance**

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*Chair(s): Diana Barro*

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Agnieszka K. Konicz (with John M. Mulvey)

Accounting for Risk Measure Ambiguity when Optimizing Financial Positions  
Erick Delage (with Jonathan Y. Li)

Time Consistent Recursive Risk Measures Under Regime Switching and Factor Models and Their Application in Dynamic Portfolio Selection  
Jia Liu (with Zhiping Chen)

Optimal Liquidation Strategies for Portfolios under Stress Conditions  
Jorge P. Zubelli (with Felipe Macias, Claudia Sagastizábal)

Controlling risk in dynamic asset allocation through stochastic optimization  
Diana Barro (with Elio Canestrelli, Fabio Lanza)

**Operations Management and Software**

[Room 10] Transportation and Logistic [page 77]  
*Chair(s): Guido Perboli, Francesca Maggioni*

A diversified tabu search approach for the open-pit mine production scheduling problem with metal uncertainty  
Amina Lamghari (with Roussos Dimitrakopoulos)

Integrated planning of operations and spare parts logistics under uncertainty in the supply chain of maintenance service providers  
Masoumeh Kazemi Zanjani (with Mustapha Nourelfath)

The Stochastic Generalized Bin Packing Problem  
Mauro M. Baldi (with Guido Perboli, Roberto Tadei, L. Gobbato)

The Stochastic Mixed Capacitated General Routing Problem: formulation and solution approaches  
Maria Elena Bruni (with Patrizia Beraldi, Demetrio Laganà)

The multi-path Traveling Salesman Problem with stochastic travel costs: a City Logistics computational study  
Guido Perboli (with Francesca Maggioni, Roberto Tadei)
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**New Concepts for Stochastic Systems**  
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*Chair(s): Laureano F. Escudero*

Multistage Stochastic Programming for Planning under Endogenous Uncertainty: Models and Algorithms  
Ignacio E. Grossmann (with Vijay Gupta)

Decision dependent distributions and the response surface methodMS: Exogenous and Endogenous Uncertainty in Stochastic Programming  
Georg Ch. Pflug

Capacity expansion using stochastic programming with decision dependent probabilities  
Asgeir Tomasgard (with L. Hellemo, Paul I. Barton)

On multistage mixed 0-1 optimization under a mixture of Exogenous and Endogenous Uncertainty in a risk averse environment  
Laureano F. Escudero (with M. Araceli Garin, María Merino, Gloria Pérez)

Stochastic Programming Models and Algorithms for Pharmaceutical R&D Planning  
Christos Maravelias (with Matthew Colvin)

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**New Approaches to Classical Problems**  
[Room 4] The Scenario approach to stochastic optimization [page 81]  
*Chair(s): Marco C. Campi*

The scenario approach to decision-making processes  
Marco C. Campi

The fundamental theorems of the scenario approach  
Simone Garatti

Constraint removal in practice: a case study in portfolio selection theory  
Bernardo K. Pagnoncelli (with Marco C. Campi, Daniel Reich)

Reconstructing the distribution of costs from observations  
Algo Carè

A Scenario Based Approach to Robust Experiment Design  
Cristian R. Rojas

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**Computation and Applications**  
[Room 3] Stochastic dominance in stochastic programming [page 82]  
*Chair(s): Rüdiger Schultz*

Stochastic Dominance Almost Everywhere in SP  
Rüdiger Schultz (with Laureano F. Escudero)

Time-consistent stochastic orders  
Darinika Detcheva (with Andrzej Ruszczynski)

On relations between stochastic dominance efficiency tests and DEA-risk models  
Martin Branda (with Milos Kopa)
On Stochastic Dominance Constraints measures in multistage mixed 0-1 optimization problems
Maria Araceli Garin (with Laureano F. Escudero, María Merino, Gloria Pérez)

Equivalents and Algorithms for Programs with Stochastic Order Constraints Induced by Linear Recourse
Dimitri Drapkin (with Rüdiger Schultz)

Finance and Applications
[Room 5] Stochastic models in natural resources [page 83]
Chair(s): Andrés Weintraub

Stochastic Models in Natural Resources
Andrés Weintraub

Open-Pit Mine Production Scheduling with Stochastic Programming for Handling Uncertainty in the Mineral Body
Natashia Boland (with Irina Dumitrescu, Gary Froyland)

Medium range optimization of copper extraction planning under uncertainty in future copper prices
Antonio Alonso-Ayuso (with Felipe Carvallo, Laureano F. Escudero, Monique Guignard, Jiaxing Pi, Raghav Puranmalka, Andrés Weintraub)

Use of Stochastic Models in Mining with Progressive Hedging
Rafael Epstein (with Andrés Weintraub, Carlos Villa, Jaime Gacitua, Rodolfo Urrutia, Roger Wets, David L. Woodruff, Jean-Paul Watson)

Modeling and estimating copper prices
Ignacio Rios (with Roger Wets)
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**Advances in stochastic programming and contiguous fields - 1**  
[Room Galeotti] Optimization under incomplete information [page 85]  
*Chair(s): Guzin Bayraksan*

- **On Robust Multistage Stochastic Optimization with application in Energy**  
  Bita Analui

- **Two-stage Stochastic Linear Programs with Incomplete Information on Uncertainty**  
  Jie Sun (with J. Ang, F. Meng)

- **Risk-Averse Stochastic Optimization with Incomplete Information**  
  Chaoyue Zhao (with Yongpei Guan)

- **Stochastic security constrained unit commitment with incomplete information**  
  Ruiwei Jiang (with Yongpei Guan)

- **On the Use of Phi-Divergences for a Class of Two-Stage Ambiguous Stochastic Programs**  
  Guzin Bayraksan (with David Love)

**Problem formulation and solution algorithms**  
[Room 5] L-shaped and Benders’ decomposition [page 86]  
*Chair(s): Laureano F. Escudero*

- **A Generalized Benders’ Algorithm for the Two-Stage Stochastic Optimization Problem with Mixed Integer Recourse**  
  Anahita Hassanzadeh (with Theodore K. Ralphs, Menal Guzelsoy)

- **Improved optimality cuts for the integer L-shaped method**  
  Gustavo Angulo (with Shabbir Ahmed, Santanu S. Dey)

- **Improvements to Benders' decomposition: systematic classification and performance comparison in a Transmission Expansion Planning problem**  
  Sara Lumbreras (with Andres Ramos)

- **A Benders Decomposition Approach to find the Nucleolus Share of a Renewable Hedge Pool**  
  Joaquim Garcia (with Alexandre Moreira, Alexandre Street, Álvaro Veiga, Bruno Fanzeres, Delberis Lima, Lucas Freire)

**Finance**  
[Room 4] Real and financial derivatives [page 87]  
*Chair(s): Alan King*

- **A stochastic programming model for hedging options in a market with transaction costs**  
  Mathias Barkhagen (with Jörgen Blomvall)

- **Management of Portfolio of Options With Two Expiration Dates**  
  Dmitry Golembiovsky (with Anatoly Abramov)

- **Using Malliavin derivative to price an American option under stochastic volatility**  
  Mohamed Kharrat (with Yacin Jerbi)
Investing in complementary renewable sources using stochastic-robust optimization and real options
Bruno Fanzeres (with Aderson Passos, Alexandre Street, Alexandre Moreira, Álvaro Veiga)

Analysis and Enhancement of Practice-based Methods for the Real Option Management of Commodity Storage Assets
Nicola Secomandi

**Advances in stochastic programming and contiguous fields - 2**
[Room 3] Endogenous uncertainty [page 88]
*Chair(s): Ignacio E. Grossmann*

A trust-region approach for optimization under decision-dependent uncertainty
Eric Laas-Nesbitt

Multi-agent multi-stage stochastic programming with endogenous uncertainty
Dimitrios Papadimitriou (with Piet Demeester)

Simulation-based SP under Endogenous Uncertainty with Applications in Operations Management
Tahir Ekin (with Nicholas Polson, Refik Soyer)

A Stochastic Programming Approach to Risk Mitigation Strategies in Project Management
Bruno Flach (with Carlos Raoni Mendes, Marcus Poggi de Aragao)

Importance Sampling in Stochastic Programming: A Markov Chain Monte Carlo approach
Quang Kha Tran (with Panos Parpas, Berk Unstun, Mort Webster)
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| Advances in stochastic programming and contiguous fields  |
| [Room Galeotti] Robust Optimization [page 90]  |
| *Chair(s): Daniel Kuhn*  |
| Minimax stochastic program with overlapping marginals  |
| Xuan Vinh Doan (with Xiaobo Li, Karthik Natarajan)  |
| Robust combinatorial optimization with cost uncertainty  |
| Michael Poss  |
| Pricing of Multi-Product Monopolistic Cloud Computing Services with Service Level Agreements  |
| Vladimir Roitch (with Daniel Kuhn, Yike Guo)  |
| Interdiction Games on Markovian PERT Networks  |
| Eli Gutin (with Daniel Kuhn, Wolfram Wiesemann)  |
| Solution of Probabilistic Constrained Problems with Compound Poisson Distributions  |
| Anh Ninh (with Andras Prekopa)  |

| Problem formulation and solution algorithms  |
| [Room 5] Stochastic Dual Dynamic Programming [page 91]  |
| *Chair(s): Jitka Dupačová*  |
| Conditional Value-at-risk Versus Multidimensional Rule Curves Within the Risk-averse Sddp Approach  |
| Débora Dias Jardim Penna (with André Luiz Diniz, Maria Elvira Piñeiro Maceira)  |
| On the solution variability reduction of stochastic dual dynamic programming applied to energy planning  |
| Murilo Pereira Soares (with Alexandre Street, Davi Michel Valladão)  |
| Representation of non-convexities in stochastic dual dynamic programming applied to hydrothermal operation problems  |
| Fernanda S. Thome (with Mario V. Pereira, Sérgio Granville, Marcia H. C. Fampa)  |
| Stochastic Dual Dynamic Programming with CVaR Risk Constraints Applied to Hydrothermal Scheduling  |
| Luiz Carlos Da Costa Jr. (with Mario V. Pereira, Sérgio Granville, Nora Campodonico, Marcia H. C. Fampa)  |
| Risk-averse multistage stochastic programming  |
| Vaclav Kozmik  |

| Energy  |
| [Room 3] Bidding in electricity market [page 92]  |
| *Chair(s): Stein-Erik Fleten, Trine Krogh Boomsma*  |
| Bidding in sequential electricity markets: The Nordic case  |
| Trine Krogh Boomsma (with Nina Juul, Stein-Erik Fleten)  |
| Electricity Market Clearing With Improved Scheduling of Stochastic Production  |
| Salvador Pineda Morente (with Juan M. Morales, Marco Zugno, Pierre Pinson)  |
| Decomposition for day-ahead bidding of hydro power portfolios - experiences and challenges  |
| Gro Klæboe  |
Model of Approximate Dynamic Programming Applied on Day-Ahead Trading of a Renewable Producer of Energy
Vadym Omelchenko

Bidding hydroelectric power via decision rules
Stein-Erik Fleten (with Jørgen Braathen, Anders Eriksrud, Gro Klæboe, Daniel Kuhn)

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[Room 4] Financial decision making [page 94]
Chair(s): Janos Mayer

Generalized quantiles as risk measures
Fabio Bellini (with B. Klar, A. Müller, E. Rosazza Gianin)

Fixed income management using Stochastic Programming
Jonas Ekblom (with Jörgen Blomvall)

A Multistage Linear Stochastic Programming Model for Optimal Corporate Debt Management
Álvaro Veiga (with Davi Michel Valladão, Geraldo Veiga)

Long-Term Bank Balance Sheet Management: Estimation and Simulation of Risk-Factors
Pedro Júdice (with John Birge)

Portfolio Selection with Objective Functions from Cumulative Prospect Theory
Janos Mayer (with Thorsten Hens)

Operations Management and Software
[Room 10] Solvers for Stochastic Optimization [page 95]
Chair(s): Vittorio Moriggia

Stochastic Decomposition: Motivation, technology and the challenges that it presents.
Francis Ellison (with Suvrajeet Sen, Yifan Liu, Gautam Mitra)

A solver for problems with second-order stochastic dominance constraints
Victor Zverovich (with Gautam Mitra, Csaba I. Fábián)

A Randomized Metaheuristic for Stochastic Integer Programs with Binary First Stage Variables and Continuous Second Stage Variables
Cristiano Arbex Valle (with Gautam Mitra, Victor Zverovich)

A computational study of on-demand accuracy level decomposition for two-stage stochastic programs
Christian Wolf (with Csaba I. Fábián, Achim Koberstein, Leena Suhl)

An open-source solver system for stochastic programming
Horand Gassmann (with Kipp Martin, Jun Ma)
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**Advances in stochastic programming and contiguous fields**  
[Room Galeotti] Stochastic Variational Problems [page 97]  
*Chair(s): Roger Wets*

- Quasi-Monte Carlo sampling for stochastic variational problems  
  Werner Römisch (with Hernan Leovey)

- Quantitative Stability Analysis of Stochastic Generalized Equations  
  Huifu Xu (with Yongchao Liu, Werner Römisch)

- On the use of epi-splines in stochastic optimization  
  Johannes O. Roysel (with Roger Wets)

- On the Strong Graphical Law of Large Numbers for Random Semicontinuous Mappings and its Applications  
  Vladimir Norkin (with Roger Wets)

- On the method of empirical average in some stochastic optimization and estimation problems  
  Pavel S. Knopov (with D.A. Gololobov)

**Problem formulation and solution algorithms**  
[Room 5] Scenario generation and Monte Carlo [page 98]  
*Chair(s): Vittorio Moriggia*

- Multi-stage stochastic optimization: The distance between stochastic scenario processes  
  Anna Timonina

- How to generate multi-stage scenario trees (if you have to)  
  Ronald Hochreiter

- On cherry-tree copula based scenario generation  
  Tamás Szántai (with Edith Kovács)

- An Effective Heuristic for Multistage Stochastic Linear Programming  
  Cesar Beltran-Royo (with Laureano F. Escudero, J. F. Monge, R. E. Rodriguez-Ravines)

- Stochastic programming handling CVaR in objective and constraints  
  Leonidas Sakalauskas

**Energy**  
[Room 3] Energy policy [page 99]  
*Chair(s): Maria Teresa Vespucci*

- Stochastic optimization of a gas plant with storage taking into account take-or-pay restrictions  
  David Wozabal (with Nils Löhndorf)

- Optimal capital planning with renewable-induced uncertainty using Markov decision processes  
  Athena Wu (with Andy Philpott)

- Gas Network Extensions for Multiple Scenarios  
  Jonas Schweiger
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### Thursday 14.00-16.25 Minisymposia

#### New Concepts for Stochastic Systems

[Room Galeotti] Equilibrium in a stochastic environment [page 104]

*Chair(s): Roger Wets*

- General economic equilibrium with incomplete markets
  - Alejandro Jofré (with Terry Rockafellar, Roger Wets)

- Computing equilibrium points in a stochastic two-stages economic model
  - Julio Deride (with Alejandro Jofré, Roger Wets)

- Stochastic Multiple Optimization Problems with Equilibrium Constraints
  - Michael C. Ferris (with Roger Wets)

- Supply function equilibrium models for electricity markets
  - Andy Philpott (with Par Holmberg, Tony Downward)

- Incomplete market in stochastic investment equilibrium models
  - Yves Smeers (with G. de Maere, A. Ehrenmann, D. Ralph)

#### New Approaches to Classical Problems

[Room 4] Time consistency in stochastic programming [page 105]

*Chair(s): Alois Pichler*

- Introduction to Dynamic Risk-Averse Optimization
  - Andrzej Ruszczynski

- Computational Methods for Risk-Averse Undiscounted Transient Markov Models
  - Ozlem Cavus (with Andrzej Ruszczynski)

- Time consistency of risk measures in markets with transaction costs
  - Birgit Rudloff (with Zachary Feinstein)

- Distributionally robust multistage inventory models with moment constraints
  - Linwei Xin (with David A. Goldberg, Alexander Shapiro)

- Time Consistency of Stochastic Programs
  - Alois Pichler

#### Computation and Applications

[Room 3] Computational SP including risk management and energy applications [page 106]

*Chair(s): Csaba I. Fábián*

- How to exploit oracles with on-demand accuracy in energy problems
  - Claudia Sagastizábal

- Bundle Methods for Multistage Stochastic Capacity Planning Problems
  - Welington Oliveira (with Sergio V.B. Bruno)

- Formulation and solver support for optimisation under uncertainty
  - Gautam Mitra (with Victor Zverovich, Christian Valente)
### Finance and Applications

[Room 5] Scenario generation for stochastic programming [page 107]

Chair(s): Alex Weissensteiner

#### Scenario generation: What are the issues?

Stein W. Wallace

**Copula-based heuristic for scenario generation for two-stage stochastic programs**

Michal Kaut

A global optimization approach to generate multi-asset, arbitrage-free, scenario trees

Andrea Consiglio (with Angelo Carollo)

**No-Arbitrage Bounds for Scenarios and Financial Optimization**

Alex Weissensteiner (with Alois Geyer, Michael Hanke)

A Simplex Rotation Algorithm for the Factor Approach to Generate Financial Scenarios

Michael Hanke (with Alois Geyer, Alex Weissensteiner)
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#### Advances in stochastic programming and contiguous fields

[Room Galeotti] Chance constrained stochastic programming [page 109]
Chair(s): René Henrion

- Joint dynamic chance constraints with projected linear decision rules for some multistage stochastic linear programs
  Vincent Guigues (with René Henrion, Andris Möller)

- Derivative Formulæ for Linear Chance Constraints under Gaussian Distribution
  Andris Möller

- Gradient formulæ for nonlinear probabilistic constraints with Gaussian and Gaussian-like distributions
  Wim van Ackooij (with René Henrion)

- Distributionally robust stochastic knapsack problem
  Jianqiang Cheng (with Erick Delage, Abdel Lisser)

- Problems in Chance Constrained Network Interdiction
  Siqian Shen (with David Escott)

#### Problem formulation and solution algorithms

[Room 5] Stochastic integer programming methods and applications [page 110]
Chair(s): Lewis Ntaimo

- Integrated Warehouse-Inventory-Transportation Planning under Uncertainty: A Stochastic Integer Quadratically-Constrained Programming Approach
  Christopher D. Hagmann (with Nan Kong, Pratik J Parikh)

- A Stochastic Integer Programming Extended Attack Response Model for Large-Scale Wildfires
  Michelle M. Alvarado (with Lewis Ntaimo)

- A Stochastic Programming Model for the Stochastic ATFM problem
  Guglielmo Lulli (with Luca Corolli, Saravanan Venkatachalam, Lewis Ntaimo)

- The Time Slot Allocation Problem under Uncertainty
  Luca Corolli (with Guglielmo Lulli, Lewis Ntaimo)

- A distributed scenario decomposition algorithm for stochastic 0-1 optimization
  Shabbir Ahmed

#### Energy

[Room 3] Renewable sources [page 111]
Chair(s): Patrizia Beraldi

- Stochastic programming models for optimal location of renewable energy power plants
  Marius Radulescu (with Constanta Zoie Radulescu)

- Optimal Power Generation Scheduling in Microgrids Using Stochastic Programming
  Abdelsalam Eajal (with Kumaraswamy Ponnambalam)

- A reliable - and flexible power system ensured through demand response
  Michael Pascal Nielsen (with Pierre Pinson, Henrik Madsen)
Integrating wind power into a pure hydro power system via a two-stage stochastic program
Ali Koc (with Jayant Kalagnanam, Innocent Kamwa, Louis Delorme)

A stochastic optimization model for long-term hydropower scheduling
Arild Helseth

Finance
[Room 4] Scenario generation in energy and finance [page 113]
Chair(s): Zhiping Chen

On Solving Dual Level Scenario Tree for the Energy Commercialization Problem in Brazil
Vitor Luiz de Matos (with Brigida Decker, Erlon Cristian Finardi, Andre Milanezi, Eduarda Alfing)

A Markov Chain Method to Bootstrap Multivariate Continuous-Valued Stochastic Processes
Cristian Pelizzari (with Roy Cerqueti, Paolo Falbo, Gianfranco Guastaroba)

Two-Stage Portfolio Optimization with Higher-Order Conditional Measures of Risk
Sitki Gulten (with Andrzej Ruszczynski)

Practical scenario tree reduction methods for dynamic portfolio management problem
Zhiping Chen (with Daobao Xu, Xinkai Zhuang)

 Tradable Permits Schemes and New Technology Adoption
Luca Taschini (with Santiago Moreno-Bromberg)

Operations Management and Software
[Room 10] Networks and transportation [page 114]
Chair(s): Alexei A. Gaivoronski

Bid Generation in Combinatorial Auctions for the Transportation Procurement under Stochastic Winning Prices
Chefi Triki (with Simona Oprea, Patrizia Beraldi, Teodor G. Crainic)

Optimizing RFID tagging in the aviation industry
Shima Shahbazi (with Kasper Klitgard Berthelsen, Esben Høg)

Container transportation problem under uncertain demand and weather conditions
Paola Zuddas (with Massimo Di Francesco, Alexei A. Gaivoronski)

Bilevel stochastic network problem
Alexei A. Gaivoronski (with Abdel Lisser)
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| Information constraints and discretization puzzles in stochastic optimal control  
Michel De Lara (with Pierre Carpentier, Jean-Philippe Chancelier) |
| Variational approaches in stochastic optimal control  
Pierre Carpentier |
| Dynamic Consistency for Stochastic Optimal Control Problems  
Jean-Philippe Chancelier (with Jean-Philippe Chancelier, G. Cohen, Michel De Lara, P. Girardeau, Pierre Carpentier) |
| Decomposition-coordination methods in stochastic optimal control.  
Jean-Christophe Alais (with Pierre Carpentier, Vincent Leclere) |
| European energy equilibrium and decomposition  
Anes Dallagi |
| **New Approaches to Classical Problems** |
| [Room 4] Integer Programming Based Approaches for Chance-Constrained SPs [page 117]  
*Chair(s): Shabbir Ahmed* |
| Recent Advances for the Solution of Sample-Average Approximations of Chance-Constrained Stochastic Programs  
James Luedtke (with Yongjia Song, Simge Kucukyavuz) |
| A Decomposition Algorithm for a Chance-Constrained Program with Recourse  
Simge Kucukyavuz (with Xiao Liu) |
| Data-driven Chance Constrained Stochastic Program  
Yongpei Guan (with Ruiwei Jiang) |
| Mixed-Integer Programming Models for Optimizing Risk Parameter in Chance Constraints  
Siqian Shen (with Miguel A. Lejeune) |
| Improved MIP models for chance-constrained problems with probabilistic right-hand sides  
Ricardo Fukasawa (with Ahmad Abdi) |
| **Computation and Applications** |
| [Room 3] Progressive hedging applied to mixed-integer and nonlinear SPs [page 118]  
*Chair(s): David L. Woodruff* |
| Progressive Hedging Applied to Mixed-Integer and Non-Linear Stochastic Programs  
David L. Woodruff |
| Progressive Hedging for Non-Linear Models that Arise in Parameter Estimation Problems  
Yankai Cao (with Daniel P. Word, Jia Kang, Jean-Paul Watson, David L. Woodruff, Carl D. Laird) |
### Progressive Hedging for Stochastic Unit Commitment
Jean-Paul Watson (with David L. Woodruff, Roger Wets, Cesar Silva Monroy, Sarah M. Ryan, Dinakar Gade)

### Progressive Hedging for Stochastic Economic Dispatch with AC Power Flow
John D. Siirola (with Zev Friedman, Cesar Silva Monroy, Jean-Paul Watson)

### A New Lower Bound from Progressive Hedging
Sarah M. Ryan

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### Finance and Applications

#### [Room 5] Asset allocation and ALM for long term investors [page 119]
*Chair(s): Giorgio Consigli*

**Improving Diversification in an Era of Contagion: Optimizing over a Set of Assets and Special Tactics**
Woo Chang Kim (with John M. Mulvey)

**Factor Models for Scenario Construction in Long Term Asset Allocation.**
Lorenzo Mercuri (with Giorgio Consigli)

**Practical Examples: Optimizing Dynamic Asset Allocation Strategies with Approximate Dynamic Programming**
Thomas Bauerfeind (with John M. Mulvey)

**Relevant short-medium-long term decision criteria for optimal Property & Casualty portfolio selection**
Massimo di Tria (with Giorgio Consigli)

**Longevity Risk Management for Individual Investors using Multi-stage Stochastic Programming**
Koray Deniz Simsek (with Woo Chang Kim, Min Jeong Kim, John M. Mulvey)
Monday 10.45-12.50 Parallel Sessions

Advances in stochastic programming and contiguous fields
[Room Galeotti] Bounds and SAA methods
Chair(s): Francesca Maggioni

Simone Sbrilli (with Gianluca Murgia)

The impact of the spot price modelling on the electricity portfolio optimization problem

Previous studies in the literature have suggested that, in deregulated markets, large consumers may adopt stochastic programming for the optimization of their electricity portfolio. Nevertheless, there may be several modeling approaches, characterized by different assumptions on the stochastic behavior of the spot price. Such different approaches could lead to different solutions of the electricity portfolio optimization problem. Besides, these solutions could vary also because of the impact of the risk aversion of each large consumer. In this paper, we then investigate how different spot prices model can lead to different solutions, generalizing the Value of the Stochastic Solution (VSS). Our aim is to build a decision support system that suggests the optimal procurement policy by using the most suitable spot prices model, based on the risk aversion of the decision maker. We evaluate our technique in a realistic case study in which the portfolio optimization problem is modeled as a two-stage problem solved with the Sample Average Approximation method.

Manuel Cepeda (with Jose Aguero)

VSS capture for the two-stage transportation problem with stochastic demand through scenario clustering

This work addresses a two-stage stochastic linear programming problem, specifically the transportation problem with stochastic discrete demand. This nonlinear problem can be formulated as an equivalent deterministic linear programming problem (EDLP). EDLP problem size is proportional to the number of possible realizations of the random demand vector, also called scenarios. Alternatively, replacing all random variables by their expected values leads to a smaller deterministic problem called the certainty linear programming problem (CLP). Then, the solution to the CLP is fixed into the EDLP to obtain the expected value of the CLP solution in the stochastic model (EV). The gap between this expected value and the EDLP optimal value corresponds to the value of stochastic solution (VSS). This work states that, by grouping scenarios appropriately through clustering techniques, it is possible to obtain solutions with an expected value close to the DLP optimal value, but by solving a considerably smaller problem. Preliminary results show that by using k-means clustering it is possible to capture the VSS by approximately 80 percent using only one percent of all possible scenarios.

Francesca Maggioni (with Elisabetta Allevi, Marida Bertocchi)

Bounds in Multistage Stochastic Programs

Multistage stochastic programs, which involve sequences of decisions over time, are usually hard to solve in realistically sized problems. Providing bounds for their optimal solution, may help in evaluating whether it is worth the additional computations for the stochastic program versus simplified approaches. In this talk we generalize the value of information gained from deterministic, pair solutions and rolling-horizon approximation in the two-stage linear case [1] to the multistage stochastic formulation both in the linear [2] and nonlinear cases [4]. We show that theorems proved for two stage case are valid also in the multi-stage case. New measures of quality of the average solution are of practical relevance [3]. Numerical results on a transportation problem illustrate the relationships.

References
David Brown (with Jim Smith)

**Subgradient Bounds for Convex Dynamic Programs**

We study the use of information relaxations and penalty functions to compute bounds on the performance of an optimal policy for convex stochastic dynamic programs. We develop two types of penalty functions, both formed from subgradients of approximate value functions. We investigate properties of the resulting bounds and show that the approach can, in theory, lead to tight bounds. Finally, we demonstrate these methods on some challenging applications, including inventory control with lost sales and long lead times.

**Problem formulation and solution algorithms**


*Chair(s): Maarten H. van der Vlerk*

Suvrajeet Sen (with Yunwei Qi)

**Multi-term Disjunctive Decomposition for Mixed-Integer Recourse in Stochastic Programming**

This presentation will focus on solving two-stage stochastic mixed integer programs (SMIP) with general mixed-integer variables in both stages. We develop two closely related decomposition algorithms which use multi-term disjunctive cuts to obtain approximations of the second stage mixed-integer programs. Both methods are finitely convergent. Among the main advantages of our decomposition scheme is that the subproblems are approximated by successive linear programming problems, and moreover, these subproblems can be solved in parallel. We will illustrate these algorithms using examples from the literature, and show how these schemes inherit the same kind of scalability as the original disjunctive decomposition scheme which was originally designed for binary decisions.

Lewis Ntaimo (with Michelle M. Alvarado, Guglielmo Lulli)

**Fenchel Disjunctive Decomposition for Mean-Risk Stochastic Integer Programs**

Mean-risk stochastic integer programs (SIPs) include both expectation and a dispersion statistic in the objective function and are difficult to solve. We derive an integrated Fenchel and disjunctive decomposition method for mean-risk SIPs with fixed recourse for the absolute semideviation mean-risk measure. In this methodology, we use subgradient-based optimization to solve the LP-relaxation of the problem. We then generate Fenchel decomposition cuts based on a subset of scenarios and use disjunctive programming to lift and translate the cuts so that they are valid for the rest of the scenarios. Preliminary computational results based on standard instances will be presented.

Nadine Wollenberg (with Rüdiger Schultz)

**Optimization under uncertainty in reverse logistics**

In recent years, the need for efficient recycling and reuse of goods and packages has risen. Taking into account the increasing importance to handle random input data, forwarding agencies are more and more dependent on adequate mathematical and algorithmic methods which consider stochastic parameters. In this talk, stochastic programming is adapted to a special class of vehicle routing problems (VRP). The underlying deterministic basic model is an extension of the VRP involving both delivery and pickup points. For the stochastic model, we assume that the quantities to be delivered are fixed and known in advance, whereas the quantities to be picked up are uncertain. Solution approaches are based on Lagrangian relaxation of nonanticipativity leading to a scenario decomposition. The single scenario subproblems are solved with column generation using a set covering formulation as master problem. To regain the nonanticipativity several heuristics for finding "promising" feasible points are employed.

Ward Romeijnders (with Maarten H. van der Vlerk, Willem K. Klein Haneveld)

**Total variation error bounds for convex approximations of two-stage mixed-integer recourse models**

We consider convex approximations of two-stage mixed-integer recourse models. For pure integer models with a totally unimodular recourse matrix, a uniform error bound for such approximations can be obtained by bounding the expectation of a class of piecewise constant periodic functions. We generalize these results, deriving bounds on the expectation of any periodic function in terms of the total variation of the probability density function.
function of the underlying random variable, and we discuss how these bounds can be used to evaluate the performance of certain convex approximations of mixed-integer recourse models.

Jian Cui

**Two-Stage Stochastic Mixed Integer Linear Programming**

Two-stage stochastic mixed integer linear programming with recourse (2SMIP) is one of the most promising methods to model the dynamic stochastic process due to the evolution of the uncertainties and the decision process over time. A novel dynamic 2SMIP formulation for the evolving multi-period multi-uncertainty (MPMU) is developed and a corresponding solution strategy, an innovative 2SMIP framework is proposed. In order to reduce the computation effort, the immediate future with the known probability distributions is modeled by a tree of scenarios of various uncertainties within a time horizon I1 whereas the distant future is represented by the expected values within a time horizon I2. Both I1 and I2 are rolling along the unlimited time axis based on MPMU, this is called rolling horizon strategy (RHS), it has two degraded forms, moving horizon strategy (MHS) and scenario group based approach (SGA), according to different parameter settings on time. Numerical simulations on two case studies, a medium-term production planning problem - The EPS Logistics, and a Make-and-Ship-to-Stock (MSTS) process considering networks with transportation and customer heterogeneity, are reported.

**Energy**

[Room 3] Market evolution and pricing

*Chair(s): Raimund Kovacevic*

*Florentina Paraschiv (with Raimund Kovacevic)*

**Medium-term planning for thermal electricity production**

In the present paper we present a mid-term planning model for thermal power generation which is based on multistage stochastic optimization and involves stochastic electricity spot prices, a mixture of fuels with stochastic prices, the effect of CO2 emission prices and various types of further operating costs. Going from data to decisions, the first goal is to estimate simulation models for various commodity prices. We apply Geometric Brownian motions with jumps to model gas, coal, oil and emission allowance (EUA) spot prices. Electricity spot prices are modeled by a regime switching approach which takes into account seasonal effects and spikes. Given the estimated models we simulate scenario paths and then use a multiperiod generalization of the Wasserstein distance for constructing the stochastic trees used in the optimization model. Finally, we solve a one year planning problem for a fictitious configuration of thermal units, producing against the markets. We use the implemented model to demonstrate the effect of CO2 prices on cumulated emissions and to apply the indifference pricing principle to simple electricity delivery contracts.

*Paolo Pisciella (with Maria Teresa Vespucci, Marida Bertocchi, Stefano Zigrino)*

**A Risk Averse Multi-stage Stochastic Optimization Model for Power Generation Expansion Planning: Analysis of Multi-stage Consistency**

We propose a multi-stage stochastic model for long term planning of capacity expansion for a single power producer. The aim of the article is twofold: first we show how different levels of risk aversion influence the mix of production technologies that the producer decides to develop, second we test the model for multi-stage consistency. Uncertainty plays a major role when considering fluctuations of fuel and electricity prices over a relatively long timespan. Therefore a mid-term reviewing of the capacity investment program could potentially lead to an improvement of the profitability via a better handling of uncertainty. When dealing with risk aversion in multistage stochastic problems, one can encounter possible distortions between decisions and actual implementation. This is due to a rigidity in risk control as new information unfolds along different stages. Consequently, different definitions of CVaR in the multi-stage framework could lead to biases in the choice of optimal decision variables. Therefore one should account for a stage-consistent modeling approach via a suitable modification of the CVaR formulation. Numerical results are shown for the generation-expansion planning model in a long time horizon for a single power producer.
Michael Schürle (with Florentina Paraschiv)

Price dynamics in electricity spot markets

The price dynamics in energy markets can differ significantly from those in financial markets due to interdependencies between fuel prices, physical trading and storage constraints and underlying cost structures. In particular, prices in electricity spot markets can also become negative. Classical models for modeling price dynamics that are adapted from financial assets do not take these peculiarities sufficiently into account. We discuss different time-series approaches and propose a new model for the simulation of electricity spot prices that is able to reflect the characteristic spike behavior. Price scenarios are generated around a price-forward curve on an hourly basis, special emphasis is placed on the derivation of the latter. The model provides realistic scenarios for various applications like power generation planning or hedging of energy commodities

Peter Gross (with Raimund Kovacevic, Georg Ch. Pflug)

Price setting for energy swing options via stochastic bilevel problems

Energy swing options are supply contracts, where the holder is free to specify the amounts to be delivered on short notice, paying a fixed price per unit delivered. Since in energy markets risk elimination by replication is not possible, an electricity producer has to explicitly consider the risk emanating from fluctuations in supply cost and demand when selling swing options. The impact of these risk factors can be influenced by the contract seller: Supply cost and fluctuations can be absorbed by the own generation portfolio whereas demand fluctuations can be influenced by the choice of the strike price, implicitly changing the contract holder’s behavior. To incorporate this effect, the determination of the optimal strike price is formulated as a multistage stochastic program, where one constraint consists of the solution of another multistage stochastic program (stochastic bilevel problem): the optimal decisions of the seller (price setting and production) have to anticipate the optimal decision of the buyer (consumption depending on the price). We illustrate the problem and its specific difficulties, present a tailored solution algorithm and provide computational results

Raimund Kovacevic (with Georg Ch. Pflug)

Pricing of Energy Contracts - From Replication Pricing to Swing Option Pricing

Energy related delivery contracts, swap contracts and swing options play an important role in energy risk management. Starting with superreplication (or hedging), we analyze valuation and pricing of such contracts in the framework of stochastic optimization. We are especially interested in the viewpoint of electricity producers, because e.g. due to the nonstorability of electricity, the usual hedging approaches break down -- at least partially. For typical delivery contracts we consider two alternatives: acceptability pricing and indifference pricing. In addition we analyze a bilevel optimization framework for electricity swing option pricing.

Leonard MacLean (with Yonggan Zhao, William T. Ziemba)

Optimal Capital Growth With Shortfall Penalties

In capital growth under uncertainty, an investor must determine how much capital to invest in riskless and risky instruments at each point in time, with a focus on the trajectory of accumulated capital to a planning horizon. Assuming that prices are not affected by individual investments but rather aggregate investments, individual decisions are made based on the projected price process given the history of prices to date. An investment strategy which has generated considerable interest is the growth optimal or Kelly strategy, where the expected logarithm of wealth is maximized period by period. In this paper the traditional capital growth model and modifications to control risk are developed. A mixture model based on Markov transitions between normally distributed market regimes is used for the dynamics of asset prices. Decisions on investment in assets are based
on a constrained growth model, where the trajectory of wealth is required to exceed a specified path over time with high probability, and the path violations are penalized using a convex loss function. This allows the determination of the optimal constrained growth wagers at discrete points in time.

Sebastien Lleo (with Mark Davis)

**Asset-Liability Management via Risk-Sensitive Control**

We solve a series of Asset-Liability Management (ALM) problems using Risk-Sensitive Control methods. The investors’ objective is to jointly select an optimal amount of leverage and an optimal asset allocation to maximise the expected utility of their portfolio's surplus or equity. Asset prices and the liability are modelled stochastically and depend on an arbitrary number of underlying factors. In our simplest setting, securities, liabilities and factors are modelled using affine diffusion processes. In this case we can find an analytical solution for both the finite time and the infinite time horizon. We also derive a mutual fund theorem. Next, we consider the impact of constraints on asset allocation and leverage in the finite time horizon case. We show that a quasi analytical solution exists and identify a second mutual fund theorem. Finally, we introduce jumps in asset prices, liabilities and factors. We show that the ALM problem admits a unique classical (C1,2) solution and that the optimal investment strategy exists and is unique. We also analyse the optimal strategy and derive a mutual fund theorem.

Min Jeong Kim (with Woo Chang Kim, Jang Ho Kim, Frank J. Fabozzi)

**Understanding and controlling high factor exposures of robust portfolios**

In this paper, we analyze the behavior of robust equity portfolios to determine whether reducing the sensitivity to input estimation errors is all robust models do and investigate any side-effects of robust formulations. We find that robust equity portfolios consistently show higher correlation with the three fundamental factors used in the Fama-French factor model. Furthermore, more robustness among robust portfolios results in a higher correlation with the Fama-French three factors. As investors need a portfolio that is not only robust but also has a desired level of dependency on factor movement, we introduce new robust formulations that allow investors to control the factor exposure of portfolios. Empirical analysis shows that the robust portfolios from the proposed formulations are more robust than the classical mean-variance approach with comparable levels of exposure on fundamental factors.

William T. Ziemba (with A. N. Shiryaev, M. V. Zhitlukhin)

**Applications in Finance - When to sell Apple and the NASDAQ100, the Nikkei and other bubble markets with a stochastic disorder model**

In this research we apply a continuous time stochastic process model developed by Shiryaev and Zhutlukhin for optimal stopping of random price processes that appear to be bubbles. By a bubble we mean the rising price is largely based on the expectation of higher and higher future prices. Futures traders such as George Soros attempt to trade such markets. The idea is to exit near the peak from a starting long position. The model applies equally well on the short side, that is, when to enter and exit a short position. We test the model in various markets including the price of Apple computer stock {AAPL} from various times in 2009-2012; plus two markets where it is known that the generally very successful bubble trader George Soros lost money by shorting the NASDAQ-100 stock index too soon in 2000 and the Nikkei225 too soon in 1988. We also study Japanese land and Japanese golf course memberships as even bigger bubbles than the Nikkei, and various US stock market crashes. The model provides good exit and entry points in all these situations that would have been profitable to speculators using the model.

Operations Management and Software

[Room 10] Production and capacity planning for stochastic systems

*Chair(s): Paolo Brandimarte*

Hande Yaman (with Alper Sen, Kemal Guler, Evren Korpeoglu)

**Multi-period Supplier Selection under Price Uncertainty**

We consider a problem faced by a procurement manager who needs to purchase a large volume of multiple items over multiple periods from multiple suppliers that provide base prices and discounts. Discounts are contingent on meeting various conditions on total volume or spend and some are tied to future realizations of random events that can be mutually verified. We formulate a scenario based multi-stage stochastic optimization
model that allows us to consider random events such as a drop in price due to most favored customer clauses, a price change in the spot market or a new discount offer. We propose certainty-equivalent heuristics and evaluate the regret of using them. We use our model for three bidding events of a large manufacturing company. The results show that considering most favored customer terms in supplier offers may create substantial savings that may surpass the savings from regular discount offers.

Serkan Kalay (with Ali Tamer Ünal)

Scenario-Based Stochastic Programming Approach to Capacity Planning Problem under Demand Uncertainty

In this study, we tackle the capacity planning problem in a manufacturing plant under demand uncertainty by developing a scenario-based stochastic programming model. The uncertainty stems from the imperfect information on demand, which as a result requires a manufacturing plan flexible enough to compensate fluctuations. Due to unique technological constraints and strict lot sizing requirements in the production of items, responding uncertainty by frequent capacity re-planning and re-allocations is very costly. We report the results regarding the robustness of the stochastic programming model compared to the traditional expected value model and effects of different scenario generation methods over model outcomes.

Luis Novoa (with Ahmad Jarrah, David Morton)

Flow Balancing with Uncertain Demand for Package Sorting Facilities

Packages arriving at a sorting facility are routed by primary sorters to secondary sorters based on the freight's final destination. We look at the problem of assigning package destinations to the secondary sorters in a fashion that balances the workload within the facility while incorporating the day-to-day fluctuation in volume. We present two general stochastic modeling approaches and propose and evaluate the performance of four alternative formulations for them. Robustness of the operation is assessed based on solutions from the two stochastic optimization modeling approaches and a deterministic one that assumes average package volumes.

Ben-Shung Chow

Image modeling using energy optimization by stochastic programming

Markov random field (MRF) is a successful image model and has been well applied to pattern recognition and image analysis. Energy is a major concept in MRF to model the generation of an image. In contrast to the conventional methods of parametric optimization that find a fixed neighborhood relation for the whole picture, the parametric optimization in this paper is to find variable neighborhood relations for different pixels. This is worked out by searching the optimal hidden line field, which will determine the corresponding neighborhood relation for every pixel. The optimal line field is achieved by minimizing the total energy of the well defined pixel cliques and line cliques. The three difficulties listed in a related literature for image modeling by MRF are solved by the mathematical model proposed in this paper. The first problem (the involved mathematical equations are not clearly defined) is solved by the clearly stated optimization equation. The second problem (The computation algorithm is not clearly described) is solved by the clearly defined optimization procedures listed in this paper. The third problem (the involved parameters in the algorithms are not clearly listed) is solved by the optimized line field found in this paper. To verify our mathematical model, we generate two artificial images according to the dynamic equation, under the optimized horizontal and vertical line fields, by two methods of using generating noise: (1) a random noise and (2) the exact generating noise. The first artificial image is very different from the original image while the second artificial image is almost same to the original image. Therefore, the generating noise is important to determine the detail of the image. In the future research, the generating noise will be coded with information bit to carry information for applications to communications.

Paolo Brandimarte

Dealing with end-of-horizon effects in stochastic lot sizing

As is well-known, in an uncapacitated and deterministic setting, theoretically optimal lot sizes obtained by taking advantage of the Wagner-Whitin property may not be appropriate.

Indeed, this "optimal" approach is outperformed by heuristics when simulated in a realistic rolling horizon setting. This is due to end-of-horizon effects related to the truncation of the planning horizon. In [Fisher et al., 2001] the inclusion of a terminal inventory valuation in the objective function is suggested. This can be interpreted as a salvage value, according to a classification by [Grinold, 1983], where primal and dual equilibrium strategies are also proposed for infinite horizon deterministic problems. The issue is also quite relevant for sto-
chastic programming approaches to lot-sizing. A naive truncation strategy requires a long planning horizon and a huge scenario tree. We investigate and compare different approaches to mitigate end-of-horizon effects and reduce the depth of the scenario tree, by formulating and solving multistage stochastic programming models for lot-sizing and simulating their application under different conditions in terms of demand uncertainty and economic parameters.
**Monday 14.00-16.25 Minisymposia**

### New Concepts for Stochastic Systems

[Room 5] **Approximation and stability for complex structural models**

*Chair(s): Petr Lachout*

David Morton (with John Hasenbein, Jinho Lee)

#### Rapidly Detecting an Anomaly Spreading Stochastically on a Network

We consider an anomaly that spreads according to stochastic dynamics on a network. Subject to a budget constraint, we install sensors on nodes of the network to optimize rapid detection of the anomaly. Rapid detection can be characterized by the probability we detect the anomaly by a time threshold or by the expected time to detection. We establish sub- and super-modularity properties for these two objective functions, respectively. Using a Monte Carlo approximation of a stochastic integer program, we solve large-scale problem instances for the probabilistic objective function using data from a cellphone service provider

Silvia Vogel

#### Stability of stochastic programming problems and mathematical statistics

Random approximations of decision problems come into play if unknown quantities are replaced with estimates or for numerical reasons. Hence there is the need for methods that help to evaluate the goodness of the solution of the approximate problem. We will consider constraint sets and solution sets of decision problems, provide convergence results and derive confidence sets which are obtained as suitable neighborhoods to the corresponding sets of the approximate problems. As many estimation procedures in parametric and nonparametric statistics occur as solutions of decision problems, we can immediately apply the results to derive consistency assertions and confidence sets for estimators. Particularly, we will discuss the approximation of densities via kernel estimators and Epi-Splines.

Jitka Dupačová (with Vaclav Kozmik)

#### Structure of Risk-Averse Multistage Stochastic Programs

We shall deal with risk-averse multistage stochastic programs with coherent risk measures such as multiperiod extensions of conditional value at risk or polyhedral risk measures. Their basic properties will be discussed and applied to scenario based input data. Using contamination technique we quantify the influence of changes in the structure of the scenario based approximation to the optimal value of the problem. Stochastic Dual Dynamic Programming algorithm will be used to provide illustrative numerical comparisons for different choices of risk measures and changes of input data for a simple multistage risk-averse stock allocation problem with scenario trees based on Log-normal distribution of the asset returns

Vlasta Kaňková (with Michal Houda)

#### Stability and Approximation in Stochastic Optimization via L1 Norm

Deterministic optimization problems depending on a probability measure correspond to many practical applications. A complete knowledge of the "underlying" measure would be a necessary assumption to determine both an exact optimal solution and exact optimal value. Since this assumption is not usually fulfilled, the solution is often determined on the database. Many efforts have been made to investigate corresponding estimates. This was mostly done under the assumptions of linear dependence on the probability measure, distributions with thin tails, and independent data. The aim of the talk will be to consider the cases in which these assumptions are rather relaxed. To this end we employ stability results based on the Wasserstein metric corresponding to the L_1 norm. Numerical illustration based on simulation techniques accompanies the given theoretical results.

Petr Lachout

#### Statistic features in stochastic optimization programs

Large stochastic optimization programs could be difficult for direct handling. Looking for its optimal solutions can be time, memory consuming. Even, it could happen we are not able to reach any optimal solution because of
immense computational complexity. For such a case we suggest an approximation, relaxation of the original problem based on constraints evaluation. The constraints will be ordered by means of importance, type, and, observed validity.

New Approaches to Classical Problems

[Room 4] Data mining methods for stochastic programming

Chair(s): Miguel A. Lejeune

Miguel A. Lejeune

Boolean Data Mining Method for Probabilistically Constrained Stochastic Programming Problems

We present a Boolean programming method to model and efficiently solve stochastic programming problems that have a joint probabilistic constraint with multi-row random technology matrix and/or random right-hand side. The method is inspired from a combinatorial data mining method, called Logical Analysis of Data (LAD), that derives disjunctions of terms and patterns to analyze archives of observations. Our method involves the binarization of the probability distribution of the random variables in such a way that we can extract a threshold partially defined Boolean function (pdBf) representing the satisfiability of the probabilistic constraint. We then construct a tight threshold Boolean minorant for the pdBf. Any separating structure of the tight threshold Boolean minorant defines sufficient conditions for the satisfaction of the probabilistic constraint and takes the form of a system of linear constraints. We use the separating structure to derive several deterministic formulations equivalent to the studied stochastic problem. A crucial feature of the integer formulations derived with the Boolean approach is that the number of integer variables does not depend on the number of scenarios used to represent uncertainty. Computational results will be presented.

Boris Defourny (with Damien Ernst, Warren B. Powell, Louis Wehenkel)

Automatic inference of decision rules for multistage stochastic programs

Motivated by the scenario tree selection problem for multistage stochastic programming, we compare approximate decision rules for the recourse stages. We consider (i) solving a scenario-tree approximation over the remaining stages, or (ii) inferring a mapping from the solution of the problem on the original scenario tree by supervised learning. In the supervised learning setup, the training set is made of the state-decision pairs extracted from the multi-nodal solution of the scenario tree, the test set is a large set of independent scenarios, and the loss function is the objective of the multistage problem itself. The work leads to a simulation-based approach for selecting a good branching structure for the scenario tree, with a performance guarantee on the expected value of the first-stage decision of the selected tree.

Victor M. Zavala

Clustering-Based Interior-Point Strategies for Stochastic Programs

We present interior-point strategies for convex stochastic programs in which inexpensive inexact Newton steps are computed from compressed Karush-Kuhn-Tucker (KKT) systems obtained by clustering block scenarios. Using Schur analysis, we show that the compression can be characterized as a parametric perturbation of the full-space KKT matrix. This property enables the possibility of retaining superlinear convergence without requiring matrix convergence. In addition, it enables an explicit characterization of the residual and we use this characterization to derive a clustering strategy. We demonstrate that high compression rates of 50-90% are possible and we also show that effective preconditioners can be obtain.

Ran Ji (with Miguel A. Lejeune)

Combinatorial Data Mining Method for Multi-Portfolio Stochastic Asset Allocation

We propose a family of probabilistically constrained models for multi-portfolio optimization. The models include a multi-row chance constraint with random technology matrix. Each row in the matrix corresponds to a specific portfolio whose stochastic return is required to be above a specified threshold. We use a combinatorial data mining method to reformulate the stochastic problem as a mixed-integer programming problem. Computational results describing the effectiveness and scalability of the method will be presented.
Learning policies from solutions of multi-stage programs, illustration on power system applications

Bertrand Cornélusse (with Arnaud-Aymeric Gibault-Nowak, Damien Ernst, Louis Wehenkel)

Learning a policy from the solution of a multistage program (MSP) has at least two advantages. First, the learned policy is usable in a close to real time context, when solving the MSP in a receding horizon manner is unaffordable, since inference is (in general) fast. Second, it allows out-of-sample validation of the policy to know whether the policy has a good generalization capacity. We provide some insight on the learning problem formulation and illustrate the approach on some power system applications. This approach may also be leveraged to set up an iterative mechanism using the learned policy for guiding the search of a new good scenario tree. This is by opposition to scenario tree reduction techniques that start from a large tree for which the MSP is unsolvable, and decrease its complexity until solving the MSP fits in the computational budget.

Computation and Applications

[Room 3] Applications and solutions for non-convex SPs
Chair(s): Asgeir Tomasgard

Steven A. Gabriel (with Sauleh Siddiqui, Chalida U-Tapao)

MPECs with Energy Applications

In this semi-plenary, we describe two-level optimization problems from the perspective of an MPEC (mathematical programs with equilibrium constraints). Besides indicating with small examples why these are generally hard, non-convex problems to solve, we review some theoretical challenges as well. Additionally, we describe several methods to solve this class of equilibrium problems and provide several large-scale energy examples as way of motivation

Marte Fodstad (with Yohan Shim, Steven A. Gabriel, Asgeir Tomasgard)

A branch-and-bound method for discretely-constrained mathematical programs with equilibrium constraints

We present a branch-and-bound algorithm for discretely-constrained mathematical programs with equilibrium constraints (DC-MPEC). This is a class of bilevel programs with an integer program in the upper-level and a complementarity problem in the lower-level. The algorithm builds on the work by Gabriel et al. (2010) and uses Benders decomposition to form a master problem and a subproblem. The new dynamic partition scheme that we present ensures that the algorithm converges to the global optimum. Partitioning is done to overcome the non-convexity of the Benders subproblem. In addition Lagrangean relaxation provides bounds that enable fathoming in the branching tree and warm-starting the Benders algorithm. Numerical tests show significantly reduced solution times compared to the original algorithm. When the lower level problem is stochastic our algorithm can easily be further decomposed using scenario decomposition. This is demonstrated on a realistic case

Elise Miller-Hooks (with Reza Faturechi, Lei Feng, Shabtai Isaac)

Emergency Shelter Design for Geographic and Building Environments using Stochastic and Robust Optimization

A bilevel, two-stage, integer stochastic program is presented that supports the planning and design of building and regional shelters and associated evacuation paths. At the upper-level, decisions are made regarding the location of shelters, their size and level of protection, with the objective of minimizing the expected (or worst-case) maximum endured risk over all scenarios. At the lower level, the choice of evacuation routes by the users, following the upper-level decisions on the location of shelters, is modeled as a user equilibrium problem. That is, individuals choose egress routes to the safe locations in the lower level to minimize disutility (travel time, exposure, geometric considerations, ...). A multi-hazard approach is utilized in which the performance of a plan is tested under various possible future emergency scenarios. Integer L-shaped and robust optimization methods are adopted for solution of the design problem. Piecewise linearization and the introduction of binary variables for converting if-then conditions to mixed integer constraints are employed to address nonlinearities in the model.
Nonconvex Generalized Benders Decomposition

Nonconvex generalized Benders decomposition is a decomposition strategy for solving scenario-based, two-stage stochastic programs in which the recourse problems are mixed-integer and/or have nonconvex functions participating. At present, the approach is limited to integer first-stage decisions. A major benefit of this decomposition strategy is the linear growth of the solution time with the number scenarios, potentially enabling the solution of nonconvex stochastic programs with very large numbers of scenarios. This presentation outlines the basic theory and implementation of the algorithm, and some numerical results from the basic algorithm.

Enhancing Nonconvex Generalized Benders Decomposition With Piecewise Relaxation and Adaptive Parallelization

This presentation introduces two approaches to reduce the time for nonconvex generalized Benders decomposition (NGBD) to solve stochastic separable mixed-integer nonlinear programs. The first approach is to accelerate the convergence of NGBD by constructing tighter convex relaxations. This is achieved for factorable nonconvex programs by a piecewise convex relaxation framework. Case study of an energy polygeneration plant design problem shows that the integration of piecewise convex relaxation can reduce the NGBD solution time by up to an order of magnitude. The second approach is to develop parallel NGBD algorithms that can utilize multiple computing resources simultaneously. Three parallelization strategies are proposed, among which the one adaptively parallelizes the scenarios and bounding procedures leads to the best overall performance. Case study of a natural gas production network planning problem shows that, with the parallelization strategies, the wall time for NGBD to solve the problem can be reduced by several times on an 8-core processor.

Finance and Applications

[Room Galeotti] Dynamic stochastic optimization and Finance
Chair(s): Elena Medova

The Values of Information and Solution in Stochastic Programming

The values of obtaining greater precision about uncertain future outcomes and of determining more effective decisions provide much of the foundation and motivation for stochastic programming. Michael Dempster's cogent analysis of these characteristics have led both to greater insights from these models and more efficient computational methods. This talk will review these seminal contributions and then discuss their relationship to more recent developments from approximate dynamic programming to statistical machine learning.

Estimating Animal Spirits

In our earlier paper 'Taming animal spirits' [Annals of Finance 2013] we developed a risk management approach for project finance in which valuations may depend on 'behavioural' factors---Keynes' 'animal spirits' or Greenspan's 'irrational exuberance'. This paper addresses estimation of the factor processes from price index data, concentrating on the real-estate market. The approach is based on the use of Hidden Markov Models as explanatory variables, estimated by the Baum-Welsh algorithm. In addition to parameter estimation we also develop prediction algorithms for the price indices.

Optimal capital allocation and strategic portfolio selection for a large property/casualty insurer

We consider a 10 year dynamic portfolio selection problem for a P/C insurer with stochastic liabilities and regulatory compliant risk capital constraints (e.g. Solvency II). The investment universe includes liquid (Treasuries in different maturity buckets, corporates, equity, indirect real estate) as well as illiquid (private equity, rene-wables, direct real estate, infrastructure) asset classes. The optimization problem is formulated as a risk-adjusted return maximization problem with penalties for shortfalls with respect to exogenous targets set by the company. The ALM model captures the key elements of the real-world development and the risk capital constraints are studied under alternative assumptions on the risk factors’ correlation matrix. This cutting-edge application
represents my best achievement so far in the applied stochastic optimization field, all of which has been inspired by initial work with M A H Dempster as a research student and postdoctoral associate.

Teemu Pennanen

Risk management and contingent claim valuation in illiquid markets

We study portfolio optimization and contingent claim valuation in markets where illiquidity may affect the transfer of wealth over time and between investment classes. In addition to classical frictionless markets and markets with transaction costs, our model covers nonlinear illiquidity effects that arise in limit order markets. We extend basic results on arbitrage bounds, attainable claims and optimal portfolios to illiquid markets and general swap contracts where both claims and premiums may have multiple payout dates. We establish the existence of optimal trading strategies and the lower semicontinuity of the optimal value of portfolio optimization under conditions that extend the no-arbitrage condition in the classical linear market model.

Francesco Sandrini (with Matteo Germano)

ALM Analysis for Pensionskasse: Asset Liability Management Study

Since the beginning of the current decade the introduction of tighter accounting standards for pension funds (e.g. FRS 17 in UK, FTK in the Netherlands) and lately for insurance companies (e.g. Solvency I and II) forced institutional investors to adopt a mindset based on the joint assessment of assets and liabilities under a set of risk scenarios. The adoption of marking-to-market assumptions, combined with the necessity for coherence when pricing assets and liabilities, has made players look deeper into techniques such as stochastic optimization. Pioneer Investments here presents its approach to ALM for a general German PensionKasse which is extensively based on such techniques.

Pioneer has spent almost a decade in developing internal expertise in stochastic optimization, alongside research partners such as Cambridge University and Cambridge Systems Associates. A close and long standing collaboration with academia, and in particular with a leading exponent of dynamic stochastic programming, Professor Dempster, and his colleagues has helped Pioneer to develop an ALM framework which is a benchmark in the market.
### Monday 16.55-19.00 Parallel Sessions

#### Advances in stochastic programming and contiguous fields

[Room Galeotti] Risk aversion and stochastic dominance  
*Chair(s): Darinka Dentcheva*

Tobias Wollenberg (with Rüdiger Schultz)

**Decomposition Methods for Two-stage Stochastic Linear Semidefinite Programs with Risk Aversion**

In recent years a growing interest in semidefinite programming under uncertainty could be observed. For two-stage risk neutral and risk averse stochastic linear semidefinite programs we discuss structure, stability and decomposition algorithms. In doing so, certain parts of the analysis follow fairly closely the traditional lines of argumentation in stochastic linear programming. Our talk will place accent on those topics where traditional arguments fail or have to be extended. To lesser extent, this concerns structure and stability, while algorithmically alternative ideas had to be developed.

Eli Wolfhagen (with Darinka Dentcheva)

**Optimization with multivariate stochastic dominance constraints**

We consider risk-averse stochastic optimization problems with a risk-shaping constraint in the form of multivariate stochastic order constraint. The constraint requires that a random vector depending on our decisions stochastically dominates a given benchmark random vector. We discuss suitable multivariate stochastic orders and focus on the linear stochastic dominance of second order. We formulate sufficient conditions for its convergence and propose both primal and dual numerical methods for solving the problem. Numerical experience confirms the efficiency of the methods.

Nilay Noyan (with Gabor Rudolf)

**Optimization with Multivariate Conditional Value-at-Risk Constraints**

For many decision making problems under uncertainty, it is crucial to develop risk-averse models and specify the decision makers’ risk preferences based on multiple stochastic performance measures. Incorporating such preference rules into optimization models is a fairly recent research area. Existing studies focus on extending univariate stochastic dominance rules to the multivariate case. However, enforcing multivariate dominance constraints can be overly conservative. As an alternative, we focus on the widely-applied risk measure conditional value-at-risk (CVaR) and develop an optimization model with multivariate CVaR constraints. For finite probability spaces we develop a cut generation algorithm, where each cut is obtained by solving a mixed integer problem. We show that our results can be naturally extended to a wider class of coherent risk measures. The proposed approach provides a flexible and computationally tractable way of modeling preferences in stochastic multi-criteria decision making. We conduct a computational study to illustrate the effect of enforcing multivariate CVaR constraints and demonstrate the computational performance of the proposed solution methods.

Gabriela Martinez (with Darinka Dentcheva)

**Regularization Methods for Stochastic Order Constrained Problems**

We consider stochastic optimization problems with stochastic order constraints. We develop two numerical methods with regularization for their numerical solution. Our methods utilize the characterization of the stochastic order by integrated survival or integrated quantile functions to progressively approximate the feasible set. Convergence of the methods is proved in the case of discrete distributions.

Milos Kopa

**Robustness and bootstrap techniques in portfolio efficiency tests**

The paper deals with portfolio efficiency testing with respect to the first and second order stochastic dominance. A portfolio is classified as efficient if it is not dominated by any other portfolio that can be created from the considered set of assets. Since the portfolio efficiency tests are usually very sensitive to changes in the underlying distribution of returns of the assets, we enrich the tests by robustness, contamination and bootstrap
techniques. Starting with robustness approach, modifications of the original tests that allow for small changes in the distribution of returns are presented. Employing contamination techniques, a notion of directional efficiency is introduced. It offers a useful tool in stress testing when the original distribution is contaminated by the stress scenario. Finally, several bootstrap ideas are discussed in order to estimate the bias of an inefficiency score and correctly estimate the p-value of the portfolio efficiency. An empirical study illustrates it on the US market data when testing the market portfolio efficiency with respect to the first and second order stochastic dominance.

### Problem formulation and solution algorithms

**[Room 5] Multistage mixed-integer stochastic programming**

*Chair(s): Suvrajeet Sen*

Gerardo A. Pérez-Valdés (with Adela Pagès-Bernaus, Asgeir Tomasgard)

#### BFC Parallel Implementation

Branch and Fix Coordination is an algorithm designed to solve large scale multi-stage stochastic mixed integer problems, based on the notion that the particular structure of such problems makes it so that they can be broken down into scenario groups with smaller subproblems, solvable almost independently. With this in mind, it is possible to use parallel computing techniques to solve the subproblems created: each processor solves the subproblems pertaining to a particular cluster, and then the solutions are reported to a master routine. To satisfy nonanticipativity in the master problem's binary variables, the values of the binary variables in the subproblem solutions are coordinated throughout the entire process. The treatment of the original problem this way not only makes it faster to solve, but also allows us to solve otherwise intractable instances, where the number of binary variables is too large to be efficiently computed in a single processor. In this work, we present details and results about our computational implementation of the Branch and Fix Coordination algorithm.

Gloria Pérez (with Unai Aldasoro, Laureano F. Escudero, María Merino)

#### Parallelized Branch-and-Fix Coordination (P-BFC) for solving large-scale multistage mixed 0-1 problems

The sequential Branch-and-Fix Coordination multistage algorithm (BFC-MS) was introduced for solving large-scale multistage mixed 0-1 optimization problems. Now, we present the Parallelization version of the BFC algorithm (P-BFC). The parallelization is performed by combined two levels; the inner one performs the parallelization of the MIP submodels at a given step of the algorithm whereas the outer one corresponds to parallel executions of the algorithm. Specifically, the inner level performs in parallel the MIP submodel optimization step at every iteration of the algorithm; and, additionally, the original tree branching process is parallelized by simultaneous and interactive BFC algorithm executions in the outer level. It is remarkable the small elapsed time required to obtain the optimal solution by jointly using the outer and inner parallelization. We have implemented an experimental C++ code that uses the IBM ILOG CPLEX optimizer within COIN-OR for solving the independent MIP submodels with the Message Passing Interface (MPI). We present the computational experience performed in the computing l cluster ARINA provided by the SGI/IZO-SGiker at the UPV/EHU.

Salima Amrouche (with Mustapha Moulaï)

#### The integer L-shaped method for multiple objective stochastic integer linear programs.

Multi-objective nature with discrete variables and imprecise parameters make the problems harder to solve with traditional approaches. In this paper, we present a new method of multiple objective stochastic integer linear programs with integer L-shaped method (MOSILP). The proposed method includes both the branching in integer linear programming with efficient cut and, two-stage stochastic program. We converting the original problem into a deterministic MOILP problem, starting with an optimal solution of (LP) whose objective is a positive combination of the criteria, with respect to the first-stage constraints as well as existing feasibility and optimality cuts, then a branching process is carried out to detect an integer solution for a constrained problem. When such a solution is obtained, it is tested for efficiency with those already found using the criteria values. The proposed method converges in a finite number of iterations. A numerical example is included for illustration.

Charlotte Henkel

#### Decomposition method for linear stochastic bilevel problems
Compared to linear stochastic two-stage programs, linear stochastic bilevel problems (LSBP) exhibit a strongly increased complexity. Nonetheless, decomposition methods known from the former can be used to derive optimal solutions of LSBPs. An algorithm for optimistic LSBPs with discrete distributions is presented as well as an evaluation of the performance.

Giovanni Pantuso (with Kjetil Fagerholt, Stein W. Wallace)

A matheuristic for a class of multi-stage mixed-integer stochastic programs: application to the maritime fleet renewal problem

We present a matheuristic for a class of multi-stage mixed-integer stochastic programs. The matheuristic is based on a node formulation of the problem, which is decomposed in a mixed-integer master problem and linear subproblems. While specialized heuristics generate feasible solutions for the master problem, the evaluation of the objective function relies on optimal solution of the linear subproblems. A scheme based on sensitivity analysis ensures a drastic reduction of the number of subproblems to solve. The matheuristic is tested on real life maritime fleet renewal problem instances. Results show that the proposed solution method provides good bounds in reasonable time and permits to solve instances for which commercial solvers fail to even load into memory the deterministic equivalent of the original problem.

Energy

[Room 3] Hydrothermal energy management

Chair(s): Bita Analui

Pedro Crespo Del Granado (with Stein W. Wallace, Zhan Pang)

The value of local electricity storage in a smart grid: How important is intermittency?

Intermittent energy sources, in particular wind power, poses new balancing challenges for the grid. To address this issue we look at a large end user, typically a university campus or an industrial site, with its own micro grid and intermittent energy production. We investigate how electricity storage, in the form of a battery, can be profitable for the site, but also how it helps regulate the energy system itself. In particular, we show how a site with both electricity storage and own wind generation is less disruptive to the grid than the same wind generation placed outside such a micro-grid. Hence, the electricity storage has value for the site itself in terms of collecting electricity from the grid when prices are low (and using the battery when they are high) as well as better utilizing the wind energy, but also for the grid since intermittency becomes less of a problem for the grid itself. To this end, we formulate a multistage stochastic programming model to consider the probabilities of possible wind energy realizations by a scenario tree over a finite planning horizon (half-hour periods for one day).

Murilo Reolon Scuzziato (with Erlon Cristian Finardi)

Hydrothermal Unit Commitment Subject to Uncertain Demand and Water Inflows

The Brazilian electrical power system has a large capacity for water storage and long transmission networks. The efficient operation of this kind of system often leads to a complex task. Thus, it is supported by studies from long to short term planning horizon. We present a model for the hydrothermal unit commitment of a power system under uncertainty in the demand and water inflows. With appropriate approximations, this problem can be formulated as a stochastic (two-stage) mixed-binary quadratic programming problem. We investigate the impact of this uncertainty by using a scenario-wise decomposition method (Progressive Hedging), to give an approximate solution to the stochastic problem. This approach divides the problem into deterministic problems, each one representing a set of demand and water inflow scenario. To solve each deterministic scenario problem we use Mixed-Integer Quadratic Program optimization solvers. Finally, we compare the solution and performance with the deterministic equivalent problem solved by a mathematical programming solver. We assess our approach by using a 46 buses hydrothermal system, including 14 cascaded head-dependent reservoirs and 7 thermal plants.

Goran Vojvodic

Determining the variable cost of pumped-storage stations for use in the real-time market

Due to the need for efficiency in terms of resource usage in the energy sector, a precise estimation of the forward-looking operating cost for pumped-storage hydroelectric power plants is needed. Considering wholesale energy prices as random, we model the short-term operation of the energy market using two-stage stochastic
optimization in order to estimate the operating cost of a pumped-storage power plant. We show that the results obtained from the stochastic approach differ from those found using deterministic optimization. We believe these results to be more accurate because they were obtained using an approach that is structurally similar to the operation of energy markets

Steffen Rebennack

Combining Sampling-based and Scenario-based Nested Benders’ Decomposition Methods: Application to Stochastic Dual Dynamic Programming

Nested Benders’ Decomposition is a widely used and accepted solution methodology for multi-stage stochastic linear programming problems. Motivated by large-scale applications in the context of hydro-thermal scheduling, in 1991, Pereira and Pinto introduced a sampling-based variant of the Benders’ Decomposition method, known as stochastic dual dynamic programming (SDDP). In this paper, we embed the SDDP algorithm into the scenario tree framework, essentially combining the Nested Benders’ Decomposition method on trees with the sampling procedure of SDDP. This allows for the incorporation of different types of uncertainties in multi-stage stochastic optimization while still maintaining an efficient solution algorithm. We provide an illustration of the applicability of our method towards a least-cost hydro-thermal scheduling problem incorporating both electricity demand and inflow uncertainties

Andre Luiz Diniz (with Tiago Norbiato dos Santos)

An Efficient Parallel Decomposition Approach for Stochastic Dual Dynamic Programming

Stochastic Dual Dynamic Programming (SDDP) has been the leading optimization technique for large-scale multistage stochastic optimization problems. Recently, instead of performing several simultaneous forward passes as originally proposed by Pereira and Pinto, some works have shown the advantages of using only one resampled scenario in each forward pass of the algorithm. However, such procedure does not take full advantage of parallel processing scheme. In this work we propose an efficient parallelized version of SDDP algorithm that combines the theoretical advantages of using a very small number of scenarios per iteration with the practical advantages of using a multi-processor framework.

The two novel contributions are: parallelization of the stochastic multi-stage problem solving procedure by stage (and not by scenario) and a simultaneous realization of the forward and backward passes of the SDDP algorithm. The proposed approach provides valid lower and upper bounds in a faster pace while the theoretical convergence properties of the SDDP approach remains assured. Numerical results are presented for a large multi-stage problem related to hydrothermal planning

Finance

[Room 4] Portfolio risk and return analysis
Chair(s): Sergio Ortobelli Lozza

Cristinca Fulga

Optimization and performance evaluation in the portfolio selection problem

In this paper we propose a quantile-based risk measure which is defined using the modified loss distribution according to the decision maker's risk and loss aversion. We establish its properties related to different classes of disutility functions using the proposed risk measure. We develop a portfolio selection model in the Mean-Risk framework and give equivalent formulations of the model generating the same efficient frontier. We investigate the practical performance of the model on a portfolio composed of some of the most representative securities of the NYSE. The advantages of this approach and the better performances of the efficient portfolios obtained by the application of the new model compared to other Mean-Risk models are discussed and empirically proven

Ales Kresta

Comparison of back-testing results for various VaR estimation methods

Value at Risk is nowadays the most frequently utilized measure of the risk. It is applied mostly by financial institutions and their regulatory authorities. In accordance to the assumed process of the price series development variety of methods for VaR estimation can be defined. One of the simplest methods, historical simulation, is based on the assumption that the future returns can be modelled non-parametrically by means of the histori-
cally observed returns. To improve the performance, the heteroskedasticity of the returns can be assumed (filtered historical simulation). Also the parametrical distribution of returns can be assumed, i.e. the Brownian motion or more complex Levy’s processes. It is obvious that the performance depends also on the length of time series utilized to estimate the parameters. In the article both the different models and the different periods for parameters estimation are assumed. The chosen methods are back-tested and the back-testing results are compared. The comparison of the results is made by means of the Kupiec’s unconditional test and Christoffersen conditional coverage test, i.e. the number of exceptions and their independency in time are tested.

Marco Cassader (with Sergio Ortobelli Lozza, Valeria Caviezel)

**Portfolio selection with European call and put options**

We describe optimization models to evaluate the portfolio performance in the options markets. In particular, we propose to use options in two different portfolio problems: in the classical reward-risk portfolio framework; exclusively to hedge the underlying portfolio risk. Since we use a large number of trading European option written on principal international stock Indexes we discuss how to reduce the dimensionality of the large scale portfolio problem taking into account of the options liquidity. In the classical reward-risk portfolio framework the optimal portfolio problem with contingent claims allows to create wealth also during financial crisis since the different option returns could present negative correlation. This is the main reason why the wealth obtained using options exclusively to hedge the underlying portfolio risk is generally lower than when it is invested only in the contingent claims. Finally we compare the ex post sample path of wealth over a two-year period using different portfolio strategies.

Sergio Ortobelli Lozza (with Daniele Toninelli, Enrico Angelelli, Tomas Tichy)

**International portfolio selection with Markov processes and liquidity constrains**

This paper proposes an ex-post comparison of portfolio selection strategies applied to 64 stock exchange markets during the period 2008-2011. In order to simplify the computational complexity of the choice we preselected assets among the global market considering three different classes of liquidity constrain which differ for their average traded daily value. In particular, we preselected a few assets for each portfolio selection problem, taking into account different return characteristics: the joint Markovian behavior of the returns; their association with market stochastic bounds; their ex-ante reward-risk performance. For each liquidity class of assets we compare the ex-post performance of three portfolio selection strategies: one of them is based on the maximization of the Sharpe ratio; the other two are based on the maximization a reward-risk performance that consider a Markovian evolution of the portfolio returns. The comparison of the ex-post final wealth obtained with the optimization of the reward-risk functionals remark very different characteristics and international portfolio composition among the three liquidity class of assets. Thus the results emphasize the importance of liquidity constrains in selecting international portfolios.

Valeria Caviezel (with Sergio Ortobelli Lozza, Lucio Bertoli Barsotti)

**Risk profile versus portfolio selection**

This paper proposes an evaluation of the investors’ risk profile in order to satisfy the minimal requirements of the law for the Italian financial institutions. Thus we investigate all aspects specific to the risk profile: the investor’s knowledge and his/her financial experience (concerning financial instruments and their use), the financial objectives, the personal predisposition to risk /earn and the temporal horizon. In particular, we suggest to use a Generalized Multidimensional IRT model to account the investors’ preferences and psychological attitudes. Therefore we assess a questionnaire whose items describe different characteristics of the main latent variables of the risk profile. As dataset we use some anonymous responses to the questionnaire of the retail category of UBI.
Supply chains are susceptible to disruptions. When these occur at the distribution centers (DCs), it is desirable to have enough inventory at the available DCs to reassign customer demands. We formulate this supply chain design as a two-stage stochastic programming problem. The first-stage decisions include selecting the locations of DCs and determining their storage capacities. The second-stage decisions depend on the set of scenarios that is given by the combinations of active and disrupted locations. They determine the distribution strategy. The objective function is to minimize the sum of investment cost and the expected cost of distribution during a finite time horizon. In order to overcome the exponential growth of scenarios given by the number of candidate DCs, we apply the SSA method that allows finding confidence intervals on upper and lower bounds of the optimal solution. The SSA is applied to a large-scale case study. The results obtained show the importance of considering DCs reliability in the formulation of the problem and the essential role of storage capacity in supply chain resiliency.

Walid Klibi (with Alain Martel)

The Design of Robust Value-Creating Supply Chain Networks

This work proposes a comprehensive methodology to design robust value-creating Supply Chain Networks (SCN). It takes into account the various types of uncertainties that may affect a supply chain, and proposes a comprehensive integrated SCN design model formulated as a bi-criterion, multi-period, scenario-based two-stage stochastic program with recourse. A scenario-based approach is thus proposed to design and evaluate SCNs structures under uncertainty. To illustrate the methodology, a common SCN design problem: the Location-Transportation Problem (LTP) is used. To solve this problem, a multi-cycle two-stage stochastic location-allocation model under a multiple-sourcing resilience strategy is proposed. Using several samples of Monte-Carlo scenarios alternative SCN designs are generated. Then, we illustrate how one could perform a detailed evaluation of candidate designs using an accurate user response model including customer reassignments under disruptions and transportation decisions, rather than the gross flow-based formulation of the second-stage program. Based on a large set of Monte-Carlo and worst-case scenarios, the computation of several coherent risk and resilience measures is provided. Using these performance measures one can observe the impact of resilience strategies on the designs generated and select the most effective and robust one.

Victor M. Albornoz (with Esteve Nadal, Lluis M. Plà)

A multistage stochastic program for production planning in the pig supply chain industry

In this paper we present a linear multistage stochastic programming model with the aim to optimize the production planning of a pig supply chain. A time horizon of three years is considered on a weekly basis, divided into different stages according to more immediate and those more tactical decisions. The model maximizes the total revenue of the chain, where incomes depend on animals sold to the abattoir and main costs summarises feeding, doses of insemination, labour, transportation and veterinary expenses. Furthermore, the proposed model provides an optimal production planning considering the best flow of animals among farms and towards the abattoir, the number of animals to be produced and transferred at each phase and stage. Also, the number of trucks and optimal replacement policy for each sow farm, as well as the optimal delivering of fattened pigs to the abattoir are obtained. Finally, the paper presents the results obtained in the application of this methodology, how the optimal solution for the whole supply chain it is different than those obtained for individual farms, the main conclusions and possible extensions of the present research.

Steven Prestwich (with Marco Laumanns, Ban Kawas)

Scenario Bundling for a Pre-Disaster Planning Problem

We consider a real-world pre-disaster planning problem from the literature: finding an optimal investment plan to strengthen links in a transportation network, given that the links are probabilistically destroyed by a future earthquake. The objective is to facilitate rescue operations by minimising the sum of expected shortest path lengths between several pairs of locations. This can be modelled as a2-stage stochastic program, but it is...
challenging as the case we consider has over a billion scenarios, and it has previously been solved only approximately. We adapt a symmetry breaking method from Constraint Programming to the random variables of the problem, enabling us to group scenarios into large bundles. This reduces the size of the problem 3 million-fold, and allows the exact solution of cases previously considered intractable.

Susanne Wiedenmann (with Jutta Geldermann)

Supply Planning for the Material Use of Renewable Resources

Material use of renewable resources is gaining increasing importance in industrial networks. Quantity and quality of raw materials and market prices are uncertain and need to be considered in supply planning for industrial production processes. This research depicts the planning problem of a processor who supplies agricultural goods to an industrial customer. A two-stage stochastic program is developed to model the decision. Possible modifications are discussed. The model is applied on the industrial use of linseed oil and sensitivity analyses are carried out. This model can be used for a variety of real world planning problems concerning the supply of agricultural raw materials.
Tuesday 10.45-12.50 Parallel Sessions

**Advances in stochastic programming and contiguous fields**

[Room Galeotti] Dynamic time consistent risk measures

*Chair(s): Tito Homem-de-Mello*

Vincent Leclere (with Michel De Lara)

**General Dynamic Programming**

Dynamic Programming is a well known method to solve multistage stochastic problems. Traditionally, Dynamic Programming is presented on problems where the objective function is the expected value of the sum over time of random costs. In this case, we stress the point that two aggregations occur: the objective function is aggregated over time through the operator "+", and aggregated over the randomness through the aggregator "E[ ]". However, it is well known that Dynamic Programming can be applied with different aggregators. For instance, an alternative to the sum can be the product of each time-stage cost, and an alternative to the expectation can be the worst case scenario operator where you consider the supremum of the cost over all random inputs. We present a general framework where we show conditions on the random and time aggregators that allow us to display a Dynamic Programming equation, and consequently a time-consistency property. Our framework covers the case of coherent and convex risk measures.

Tsvetan Asamov (with Andrzej Ruszczynski)

**Dynamic Time-Consistent Approximations of Risk Measures**

We consider coherent measures of risk and study their properties as they relate to the notion of time consistency. We employ duality theory to find families of probability measures that are relevant to the original risk measures. We use the dual representations to derive dynamic time-consistent approximations to the original risk measure. Our numerical results indicate that the dynamic time-consistent functions present good approximations to the original risk function for a wide range of risk parameters.

Alexandre Street (with Davi Michel Valladão, Birgit Rudloff)

**Consistency and risk averse dynamic decision models: Definition, interpretation and practical consequences.**

This paper aims at resolving a major obstacle to practical usage of time-consistent risk-averse decision models. The recursive objective function, generally used to ensure time consistency, is complex and has no clear/direct interpretation. Practitioners rather choose a simpler and more intuitive formulation, even though it may lead to a time inconsistent policy. Based on rigorous mathematical foundations, we impel practical usage of time consistent models as we provide practitioners with an intuitive economic interpretation for the referred recursive objective function. We also discourage time-inconsistent models by arguing that the associated policies are sub-optimal. We developed a new methodology to compute the sub-optimality gap associated with a time inconsistent policy, providing practitioners with an objective method to quantify practical consequences of time inconsistency. Our results hold for a quite general class of problems and we choose, without loss of generality, a CVaR-based portfolio selection application to illustrate the developed concepts.

Tito Homem-de-Mello (with Bernardo K. Pagnoncelli)

**Risk aversion in multi-stage stochastic programming: a modeling and algorithmic perspective**

Multi-stage stochastic linear programs have been studied for a long time. Recently, much attention has been devoted in the literature to the incorporation of risk measures into this type of model. It appears however that there is no consensus on the "best" way to accomplish that goal. In this presentation, we discuss pros and cons of some of the existing approaches. A key notion that must be considered in the analysis is that of consistency, which roughly speaking means that decisions made today should agree with the planning made yesterday for the scenario that actually occurred. A popular way to ensure consistency is to "nest" the risk measures calculated in each stage, but such an approach also has drawbacks both from modeling as well as from algorithmic perspectives. We discuss a class of risk measures that address those shortcomings, and illustrate it with numerical results for a problem in pension funds.
Lijian Chen

**Nested Preprocessing for Multi-stage Stochastic Programming**

We present an improvement to the well-known Sample Average Approximation (SAA) method for the multi-stage stochastic programming. The SAA method usually demands a very large sample size to obtain a good-quality solution, for the stochastic programming with three or more stages in particular. When SAA requires a sample with large number of scenarios, our approach, named nested preprocessing, can reduce the sample size considerably without compromising the solution quality. The word "preprocessing" is rather a vague term which is to remove redundant scenarios before solving the problem for the sake of computational savings. We quantify each scenario within each stage by its unique Maximum Volume Inscribed Ellipsoid (MVIE) and extract geometric information to identify redundant scenarios for all the stages. The nested preprocessing approach works on a pre-generated Monte-Carlo sample and this approach inherits all of SAA's nice theoretical properties, such as consistency, with a faster rate of convergence. Nested preprocessing Monte-Carlo sample needs to solve many but separable ellipsoidal and convex auxiliary optimizations. Thus, our approach can be implemented in a distributed computational infrastructure. Numerical results are presented.

**Problem formulation and solution algorithms**

[Room 5] Non-Linear and Monte Carlo algorithms

*Chair(s): Anton J. Kleywegt*

Jong-Shi Pang (with Che-Lin Su, Yu-Ching Lee)

**Estimation of Pure Characteristics Demand Models with Pricing**

A pure characteristics model is a class of discrete-choice random coefficients demand models in which there is no idiosyncratic logit error term in a consumer's utility. The absence of the logit error term and the use of numerical integration to approximate the integral in aggregate market shares lead to a nonsmooth formulation of approximated market share equations. As a result, inverting the approximated market share equations for the unobserved product characteristics and estimating the model by using the nested fixed-point approach as proposed in the existing econometrics literature become computationally intractable. To overcome this difficulty, we introduce lotteries for consumers' purchase decisions, which we show can be characterized by a system of complementarity constraints. This reformulation leads to smooth approximated market share equations and allows us to cast the generalized method of moments estimation of a pure characteristics model as a quadratic program with nonlinear complementarity constraints. We also embed the smooth approximated market share equations in the formulation of firms' competitive pricing problems and extend the GMM estimation problem of pure characteristics models to incorporate the endogenous pricing mechanism. We present numerical results to demonstrate the effectiveness of our approach.

Wajdi Tekaya (with Alexander Shapiro, Murilo Pereira Soares, Joari Paulo da Costa)

**Worst-case-expectation approach to optimization under uncertainty**

In this talk, we discuss multistage programming with the data process subject to uncertainty. We consider a situation where the data process can be naturally separated into two components, one can be modeled as a random process, with a specified probability distribution, and the other one can be treated from a robust (worst case) point of view. We formulate this in a time consistent way and derive the corresponding dynamic programming equations. In order to solve the obtained multistage problem we develop a variant of the Stochastic Dual Dynamic Programming (SDDP) method. We give a general description of the algorithm and present computational studies related to planning of the Brazilian interconnected power system.

Marc C. Steinbach (with Jens Hübner)

**Distributed Algorithms for Nonlinear Multistage Stochastic Programs**

The lecture addresses multistage stochastic NLP models in scenario tree form. Our solution approach combines interior point methods for NLP with tree-sparse direct algorithms for KKT system solution, which is well suited both for shared-memory and distributed parallel computation. We introduce a C++ software framework that enables the combination of a generic implementation of the interior point method with application-tailored implementations of the KKT solver. Computational results will be presented for several application areas, including a convex QP model with over 11 billion primal variables that is solved within a minute on a massively parallel machine.
Ozan Kocadağlı

Hierarchical Bayesian Learning in Neural Networks using Genetic Algorithms

In nonlinear systems, the neural networks are useful tools to determine the functional structure between inputs and outputs. However, the traditional neural networks with sum squared errors suffer from approximation and estimation errors in the estimation process of parameters and hyper-parameters in the Neural Networks. The Bayesian neural networks provide a natural way to alleviate this issue. The aim of this study is to improve a novel Markov Chain Monte Carlo method which estimates parameters and hyper-parameters in the Neural Networks using the full hierarchical Bayesian approach with genetic algorithms. In the application section, the proposed approach is compared with traditional neural networks in terms of their performance against the complex problems.

Anton J. Kleywegt (with Xinchang Wang)

A Stochastic Trust Region Algorithm for Mixed Logit Type Problems

Motivated by mixed logit estimation problems, we consider stochastic optimization problems of the form \( \min_x \sum_n f(E[G_n(x, w_n)]) \), where \( x \) is the decision variable, and \( w_n \) is a random variable with chosen distribution. In the case of mixed logit estimation, the sum involves observations in a data set, \( f \) is a logarithm, and \( x \) includes parameters of the systematic utility as well as parameters of the probability distribution. In many applications, the dimension of \( w_n \) is sufficiently high to exclude calculation of the expectation using quadrature methods. Thus we propose an algorithm that embeds a sample average approximation of the expectation. The algorithm controls the sample size for each observation \( n \) in the data set to minimize the total sample size subject to a constraint on the variance of the objective estimate. In addition, the algorithm controls sampling from the data set. We provide sufficient conditions for convergence of a trust region based algorithm. We demonstrate the algorithm with numerical results for the estimation of a mixed logit discrete choice model for customer selection of airline flights, using data from a very busy air travel market.

Energy

[Room 3] Stochastic models in energy planning

Chair(s): Boris Defourny

Heejung Park (with Ross Baldick)

A stochastic transmission planning model with dependent random variables: wind and load

We apply two-stage stochastic programming to electric transmission system expansion planning by generating samples with Gaussian copula. Total electric load and available wind power are considered two dependent random variables and random samples are drawn by using their univariate marginal distributions and the correlation coefficient. Decomposition is applied to the model to solve a large-scale optimization problem. Optimal power flow (OPF) is solved based on the linearized direct current (DC) power flow. The Electric Reliability Council of Texas (ERCOT) network model and its wind and load data are used as a test case. An optimality gap with 95% confidence interval is adopted to validate the stochastic solution quality with 200 samples.

Fabian Bastin (with Pierre-Luc Carpentier, Michel Gendreau)

A \( L \)-shaped method for mid-term hydro scheduling under uncertainty

We propose a new approach for solving the mid-term hydro scheduling problem with stochastic inflows. This problem aims at finding reservoir release targets to minimize the expected operation cost subject to reservoir dynamics and energy budget constraints. Head and hydroelectric efficiency variations are taken into account through concave and piecewise linear generation functions. The planning horizon is uniformly discretized and partitioned in two stages. To gain computational efficiency, we assume that the hydrological stochastic process loses memory of previous realizations at the end of the first stage. This assumption allows us to represent inflow uncertainty using two successive scenario trees. The special structure of the resulting mathematical program is exploited using a two-stage decomposition scheme. The master problem and subproblem solved at each iteration are stochastic linear programs defined on the first- and second-stage scenario trees, respectively. The proposed approach is tested on a large hydroelectric power system in Québec, Canada for a 92 weeks planning horizon.
Ruud Egging

Benders Decomposition for solving multi-stage stochastic mixed complementarity problems.

The Stochastic Global Gas Model is a mixed complementarity problem for the global natural gas market. Uncertainty about future parameter values is represented using an extensive-form stochastic model formulation. The inclusion of multiple scenarios enlarges the model size drastically with a severe impact on memory and time needed to solve the model. An alternate Benders Decomposition approach is discussed and implemented successfully in GAMS. Several numerical issues are discussed and resolved.

Somayeh Moazeni (with Warren B. Powell)

Risk Averse Computational Stochastic Programming

Computing optimal (stochastic) policies under an appropriate risk consideration presents many computational challenges. In this talk, we present an approach based on direct policy search and extended myopic policy to minimize the expected cost and risk in decision making problems under stochastic uncertainty. This approach makes no assumption about the smoothness or convexity of the risk measure or the objective function, and can handle any number of constraints. We motivate the approach through a energy storage application. We show that the proposed approach is computationally tractable and can handle a variety of risk measures. In addition, we illustrate the effect of including risk on the stochastic optimal battery dispatch policy.

Finance

[Room 4] Risk control for dynamic portfolios
Chair(s): Diana Barro

Agnieszka K. Konicz (with John M. Mulvey)

Improving pension product design

Pension products characterized by linking an individual’s savings directly to market returns represent the most popular, growing pension domain globally. These products are widely sold in contribution-defined pension schemes, labor market pensions, and individual schemes. However, available products are designed with a tendency to assume greater risk the longer it is until retirement, but are not adjusted to individual preferences and circumstances. This paper develops an optimal asset allocation strategy for a defined contribution plan by adjusting to individual needs, such that the expected utility of retirement benefits is maximized. An asset allocation strategy should not only depend on the plan member’s age (or time left to retirement), nor only on her risk preferences, but should capture personal characteristics. Among other factors, we include current wealth, expected lifetime salary progression, expected social benefits, choice of assets, type of retirement distribution schedules, bequest motive and life insurance. The problem is solved via a model that combines two optimization technologies: stochastic control and multi-stage stochastic linear programming (SLP). As an example of an optimal pension product design, we present the operations research methods, which have potential to stimulate new thinking and add to actuarial practice.

Erick Delage (with Jonathan Y. Li)

Accounting for Risk Measure Ambiguity when Optimizing Financial Positions

Since the financial crisis of 2007-2009, there has been a renewed interest towards quantifying more appropriately the risks involved in financial positions. Popular risk measures such as variance and VaR have been found inadequate as we now value monotonicity, translation equivariance, positive homogeneity, and law invariance. Unfortunately, the challenge remains that it is unclear how to choose a convex risk measure that faithfully represents the decision maker’s true risk attitude. In this work, we show that one can account precisely for (neither more nor less than) what we know of the risk preferences of an investor/policy maker when comparing and optimizing financial positions. We assume that the decision maker can commit to a subset of the above properties (the use of a law invariant convex risk measure for example) and that he can provide a series of assessment comparing pairs of potential risky returns. Given this information, we propose valuing the riskiness of a financial position according to the most pessimistic estimation of the level of risk potentially perceived by the decision maker. We present how this value can be measured and optimized numerically through solving a linear program and apply the new method to a portfolio selection problem.
Jia Liu (with Zhiping Chen)

Time Consistent Recursive Risk Measures Under Regime Switching and Factor Models and Their Application in Dynamic Portfolio Selection

The proper description of dynamic information correlation among individual stages is very important, it directly affect the proper construction of multi-period risk measures and the selection of efficient investment strategy. To overcome the limitations of existing random frameworks, we initially introduce a "two-level" structure to describe the dynamic information evolution: the outer level describes endogenous marco-market factors under the regime switching framework; the inner-level describes exogenous random events by the multi-fact or model, where the time-varying factor coefficients are modeled by a time series model. Under the new random framework, we define the convex conditional risk measure, from which we derive the recursive multi-period risk measures. It is proved that the proposed multi-period risk measure satisfies dynamic monotonicity, convexity and time consistency. We show how to efficiently compute the new multi-period risk measure under our random framework and how to establish the corresponding multi-stage portfolio selection models. Take the static conditional value-at-risk (CVaR) measure as an example, we show how to deduce the corresponding recursive CVaR measure under our new random framework, and derive its explicit formulation when the factor coefficients follow the t-distribution. More importantly, we show that the resulting multi-stage portfolio selection problem under the recursive CVaR measure is a second-order conic programming, which can be quickly solved in polynomial time. Finally, we carry out a series of numerical experiments to show the necessity, reasonability and efficiency of our new random framework, and to demonstrate the superior performance and robustness of the optimal portfolios obtained with our multi-stage portfolio selection model under the recursive CVaR measure.

Jorge P. Zubelli (with Felipe Macias, Claudia Sagastizábal)

Optimal Liquidation Strategies for Portfolios under Stress Conditions

This work concerns the problem of liquidating a portfolio of financial instruments under stress or adverse conditions. The liquidation problem is of crucial importance for many clearing houses whenever an account holder (say a hedge fund) enters a situation of default and all its positions have to be liquidated satisfying certain time and volume constraints. This in turn is fundamental for the stability of the whole system. It is also fundamental in order for the clearing house to be able to compute the associated margin. Typically, the liquidation process under consideration has to be performed under adverse market conditions and thus issues of liquidity and high volatility have to be taken into account. We compare different approaches and present a few methodologies that make use of risk measures.

Diana Barro (with Elio Canestrelli, Fabio Lanza)

Controlling risk in dynamic asset allocation through stochastic optimization

The availability of dynamic investment strategies and the growing number of assets available to a broad range of investors lead to an increased interest in risk-controlled investment strategies. In this contribution we are interested in analyzing the role of optimization in the definition of proper dynamic strategies with the goal of controlling risk and protecting the portfolio performance thus enhancing the risk return profile of the investment. In particular we compare different strategies to highlight their effectiveness in providing downside protection and control ling costs of portfolio turnover. To this aim we consider both backward looking strategies, which adapt portfolio composition to the movements of the markets, and forward looking strategies which take advantage of the information content in volatility to improve portfolio performance. We provide an analysis of different strategies in different market conditions on real data.

Operations Management and Software

[Room 10] Transportation and Logistic

Chair(s): Guido Perboli, Francesca Maggioni

Amina Lamghari (with Roussos Dimitrakopoulos)

A diversified tabu search approach for the open-pit mine production scheduling problem with metal uncertainty

The open-pit mine production scheduling problem (MPSP) is an important and difficult problem arising in surface mine planning, solved to optimize the net present value of a mining operation. The MPSP has received significant attention in recent years. Several solution methods have been proposed for its deterministic version.
However, little is reported in the literature about its stochastic version, where metal uncertainty is accounted for. We formulate the MPSP with metal uncertainty as a two-stage stochastic program with recourse, and to solve it, we propose two metaheuristic methods based on tabu search and variable neighborhood search. Numerical results are provided to indicate the efficiency of the proposed methods to generate very good solutions in reasonable computational times.

Masoumeh Kazemi Zanjani (with Mustapha Nourelfath)

Integrated planning of operations and spare parts logistics under uncertainty in the supply chain of maintenance service providers

We investigate the integrated planning of operations and spare part logistics for the third-party maintenance service providers in the framework of supply chain Sales & Operations Planning. In such industries, due to the multi-indenture structure of the equipment, different types of components might randomly fail to perform at different points of time. As a consequence, the demand is hard to forecast. The company is looking for the optimal number of maintenance jobs that must be completed to deliver at each period, as well as the amount of spare parts that must be purchased from external suppliers so as to minimize the cost of spare parts procurement and inventory in addition to the delivery delay penalty, while taking into account the spare part procurement lead-time and availability. We first consider the demand uncertainty by modeling it as a manageable-size scenario tree. The problem is then formulated as a multi-stage stochastic program (MSP) with recourse and solved by the aid of progressive hedging algorithm for a small case study. Due to the large number of components in complex products, and regarding the multi-period nature of this problem, solving the resulting large-scale MSP model is a big challenge in real cases. As a solution to reduce the degree of uncertainty in the demand and spare parts lead time, we propose the company adapts a collaborative approach with customers and suppliers.

Mauro M. Baldi (with Guido Perboli, Roberto Tadei, L. Gobbato)

The Stochastic Generalized Bin Packing Problem

We present the Stochastic Generalized Bin Packing Problem (SGBPP), a further generalization of the novel Generalized Bin Packing Problem (GBPP) where items and bins are characterized by multiple attributes and item profits depend on the chosen bins and are random variables with unknown probability distribution. The SGBPP is a fundamental problem arising in logistics, multi-modal and cross-continent transportation where freight is not shipped directly from origins to destinations but calls at intermediate logistics platforms. At these facilities freight consolidation takes place and freight is moved to another transportation vector through handling operations which yield a utility but are random variables due to bin loading profit oscillations. Aim of the SGBPP is to model this setting in order to maximize the expected overall profit, given by the difference between the expected value of the profits of the selected items and the costs of the chosen bins. By means of the asymptotic extreme value theory, we derive a deterministic approximation.

Maria Elena Bruni (with Patrizia Beraldi, Demetrio Laganà)

The Stochastic Mixed Capacitated General Routing Problem: formulation and solution approaches

We study the Stochastic General Routing Problem defined on a mixed graph and subject to probabilistic capacity constraints. Such a problem aims to find the set of routes of minimum overall cost servicing a subset of required elements like vertices, arcs and edges. Since the demand associate to these elements is stochastic, the capacity constraints are chance constraints to be satisfied with a certain probability. In other words, we aim at minimizing some objective for a given feasibility tolerance. The problem is very interesting from a modeling point of view, since it is a generalization of a large variety of node and arc routing problems, but very challenging from a computational standpoint belonging, even in its deterministic version, to the family of NP-hard combinatorial problems. In this paper we present the mathematical formulation of the problem and tailored solution approaches. We demonstrate the effectiveness of this approach through an extensive computational study on a set of benchmark instances.
Given a set of nodes, where each pair of nodes is connected by several paths and each path shows a stochastic travel cost with unknown distribution, the multi-path Traveling Salesman Problem with stochastic travel costs (mpTSPs) aims at finding an expected minimum Hamiltonian tour connecting all nodes. The mpTSPs arises in City Logistics applications when one has to design tours to provide services such as garbage collection, periodic delivery of goods in urban grocery distribution, and periodic checks of shared resources as in bike sharing services. In these situations the decision maker must provide tours that will be used for a time horizon which spans from one to several weeks. In this case the different paths connecting pairs of nodes in the city are affected by the uncertainty due to the different time dependent travel time distributions of the paths. Moreover, in many cases even an approximated knowledge of the travel time distribution is made difficult by the large size of the data involved and the high variance of the travel times. Aim of this paper is twofold. First, we extend existing instances of the literature in order to cope realistic City Logistics applications to large and medium sized cities. Second, we deeply analyze the results obtained by combining the given instances with real data on the traffic flows taken from the city of Turin.
Tuesday 14.00-16.25 Minisymposia

New Concepts for Stochastic Systems

[Room Galeotti] Exogenous and endogenous uncertainty in SP
Chair(s): Laureano F. Escudero

Ignacio E. Grossmann (with Vijay Gupta)

Multistage Stochastic Programming for Planning under Endogenous Uncertainty: Models and Algorithms

In endogenous uncertainty, decisions can affect the stochastic processes in two different ways. Either they can alter the probability distributions, or they can control the times when uncertainties in are resolved. In this talk, we focus on the latter type of endogenous uncertainty where the decisions are used to gain more information, and resolve uncertainty either immediately or in a gradual manner. Therefore, the resulting scenario tree is decision-dependent. We present a multistage stochastic programming framework to model the problems in this class in which disjunctive constraints with propositional logic are considered to enforce the conditional non-anticipativity (NA) constraints that define the decision-dependent scenario tree. We first present full-space based approaches that exploit properties to reduce the potential number of NA constraints. Several decomposition algorithms are presented, including Lagrangean decomposition with scenario grouping that lends themselves to parallel solution of the scenario subproblems. Numerical results are presented on planning of process networks, and oilfield planning problems.

Georg Ch. Pflug

Decision dependent distributions and the response surface method
MS: Exogenous and Endogenous Uncertainty in Stochastic Programming

While the usual assumption in stochastic optimization is that the decision does not have an influence on the probability distribution of the uncertain parameters, there are quite a few problems with decision dependent distributions. Sometimes a reformulation may help to push the decision dependency out of the distributions and into the cost or profit functions. We illustrate this in some examples. But there are cases where this is not possible, especially if the uncertain parameters are stationary or transient distributions of Markov processes. In those cases, it is impossible to generate an approximate discrete stochastic parameter process beforehand. Typically the evaluation of just the value of the objective function is difficult and time consuming. We demonstrate how an optimization method can be designed, which is based on the response surface technique. Using measure-valued differentiation, it is possible to estimate not only the value of the objective function, but also some derivatives. This allows to construct a local approximation to the response surface. The approximate objective is used for an optimization in a trust region. Some examples show how the algorithm works.

Asgeir Tomasgard (with L. Hellemo, Paul I. Barton)

Capacity expansion using stochastic programming with decision dependent probabilities

We propose an investment problem modeled as a stochastic program with decision dependent probabilities. In addition to the available production technologies, we assume there is an activity or technology available that will alter the probabilities of the discrete scenarios occurring. By investing in such technology or activity, it is possible to increase the probability of some scenarios, while reducing the probability of the remaining scenarios, or viceversa. We also demonstrate the use of a specialized decomposition algorithm for this class of problems, using generalized Benders decomposition and relaxation of algorithms/McCormick relaxations. We illustrate the potential usefulness and the performance of the decomposition algorithm on this class of problems through an application from the Energy business.

Laureano F. Escudero (with M. Araceli Garin, María Merino, Gloria Pérez)

On multistage mixed 0-1 optimization under a mixture of Exogenous and Endogenous Uncertainty in a risk averse environment

We present a general multistage stochastic mixed 0-1 problem where the uncertainty appears everywhere. Two types of uncertainty are considered, namely, the exogenous uncertainty where the only action to be made by the modeler is to react in order to protecting his decisions and the non-usually treated uncertainty so named endogenous one, where the modeler decisions can change the weights of the potential scenarios to occur. The
stochastic model that considers a mixture of both types of uncertainty is converted in a mixed 0-1 Deterministic Equivalent Model. We model optimize the objective function expected value subject to Stochastic Dominance Constraints recourse-integer (SDC) for a set of profiles where both types of uncertainty are treated. An extension of our Branch-and-Fix coordination algorithm, the so named BFC risk averse SDC is presented, where a special treatment is given to the endogenous uncertainty as well as the cross scenario constraints required by the SDC strategies to consider in this work. Some computational experience is presented.

Christos Maravelias (with Matthew Colvin)

**Stochastic Programming Models and Algorithms for Pharmaceutical R&D Planning**

We first give an overview of the pharmaceutical research and development (R&D) pipeline and discuss how the planning of these activities results in problems where the decision maker alters the underlying stochastic process by affecting the timing of uncertainty observation. We discuss how this planning problem can be formulated as a large-scale multi-stage stochastic programming model. To address this challenging problem, we develop a number of theoretical results, modeling methods and computational techniques. First, we show how the structure of the problem can be exploited to formulate substantially smaller yet tighter models. Second, we discuss a number of approximations (e.g. finite-horizon approximation for rolling-horizon approaches) that can be used to obtain solutions of high quality. Third, we present a novel branch-and-cut algorithm where we start from a reduced model and add essential constraints only if they are violated. Finally, we discuss a number of extensions including, resource planning, interdependencies between tasks, and risk management.

**New Approaches to Classical Problems**

[Room 4] The Scenario approach to stochastic optimization

*Chair(s): Marco C. Campi*

Marco C. Campi

**The scenario approach to decision-making processes**

The "scenario approach" is a sample-based technique that has proved effective to address chance-constrained optimization problems. This first presentation aims at delivering a broad introduction to the scenario approach. The scenario approach will be presented as a tool for optimizing uncertain cost functions. The main idea of sampling from the uncertainty set and optimizing with the sampled scenarios as constraints is introduced. Moreover, it is shown that a suitable trade-off between risk and return can be pursued by constraint removal. Extensions and examples will complement the presentations.

Simone Garatti

**The fundamental theorems of the scenario approach**

The scenario approach stands on some fundamental theorems, which make this approach a valid method to approximate chance-constrained optimization problems. In this talk, the mathematical foundations of the scenario approach will be reviewed in a self-contained and rigorous manner.

Bernardo K. Pagnoncelli (with Marco C. Campi, Daniel Reich)

**Constraint removal in practice: a case study in portfolio selection theory**

The scenario approach with constraint removal is applied in this talk to portfolio optimization along two schemes, the first greedy and the other randomized. Along the way, new variants of the scenario approach are explored consisting in solving several instances of the scenario program, and then selecting the best among the achieved solutions. The results obtained in a problem with up to 200 assets are presented, and the effectiveness of the various methodologies is discussed.

Algo Carè

**Reconstructing the distribution of costs from observations**

After the scenario solution has been found, one can inspect the costs incurred by the chosen solution in correspondence of the various seen scenarios. These costs are called "empirical costs", and they offer an empirical description of the theoretical cost distribution.
This talk aims at presenting precise results able to link the empirical costs to the theoretical cost distribution. It is shown that the coverage of the empirical costs follows a Dirichlet distribution. This offers a mathematically precise tool applicable in diverse application contexts.

Cristian R. Rojas

A Scenario Based Approach to Robust Experiment Design

System identification deals with the problem of estimating dynamic models from input-output data. In this context, an important role is played by the information content in the available data set, so that, when the input to the system can be selected, a suitable choice becomes key to a successful result. This talk presents an input selection procedure where the input is obtained by optimizing the model accuracy over all candidate systems lying in a specified region. This problem can be formulated as a complex robust convex optimization program, which can be addressed by using the scenario approach.

Computation and Applications

[Room 3] Stochastic dominance in stochastic programming
Chair(s): Rüdiger Schultz

Rüdiger Schultz (with Laureano F. Escudero)

Stochastic Dominance Almost Everywhere in SP

To this minisymposium we have invited contributions on stochastic dominance models from different branches of stochastic programming. A proven instrument in decision theory, stochastic dominance gained attraction as an alternative means of risk management in stochastic programming from the 90s on. Today, stochastic dominance relations are established in two- and multi-stage stochastic programs with or without integer variables, in finite- or infinite-dimensional spaces.

Darinka Dentcheva (with Andrzej Ruszczynski)

Time-consistent stochastic orders

We consider stochastic order relations, which compare two stochastic processes. In the context of optimization of dynamic systems, a key property of the decision policy is its time-consistency. We present an approach to time-consistent stochastic orders. The approach will be illustrated by several examples.

Martin Branda (with Milos Kopa)

On relations between stochastic dominance efficiency tests and DEA-risk models

We deal with problem of investors who are looking for “attractive” investment opportunities on financial markets. They can invest into a single asset or combine the assets into a portfolio. Several approaches to efficiency testing are compared, based on stochastic dominance (SD) relations or Data Envelopment Analysis (DEA). We employ three different SD efficiency classifications: pair-wise, convex and portfolio with focus on the second-order SD criterion. In DEA-risk models, several risk or deviation measures and are used as the inputs, reward measures are chosen as the outputs. Various DEA models with constant return to scale (CRS), variable return to scale (VRS), and diversification-consistent (DC) DEA models are considered. We focus on the relations between the efficiency tests with suitable chosen risk measures and reward measures. In particular, we prove the equivalence between VRS DEA model with binary weights and the SSD pairwise efficiency test, between VRS DEA-risk model and convex SSD efficiency test, and between DC DEA-risk model and SSD portfolio efficiency test. In the empirical application, the efficiency of 48 US representative industry portfolios is investigated.

Maria Araceli Garin (with Laureano F. Escudero, María Merino, Gloria Pérez)

On Stochastic Dominance Constraints measures in multistage mixed 0-1 optimization problems

We extend to the multistage case the recent two-stage risk averse measures introduced in Gollmer et al., (2008) and (2011), such that in the formulation of the whole multi-stage stochastic mixed 0-1 optimization problem an objective function is maximized in the domain of a feasible region subject to first- and second-order Stochastic Dominance Constraints integer-recourse (SDC). Given the dimensions of these large-scale problems augmented by the new set of variables and constraints required by these two risk measures, it is unrealistic to solve the problem up to optimality by plain use of MIP solvers. Instead of it, decomposition algorithms of some type
should be used. We present an extension of our Branch-and-Fix Coordination algorithm, the so named BFC-MS risk averse SDC, where (besides some important refinements for cutting branches purposes) a special treatment is given to cross scenario cluster constraints that appear in SDC risk measures. A computational experience is presented by comparing the risk neutral approach and the tested risk averse strategies by using a randomly generated set of instances. The performance of the new version of the BFC-MS algorithm versus the plain use of a state-of-the-art MIP solver is also reported.

Dimitri Drapkin (with Rüdiger Schultz)

Equivalents and Algorithms for Programs with Stochastic Order Constraints Induced by Linear Recourse

We focus on two-stage problems with stochastic order constraints and only continuous variables in the second stage. MILP equivalent formulations are presented and compared along with suitable decomposition techniques for this problem class.

Finance and Applications

[Room 5] Stochastic models in natural resources

Chair(s): Andrés Weintraub

Andrés Weintraub

Stochastic Models in Natural Resources

Stochastic models have played an increasing role in planning and operating natural resources. The driver for this can be seen mainly in two factors: a) The increasing need to handle uncertainty more rigorously and b) The availability of much more powerful algorithms, softwares and computers. This talk does not pretend to cover the whole literature or a complete state of the art in the subject, but discusses main approaches we have seen in major natural resources. We will discuss as natural resources: forestry, mining, and fisheries. The two first areas are represented by the papers presented in this mini symposium. Depending on the area, the nature of uncertainty is usually markets (future prices), availability of the resource (present and future), growth and perishability, catastrophic events (as fires). We discuss how these problems come about, some of the models and algorithms proposed. The main models used represent uncertainty through scenarios. Typical algorithms to handle difficult to solve problems due to the non-anticipativity constraints are decomposition approaches such as Lagrangean relaxation, Progressive hedging, Coordinated Branching. This session will present work carried out along these lines, showing results on mostly real problems, and how these tools might be used by firms.

Natashia Boland (with Irina Dumitrescu, Gary Froyland)

Open-Pit Mine Production Scheduling with Stochastic Programming for Handling Uncertainty in the Mineral Body

The Open Pit Mine Production Scheduling Problem, which decides the time at which each unit of material will be extracted from the mine so as to maximize total NPV, has received a lot of attention in the research literature in recent years. However the production scheduling model is usually based on a single geological estimate of material to be excavated and processed. While some attempts have been made to use such multiple stochastic geological estimates in mine production scheduling, none allow mining and processing decisions to flexibly adapt over time in response to observation of the geology of the material mined. Doing so gives rise to the difficult case of multi-stage integer stochastic programming under endogenous uncertainty: mineral bodies have spatial correlations, so where mining occurs (a decision of the model) affects what is learned about the body. We show that this uncertainty can be modelled naturally using integer variables already present in the integer linear programming formulation. The resulting formulations have a large number of constraints which can be reduced using the scenario structure, even for quite general underlying probability distributions. We also discuss heuristics that can be used to further reduce solution times and illustrate the various numerical approaches on realistic data sets.

Antonio Alonso-Ayuso (with Felipe Carvallo, Laureano F. Escudero, Monique Guignard, Jiaxing Pi, Raghav Puranmalka, Andrés Weintraub)

Medium range optimization of copper extraction planning under uncertainty in future copper prices

Deterministic mine planning models have proved to be effective in supporting decisions on sequencing the extraction of material in copper mines. These models have been developed for, and used successfully by CODELCO (Chilean state company). In this contribution, we consider the uncertainty in the (very volatile) cop-
per price, represented by a multistage scenario tree. The resulting stochastic model is then converted into a mixed 0-1 Deterministic Equivalent Model using a compact representation. We introduce the risk neutral stochastic and several approaches for risk management (based on the Value-at-Risk, the Conditional Value-at-Risk, the weighted probability of having a undesirable scenario in the solution provided by the model, or on stochastic dominance constraints). We present an extensive computational experiment, by comparing the risk neutral approach, the different risk aversion strategies and the performance of the traditional deterministic approach (based on expected value of the uncertain parameters). The results clearly show the advantage of using the stochastic approaches over the deterministic one, as well as the advantage of using any risk aversion strategy.

Rafael Epstein (with Andrés Weintraub, Carlos Villa, Jaime Gacitua, Rodolfo Urrutia, Roger Wets, David L. Woodruff, Jean-Paul Watson)

Use of Stochastic Models in Mining with Progressive Hedging

CODELCO, the largest copper firm in the world, has been using deterministic MIP models we have developed to plan long range extraction and processing of material for the last decade, with very good results. The firm has always been aware of important issues of uncertainty, mainly in terms of future copper prices, which are highly volatile. In this paper we present the development of a Progressive Hedging (PE) approach to handle this problem. The uncertainties in prices, through a 5 year horizon are represented through scenarios. Developing the scenarios is a challenge by itself. In order to represent well the price uncertainties at least several hundred scenarios would have to be defined. This makes the problem very difficult to solve, given the non-anticipativity constraints. PE decomposes the problem by scenarios. The algorithm is combined with heuristics to accelerate convergence, and then going to a MIP algorithm after a small number of PE iterations for efficient solutions. We present the algorithm developed and results on a real open pit mine. We discuss the advantages of this approach. We also show how by using a parallel algorithm we can take advantage of this decomposition by scenarios.

Ignacio Rios (with Roger Wets)

Modeling and estimating copper prices

Many optimization problems consider copper prices as an important input. Nevertheless, prices are highly volatile and no one can predict them, but they can be estimated and scenario trees can be constructed to handle their stochasticity. In this talk we present a new methodology for modeling and estimating copper prices, based on two novel approaches. The first one is to make a distinction between short and long term (also known as the transient and the stationary processes), because the evidence shows that in the short term prices are highly volatile around a drift term, whereas in the long term prices are mean-reverting as the microeconomic theory suggests. The second approach considers the inclusion of market information to complement the historical data in the estimation of the drift term for the short term model. The use of market prices should be very important because it contains all the information available in markets at this time (stocks, expectations, etc.), so its inclusion should help to capture the real drift term for our transient process. Finally, our model also takes into account inflation which leads us to a multi-dimensional (nonlinear) system for which we can generate explicit solutions.
Tuesday 16.55-19.00 Parallel Sessions

Advances in stochastic programming and contiguous fields - 1
[Room Galeotti] Optimization under incomplete information
Chair(s): Guzin Bayraksan

Bita Analui

On Robust Multistage Stochastic Optimization with application in Energy

Despite the wide range of stochastic programming literature, the majority of research efforts share one crucial assumption, specifically, that the underlying probability model is known in advance. However, in practice there is some uncertainty about the probability model of the random parameters. The incomplete knowledge of the probability model has led a series of studies assuming that true underlying probability model belongs to a specified class of models and has motivated the utilization of minimax (maximin) decision rule. In this paper we introduce an approach that explicitly takes into account the ambiguity in probability model for the real world class of multistage stochastic optimization problems where the robustness of the decisions are highly expected. We study and develop the concept "ambiguity" of dynamic trees and related results for multistage stochastic optimization problems incorporating the results from multistage distance. In this line, we define the ambiguity set as a "nested" ball around a reference measure P with respect to multistage distance dl and therefore robustify the original problem by a worst case approach with respect to this ambiguity neighborhood. Finally the algorithm is applied to a multistage energy portfolio optimization problem and this way we analyze the sensitivity of decisions with respect to model changes for a real world class of problem

Jie Sun (with J. Ang, F. Meng)

Two-stage Stochastic Linear Programs with Incomplete Information on Uncertainty

Two-stage stochastic linear programming is a classical model in operations research. The usual approach to this model requires detailed information on distribution of the random variables involved. In this paper, we only assume the availability of the first and second order moments information of the random variables. By using duality of semi-infinite programming and adopting a linear decision rule, we show that a deterministic equivalence of the two-stage problem can be reformulated as a second-order cone optimization problem. A numerical example is presented to demonstrate the computational advantage of this approach

Chaoyue Zhao (with Yongpei Guan)

Risk-Averse Stochastic Optimization with Incomplete Information

In this paper, we study the two-stage stochastic optimization with incomplete information of probability distributions of random parameters, i.e., instead of knowing the true distribution of the random parameter, we only know some historical data/samples that taken from the true distribution. To obtain a risk-averse decision, we develop a robust two-stage stochastic optimization formulation with the objective of minimizing the worst-case cost over a set of distributions that agree with the historical data. We propose to explore reformulations for the problem and develop approximation approaches to solve the problem.

Ruiwei Jiang (with Yongpei Guan)

Stochastic security constrained unit commitment with incomplete information

Continuously increasing renewable energy penetrations (such as wind and solar) have made the power system more volatile and uncertain, and brought new challenges for the system operators in both regulated and deregulated electricity markets to ensure system reliability and maintain cost effectiveness with incomplete information. In this talk, we study a stochastic security constrained unit commitment (SCUC) model with incomplete information. Based on historical data of renewable energy, we construct a confidence set for the probability distributions of the renewable energy and propose a data-driven SCUC model to hedge against the distributional ambiguity. Furthermore, we develop a solution approach for the model based on decomposition and separation. Our case studies verify the effectiveness of our proposed model and solution approach
Guzin Bayraksan (with David Love)

On the Use of Phi-Divergences for a Class of Two-Stage Ambiguous Stochastic Programs

Instead of using a probability distribution (assumed known) in a two-stage stochastic program, we consider an ambiguity set of distributions that are sufficiently close to a specified distribution in terms of phi-divergences (e.g., Kullback-Leibler, chi-squared, etc.). This results in a class of stochastic minimax problems that can be used in data-driven settings. In this talk, we examine the value of collecting additional data and cost of finding a solution to an ambiguous probability distribution set defined by phi-divergences. We present basic properties and examine the asymptotic behavior when the central, specified distribution is the empirical distribution. We present a decomposition-based algorithm to solve these programs efficiently. We illustrate our results on a special case, which has been studied as the likelihood robust optimization (LRO). LRO considers a set of distributions with sufficiently large likelihood for a given set of observations and is equivalent to restricting the set of distributions to be close enough to the empirical distribution in terms of the Kullback-Leibler divergence. An application to water distribution is provided.

Problem formulation and solution algorithms

[Room 5] L-shaped and Benders’ decomposition
Chair(s): Laureano F. Escudero

Anahita Hassanzadeh (with Theodore K. Ralphs, Menal Guzelsoy)

A Generalized Benders’ Algorithm for the Two-Stage Stochastic Optimization Problem with Mixed Integer Recourse

The structure of the value function of a mixed integer linear program makes direct application of the traditional Benders’ method to general two-stage stochastic optimization problems difficult. One difficulty arises in the challenge of finding effective dual functions that can be used approximate the value function from below. In general, the value function is piecewise polyhedral, discontinuous, and non-convex and it can therefore be best approximated by similarly structured functions. Unfortunately, the use of such functions renders the master problem challenging to solve. In this presentation, we focus on both the theoretical and computational challenges arising when the dual functions are derived from the branch-and-bound trees arising from solution of recourse subproblems. We discuss cut-pool management techniques and a trust-region-based modification to the main method that improves its practicality.

Gustavo Angulo (with Shabbir Ahmed, Santanu S. Dey)

Improved optimality cuts for the integer L-shaped method

We propose an approach to improve the optimality cuts generated by the integer L-shaped method. While the original implementation only uses local information of the solution to be cut off, our approach generates optimality cuts based on the information provided by all feasible solutions visited so far at a given step of the method. In developing this approach, we prove the tractability of describing the convex hull of all binary vectors except a list of forbidden vectors.

Sara Lumbreras (with Andres Ramos)

Improvements to Benders’ decomposition: systematic classification and performance comparison in a Transmission Expansion Planning problem

Benders’ decomposition has been widely applied as an efficient way of solving two-stage stochastic problems with linear recourse. Extensive research has been dedicated to improvements to this method. This presentation performs a comprehensive review of these techniques and compares them in a practical setting. The methods can be classified as modifications to the master problem and modifications to the subproblem. Within the first group, there are changes to the solution technique (such as the use of relaxed, suboptimal or alternative master solutions) and changes to the calculation of the cuts (such as alternative cut definitions and cut removal). The techniques that modify the subproblem include methods such as scenario aggregation, bunching, inexact solutions or incremental modelling. These techniques are concisely presented and related to the situations where they can improve the performance of a straightforward decomposition. Several of them are compared using a Transmission Expansion Planning Problem (TEP), which is particularly amenable to Benders’ decomposition and that has been extensively studied with this method in the literature. The main improvement techniques
that are applicable in this case are identified and implemented in several case studies of different sizes. Their performance is assessed and compared.

Joaquim Garcia (with Alexandre Moreira, Alexandre Street, Álvaro Veiga, Bruno Fanzeres, Delberis Lima, Lucas Freire)

A Benders Decomposition Approach to find the Nucleolus Share of a Renewable Hedge Pool

Due to its energy production intermittency, renewable sources are exposed to the so-called price-quantity risk, which occurs whenever the seller is long in contracts and must settle the amount sold but not produced at highly volatile spot prices. Since these sources shows great complementarity, we propose a pool in which generators will trade their energy jointly, creating a less intermittent profile with greater commercial value. In this context, the pool members will be less exposed to these spot-prices, mitigating the price-quantity risk. In order to share the financial quotas of the renewable hedge pool, we resort to cooperative games theory. We make use of a core-based method, which consists of finding a set of imputations under which no coalition has a value greater than the sum of its members’ payoffs in the pool. Thus, no coalition has enough stimuli to leave the pool, creating a stable set. However, the computational effort to find this solution grows exponentially with the number of players. In this context, we present a methodology based on Benders decomposition to find a set of umbrella constraints that shapes the feasible region without considering all of them.

Mathias Barkhagen (with Jörgen Blomvall)

A stochastic programming model for hedging options in a market with transaction costs

We consider the problem of hedging a portfolio of options with the help of standardized options and futures. For this problem we propose a stochastic programming (SP) hedging model which minimizes the variance of the daily portfolio returns and at the same time penalizes transaction costs in order to produce a cost-effective hedge. The performance of the SP hedging model crucially depends on using a high quality representation of the joint distribution of future market variables, which consist of the price of underlying security, the volatility surface, the interest rates and the dividends for the underlying security. The volatility surface is unobservable and must be estimated from a cross-section of observed option quotes that contain noise and possibly arbitrage. In order to produce arbitrage-free volatility surfaces with high quality as input to the SP model a novel non-parametric estimation method is used. The dimension of the volatility surface is infinite and in order to be able solve the problem numerically we use discretization and PCA to reduce the dimensions of the problem. Using historical market data we present preliminary results of the hedging model and compare the results with a dynamic delta-vega hedging strategy.

Bruno Fanzeres (with Aderson Passos, Alexandre Street, Alexandre Moreira, Álvaro Veiga)

Investing in complementary renewable sources using stochastic-robust optimization and real options

The complementarity between renewable sources allows trading energy with less exposure to short-term market variabilities. From the energy trader point of view, a hybrid model that merges robust and stochastic optimization coupled with a real option binomial model was built. Such model allows a better planning for this sort of trade by defining how much of each source should be bought/sold and indicating the best moment to start trading. In doing so, it enables long-term investments and mitigate risks.

Dmitry Golembiovsky (with Anatoly Abramov)

Management of Portfolio of Options With Two Expiration Dates

In [1] a model of option portfolio management using stochastic programming is developed. The artificial risk-neutral market is considered. That work also presents results of experiments, where the portfolio includes options of a unique expiration date only. Now we consider portfolio of options with two maturities. To solve the optimization problem, we construct an approximated chance constrained problem with continuous variables that decreases computer time consumption dramatically. The option portfolio starts with options of the nearest expiration only. The following strategy of entering in the next expiration options is used. At first the scenario tree includes stages for the current day, for the 7th day, for the 14th day and for 21st day (the last day because
only working days are considered) of a current month. If achieved probability to make profit not less than demanded during optimization on the 7th or 14th day is less than 0.999, we include the next expiration options in the portfolio. To do this, a new scenario tree is constructed and the according optimization problem is solved. For example, for the 7th day of the current month the tree can include stages for the current day (7th), 14th day, 21st day and for 21st day of next month. Thus options of two expiration months can be included in the portfolio. In case when on 7th or 14th day achieved probability of success is more than 0.999, we do not include next expiration options in the portfolio. Since we don't use options of the next expiration, the portfolio expires on the 21st day of the current month. The described strategy is used for each simulated month. In the whole, we simulated 10 1-year traces of portfolio management. It took about 96 hours on the computer Intel Pentium Dual-Core 2.20 GHz. Not one trace finished with a loss. References [1] Golembiovsky D., Abramov A. (2013). Options Portfolio Management As a Chance Constrained Problem. In the book: Stochastic Programming: Applications in Finance, Energy, Planning and Logistics. World Scientific Publishers, p.155-173.

Mohamed Kharrat (with Yacin Jerbi)

Using Malliavin derivative to price an American option under stochastic volatility

The aim of this paper is to elaborate a methodology based on the Malliavin calculus, for the conditional expectation calculus, in order to price an American option under stochastic volatility. This methodology is an extension of the Bally and al. (2005) work based on the constant volatility hypothesis. In the present work the volatility is supposed to follow the CIR process (Heston Process). Our main contribution consist on the elaboration of the aforesaid methodology which is based on two new theorems we have developed and proved.

Nicola Secomandi

Analysis and Enhancement of Practice-based Methods for the Real Option Management of Commodity Storage Assets

The real option management of commodity storage assets is an important practical problem. Practitioners approach the resulting stochastic optimization model using the rolling intrinsic (RI) and rolling basket of spread options (RSO) heuristic policies, which rely on sequential reoptimization of a deterministic dynamic program and a linear program based on futures price spread options, respectively. Used in conjunction with Monte Carlo simulation, these methods typically yield near optimal lower bound estimates on the value of storage. This paper provides novel structural and numerical support for the use of the RI and RSO policies, and enhances them by developing a simple and effective dual upper bound to be used in conjunction with these policies.

Advances in stochastic programming and contiguous fields - 2

[Room 3] Endogenous uncertainty

Chair(s): Ignacio E. Grossmann

Eric Laas-Nesbitt

A trust-region approach for optimization under decision-dependent uncertainty

The usual setting in stochastic optimization is one where the decision-maker faces uncertain outcomes driven by a stochastic system that he cannot influence. Under this exogenous uncertainty, his aim is to optimize the expectation, risk or some other functional of the expected cost or reward. In the setting considered by us, uncertainty is instead endogenous, meaning that the decision-maker can choose parameters that directly determine the underlying probability distribution. Examples of applications are found in stochastic control and maintenance. Our approach combines ideas from response surface methodology (RSM) and trust-region (TR) methods, which are joined together by the measure-theoretic differentiation concept known as measure-valued differentiation (MVD). TR methods are widely applied in deterministic optimization, but in stochastic optimization, it is often unclear how to compute derivatives. MVD provides a widely applicable method that has been shown to produce good computational results when used for simulation. These simulations are run within an RSM framework, but the response surface at each iteration is approximated not by regression, as usually the case, but by a Taylor polynomial, in accordance with the TR approach. Because this method avoids simulating in many different points, instead focusing on one point and extracting local information from the first, second and possibly higher derivatives at that point, the total simulation time of the algorithm should be reduced.
Dimitrios Papadimitriou (with Piet Demeester)

Multi-agent multi-stage stochastic programming with endogenous uncertainty

In multi-stage stochastic programming (MSP), the uncertainty in parameters, e.g. demands, yields, defining a decision problem are represented by probability distributions and the interactions between the stochastic and decisions processes are modeled so that the decision-maker can take corrective actions (recourse) as uncertainty is revealed sequentially over multiple stages (time periods). Compared to exogenous uncertainty where decisions cannot influence the stochastic process, with endogenous uncertainty the stochastic process depends on the decisions that can alter it by changing the probability distribution or resolving the uncertainty partially or fully. Recently, the problem of finding optimal decisions with gradual reduction of uncertainty in the yields has been formulated as a decision-dependent MSP where investment plans reduce uncertainty and time-varying distributions describe uncertainty. We extend this problem to multi-agent decision processes for distributed systems with uncertain yields, where agents determine at each time period their capacity allocation and expansion/reduction following coordination processes that reduce randomness in predicting agents decisions.

Tahir Ekin (with Nicholas Polson, Refik Soyer)

Simulation-based SP under Endogenous Uncertainty with Applications in Operations Management

In a multi-stage decision making framework under uncertainty, previously made decisions may make some scenarios of the random variable more likely or unlikely. We consider so called endogenous (decision dependent) uncertainty within two-stage stochastic optimization problems with recourse. We provide a simulation-based approach by developing an augmented probability model over the sources of stochastic uncertainty and decision variables. Markov chain Monte Carlo methods are utilized to sample from the resulting non-standard distributions. Our method can deal with both discrete and continuous sources of uncertainty. Efficiency gains are expected for particular settings as computation of expectation and optimization are processed simultaneously. Proposed approach is illustrated by solving integrated maintenance and production planning problems in which the randomness of the yield of a machine depends on the previous maintenance and production decisions.

Bruno Flach (with Carlos Raoni Mendes, Marcus Poggi de Aragao)

A Stochastic Programming Approach to Risk Mitigation Strategies in Project Management

Large projects are often conducted by governments or large enterprises for the construction of the massive infrastructure required for a diverse set of economic activities - for example, those related with energy, transportation and industrial applications. A number of potential risk sources coupled with resource constraints, intricate precedence relationships and multiple inter-dependencies among different sets of activities and various projects render monitoring and managing such endeavors into a very complicated task. Project managers are constantly challenged to define plans and take actions to ensure that projects are completed within limits of time, cost and scope. In this work, we describe the development of a stochastic programming model with endogenous uncertainty aimed at determining optimal risk mitigation strategies. Computational results are provided to illustrate the proposed methodology.

Quang Kha Tran (with Panos Parpas, Berk Unstun, Mort Webster)

Importance Sampling in Stochastic Programming: A Markov Chain Monte Carlo approach

Stochastic programming is a framework for modeling large-scale optimization problems under uncertainty. Optimization algorithms for such problems need to evaluate the expected future cost of current decisions, often referred to as the recourse function. In practice, this calculation is computational difficult as it requires the evaluation of multidimensional integral whose integrand is an optimization problem. In this paper, we propose a novel importance sampling framework for multistage stochastic programming that can produce accurate estimates of the recourse function. Our framework exploits the techniques in Markov Chain Monte Carlo and Kernel Density Estimation to create a non-parametric importance sampling distribution that can form a low variance estimate of the recourse function. Using variants of the Newsvendor problem in the context of multistage stochastic programming, our numerical results show that our approach outperforms other existing methods in terms of accuracy and efficiency, especially for problems with moderate to high variance, multimodal or rare-event distribution.
### Advances in stochastic programming and contiguous fields

**[Room Galeotti] Robust Optimization**  
*Chair(s): Daniel Kuhn*

**Xuan Vinh Doan (with Xiaobo Li, Karthik Natarajan)**

**Minimax stochastic program with overlapping marginals**

We investigate the effect of distribution ambiguity given (overlapping) multivariate marginals of random parameters on the evaluation of expectations of convex piece-wise linear functions. We discuss the computational tractability of the evaluation of the tight bound and the construction of the extremal distributions that achieve the bound. We apply the proposed model for worst-case conditional value-at-risk evaluation. Numerical results are presented for bounds on sum of dependent risks and portfolio optimization.

**Michael Poss**

**Robust combinatorial optimization with cost uncertainty**

We present a new model for robust combinatorial optimization with cost uncertainty that generalizes the classical budgeted uncertainty set. We suppose here that the budget of uncertainty is given by a function of the problem variables, yielding an uncertainty multifunction. The new model is less conservative than the classical model and approximates better Value-at-Risk objective functions, especially for vectors with few non-zero components. We provide an asymptotically tight bound for the cost reduction obtained with the new model. We show that when the budget function is affine, the resulting optimization problems can be solved by solving $n+1$ deterministic problems. We propose combinatorial algorithms to handle problems with more general budget functions. We also adapt existing dynamic programming algorithms to solve faster the robust counterparts of optimization problems, which can be applied both to the traditional budgeted uncertainty model and to our new model. We evaluate numerically the reduction in the price of robustness obtained with the new model on the shortest path problem and on a survivable network design problem.

**Vladimir Roitch (with Daniel Kuhn, Yike Guo)**

**Pricing of Multi-Product Monopolistic Cloud Computing Services with Service Level Agreements**

Cloud Computing is a new computing paradigm that gives end-user-demand access to computing resources of companies that maintain large data centres. Here, we address the optimal pricing of cloud computing services from the perspective of a monopolistic service provider that needs to manage demand responsiveness and uncertainty for many products. We formulate the pricing problem for on-demand services as a multi-stage stochastic program and model service level agreements via chance constraints. Under weak assumptions about the demand uncertainty we show that the resulting model can be reduced to an equivalent two-stage stochastic program. As cloud computing is only just emerging, it is impossible to reliably estimate demand distributions from historical data. Indeed, such data may even be difficult to collect. We address this type of model uncertainty by adopting a distributionally robust approach, assuming that only information about the location, size and support (but not the shape) of the demand distribution is available. We show that the arising robust model can be reformulated as a (possibly non-convex) quadratic program and develop insights into its solution.

**Eli Gutin (with Daniel Kuhn, Wolfram Wiesemann)**

**Interdiction Games on Markovian PERT Networks**

In a stochastic interdiction game a proliferator aims to minimize the expected duration of a nuclear weapons development project, while an interdictor endeavors to maximize the project duration by delaying some of the project tasks. We formulate static and dynamic versions of the interdictor's decision problem where the interdiction plan is either pre-committed or adapts to new information revealed over time, respectively. The static model gives rise to a stochastic program, while the dynamic model is formalized as a multiple optimal stopping problem in continuous time and with decision-dependent information. Under a Markov assumption, we prove that the static model reduces to a mixed-integer linear program, while the dynamic model reduces to a finite Markov decision process in discrete time that can be solved via efficient value iteration. We then generalize the dynamic model to account for uncertainty in the outcomes of the interdiction actions. We also discuss a crash-
ing game where the proliferator can use limited resources to expedite tasks so as to counterbalance the interdictor’s efforts. The resulting problem can be formulated as a robust Markov decision process.

Anh Ninh (with Andras Prekopa)

**Solution of Probabilistic Constrained Problems with Compound Poisson Distributions**

We prove that the compound Poisson distribution is log-concave, under some conditions for the distribution of the terms, then formulate and solve probabilistic constrained stochastic programming problems, for both the discrete and continuous distribution cases, regarding the compound Poisson random variables. Applications in insurance and finance will be mentioned.

**Problem formulation and solution algorithms**

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Débora Dias Jardim Penna (with André Luiz Diniz, Maria Elvira Piñeiro Maceira)

**Conditional Value-at-risk Versus Multidimensional Rule Curves Within the Risk-averse Sddp Approach**

Recently, risk-averse approaches have been applied to hydrothermal generation planning problems, via chance-constrained programming, robust optimization or by applying risk measures such as CVaR. The latter approach has been successfully applied to real systems under a stochastic dual programming algorithm (SDDP) framework. Although simulation studies show that the policy obtained by such procedure yields a more secure operation, it is difficult to calibrate its parameters in order to ensure a specific level of protection to some benchmark drought scenarios. We propose the iterative construction of a multidimensional rule curve for the reservoir operation within the SDDP algorithm, where an inner iterative procedure is included to solve the subproblem for each stage, in order to ensure a desired level of protection along given critical scenarios some months ahead. Feasibility cuts - which are a function of state variables of the problem and can be shared among the forward states - can be added to the stage subproblems to create a time-variant secure region for system operation. We compare the results obtained by the CVaR and the proposed approach for the Brazilian system operation.

Murilo Pereira Soares (with Alexandre Street, Davi Michel Valladão)

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

In the Brazilian energy operation planning context, Stochastic Dual Dynamic Programming (SDDP) determines hydrothermal planning decisions based on auto-regressive (AR) models for associated risk factors. In this work we show that using AR models to generate realizations leads to an undesirable drawback on SDDP: the variability of the solutions increases with respect to changes in the AR initial conditions due to its propagation to the future. We propose a slightly modified version of the risk averse SDDP algorithm aimed at reducing decisions and marginal costs variability induced by the use of AR models. The proposed approach consists of solving the algorithm with an independent model in the backward procedure, to ensure solution variability reduction, and a realistic time series model in the forward procedure, to ensure good trial points for the backward step. It is shown by numerical results that this approach can lead to conservative solutions with much less variability than the traditional approach. Moreover, we argue that this approach is more flexible since it is not restricted to AR models as in the original SDDP algorithm.

Fernanda S. Thome (with Mario V. Pereira, Sérgio Granville, Marcia H. C. Fampa)

**Representation of non-convexities in stochastic dual dynamic programming applied to hydrothermal operation problems**

This work describes an extension of the Stochastic Dual Dynamic Programming (SDDP) algorithm to represent non-convexities on the hydrothermal operation planning problem formulated as a mixed integer multistage stochastic model. The proposed methodology makes use of a non-conventional approach of the Lagrangian relaxation technique for convexification of the recourse function, and a special procedure is applied in order to find valid stronger Benders cuts to build the approximated future cost functions. Discussion is made over the topic of whether we should really worry about guarantying approximations that are lower bounds to the original functions. Although it avoids feasible solutions to be cut, those outer approximations could lead to inefficient strategies when dealing with highly non-convex problems and, consequently, to inadequate system opera-
tion. By focusing on the non-convexity introduced by the hydro production variation with storage, a more aggressive cut-generation strategy is also proposed using variables transformation. Finally, study cases of real hydrothermal systems are used to make analysis over the dilemma of choosing the best methodology for this problem.

Luiz Carlos Da Costa Jr. (with Mario V. Pereira, Sérgio Granville, Nora Campodonico, Marcia H. C. Fampa)

Stochastic Dual Dynamic Programming with CVaR Risk Constraints Applied to Hydrothermal Scheduling

The classic hydro-thermal scheduling problem involves the computation of the optimal operating policy for the use of hydro and thermal resources in order to meet the electricity demand while minimizing total expected costs over a given time horizon. This problem can be formulated as a multi-stage stochastic linear programming model and has been efficiently solved using the well know SDDP technique, which is based on multi-stage stochastic Benders decomposition, avoids the discretization of state space and also the deals with the “explosion” of scenario tree as the number of stages increase. The minimization of expected costs in the classic hydrothermal scheduling problem has always been challenged under a risk-constrained framework: the risk-neutral operations policy fails to capture events that have low probability of occurrence but might have important cost impacts. More recently, several studies attempted to overcome this aspect and incorporate risk aversion in the stochastic hydrothermal scheduling problem by means of Conditional Value-at-Risk (CVaR). CVaR is introduced in the objective function of the optimization problem and the minimization of the convex combination of the expected value and CVaR of the operation costs is carried out in the classic SDDP scheme. The objective of this work is to propose an alternative representation of risk-aversion in the stochastic hydrothermal scheduling problem: instead of representing CVaR in the objective function, we propose the explicit consideration of CVaR as constraints of the optimization model. In our model we are not interested in controlling the CVaR of the operation cost at a risk level but to control the expected value of the non-served energy at a risk level, thus aiming a reconciling the planning and operations objectives (ensuring supply reliability at a given risk level). At first hand, this formulation requires the representation of all variables and constraints of each scenario into a single programming problem and, thus, would confine its application to small instance problems. Moreover, it would also prevent the application of the SDDP algorithm once SDDP is based on the decomposition of the original problem into smaller problems one for each time stage and scenario. We present an extension of the SDDP algorithm to incorporate such CVaR constraints and show that these constraints can be represented as piecewise linear penalties on the energy not supplied, and then develop an efficient algorithm to calculate the segment coefficients. The methodology will be illustrated with a realistic stochastic hydrothermal scheduling problem.

Vaclav Kozmik

Risk-averse multistage stochastic programming

This paper deals with a risk-averse multistage stochastic problem using a coherent measure of risk, such as CVaR. The underlying random process is assumed to be stage-wise independent and Stochastic Dual Dynamic Programming algorithm (SDDP) is applied. We discuss the poor performance of upper bound estimators in the CVaR setting and provide a modified procedure, which tightens the upper bound. Only mild conditions and a little additional computational effort are required to apply the new upper bound estimator. In addition, numerical examples for various risk measures are given for a simple stock allocation multistage problem using Lognormal distribution for the asset returns.

Energy

[Room 3] Bidding in electricity market

Chair(s): Stein-Erik Fleten, Trine Krogh Boomsma

Trine Krogh Boomsma (with Nina Juul, Stein-Erik Fleten)

Bidding in sequential electricity markets: The Nordic case

For electricity market participants trading in sequential markets with differences in price levels and risk exposure, coordinated bidding is highly relevant. We consider a Nordic power producer who engages in the day-ahead spot market and the near real-time balancing market. In both markets, clearing prices and dispatched volumes are unknown at the time of bidding. However, in the balancing market, the agent faces an additional risk of not being dispatched. Taking into account the sequential clearing of these markets and the gradual realization of market prices, we formulate the bidding problem as a multi-stage stochastic program. We investigate
whether higher risk exposure can explain the hesitation, often observed in practice, to bid into the balancing market, even in cases of higher expected price levels. Furthermore, we quantify the gain from coordinated bidding, and by deriving bounds on this gain, assess the performance of alternative bidding strategies used in practice.

Salvador Pineda Morente (with Juan M. Morales, Marco Zugno, Pierre Pinson)

**Electricity Market Clearing With Improved Scheduling of Stochastic Production**

We consider an electricity market that consists of a day-ahead and a balancing settlement, and includes a number of stochastic producers. We first introduce two reference procedures for scheduling and pricing energy in the day-ahead market: a conventional network-constrained auction purely based on the least-cost merit order, where stochastic generation enters with its expected production and a low marginal cost; and a counterfactual auction that also accounts for the projected balancing costs using stochastic programming. Although the stochastic clearing procedure attains higher market efficiency in expectation than the conventional day-ahead auction, it suffers from fundamental drawbacks with a view to its practical implementation. In particular, it requires flexible producers to accept losses in some scenarios. Using a bilevel programming framework, we then show that the conventional auction, if combined with a suitable day-ahead dispatch of stochastic producers (generally different from their expected production), can substantially increase market efficiency and emulate the advantageous features of the stochastic optimization ideal, while avoiding its major pitfalls.

Gro Klæboe

**Decomposition for day-ahead bidding of hydro power portfolios - experiences and challenges**

In the hydro power dominated Nordic electricity market, short term optimization tools for production planning has been in use for the last decade. When it comes to bidding, however, there is a pronounced lack of formalized tools. Faced of an uncertain day-ahead market price, a stochastic optimization model could be useful. To outperform the current manual or scenario-analysis based bids, the model would need to take a sufficient level of technical details into account and also be able to calculate a optimal bid within reasonable time. Detailed modelling of hydro power gives challenges in the form of non-linearities (head water level dependence), non-convexities (variable efficiency) and integer variables (start-up costs). In this talk I summarize the experiences with different decomposition attempts (Benders decomposition, progressive hedging), and compare performance with scenario based bid construction.

Vadym Omelchenko

**Model of Approximate Dynamic Programming Applied on Day-Ahead Trading of a Renewable Producer of Energy**

In our model, we determine optimal bidding strategies of a producer that generates energy from renewable sources by using approximate dynamic programming. The assumptions of the model correspond to a competitive market environment. The producer will have an option to store the energy in a reservoir. To model transition matrix, we will use elliptical stable distributions and classification methods. The results will be demonstrated on data of Central European markets.

Stein-Erik Fleten (with Jørgen Braathen, Anders Eriksrud, Gro Klæboe, Daniel Kuhn)

**Bidding hydroelectric power via decision rules**

The main way to sell power physically in Europe is through organized auctions for exchange of power for the next 12-36 hours. Consumers and producers can submit piecewise linear (in some countries piecewise constant) price-quantity curves for each hour, to signal their willingness to produce at different price levels. Since the prices are not known prior to submission of bids, a stochastic programming approach is meaningful. Furthermore, a practical way of characterizing the marginal cost of production for a hydropower producer is by detailed modelling of the power plants including the reservoir dynamics. This aspect also lends itself to an optimization approach. The bids can be thought of as piecewise linear decision rules, and we explore the decision rule approach to stochastic programming in this talk, with application to a power plant in Norway.
Generalized quantiles as risk measures

It is well known that the quantiles of a random variable may be defined as the minimizers of a piecewise linear loss function. In the statistical and actuarial literature several generalized quantiles have been introduced, by considering more general loss functions: expectiles (Newey and Powell, 1987), $L^p$ quantiles (Chen, 1996), M-quantiles (Breckling and Chambers, 1988), Orlicz quantiles (Bellini and Rosazza Gianin, 2012). In this paper we investigate the potential applicability of generalized quantiles as risk measures; as a natural domain for the loss minimization problem we choose Orlicz spaces. We characterize those generalized quantiles that have convexity or positive homogeneity properties, and in particular we focus on the expectiles, that are the minimizers of a piecewise quadratic loss function. Expectiles are a class of coherent risk measures that is becoming increasingly popular in the financial literature. We provide their dual and Kusuoka representations, we discuss their robustness properties (in particular, we prove that they are Lipschitz with respect to the Wasserstein metric) and we discuss comparison results with CVaR and with usual quantiles.

Fixed income management using Stochastic Programming

Stochastic Programming for fixed income management is associated with several major challenges. First, the term structure is unobservable, and has to be derived from a finite set of noisy market prices. Contrary to using standard methods, which amplify the noise and thus deteriorate the quality of the SP solution, we estimate the term structure with a recently developed method which adds exceptionally little noise. Second, the term structure contains an infinite set of interest rates, which from an SP modeling perspective corresponds to an infinite set of random variables. Working with a single market, the dependence between interest rates enables the vast majority of term structure movements to be explained by a few risk factors. Finally, expected returns in the SP model governs which risks the optimal portfolio will be exposed to and are thus critical for the quality of the optimal solution. For the fixed income market, expected returns are determined by the term premium, which we estimate using a new method based on the Heath-Jarrow-Morton framework. The SP model is backtested on daily U.S. Government data from 1961 to 2011.

A Multistage Linear Stochastic Programming Model for Optimal Corporate Debt Management

Large corporations fund their capital and operational expenses by issuing bonds with a variety of indexations, denominations, maturities and amortization schedules. We propose a multistage linear stochastic programming model that optimizes bond issuance by minimizing the mean funding cost while keeping leverage under control and insolvency risk at an acceptable level. The funding requirements are determined by a fixed investment schedule with uncertain cash flows. Candidate bonds are described in a detailed and realistic manner. A specific scenario tree structure guarantees computational tractability even for long horizon problems. Based on a simplified example, we present a sensitivity analysis of the first stage solution and the stochastic efficient frontier of the mean-risk trade-off. A realistic exercise stresses the importance of controlling leverage. Based on the proposed model, a financial planning tool has been implemented and deployed for Brazilian oil company Petrobras.

Long-Term Bank Balance Sheet Management: Estimation and Simulation of Risk-Factors

We propose a dynamic framework which encompasses the main risks in balance sheets of banks in an integrated fashion. Our contributions are fourfold: 1) solving a simple one-period model that describes the optimal bank policy under credit risk; 2) estimating the long-term stochastic processes underlying the risk factors in the balance sheet, taking into account the credit and interest rate cycles; 3) simulating several scenarios for interest rates and charge-offs; and 4) describing the equations that govern the evolution of the balance sheet in the long run. The models that we use address momentum and the interaction between different rates. Our re-
results enable simulation of bank balance sheets over time given a bank's lending strategy and provides a basis for an optimization model to determine bank asset-liability management strategy endogenously.

Janos Mayer (with Thorsten Hens)

Portfolio Selection with Objective Functions from Cumulative Prospect Theory

We consider financial portfolio selection problems with several assets, involving objective functions with probability distortion of the cumulative prospect theory (CPT) of Tversky and Kahneman (1992). These are numerically difficult optimization problems since the objective function to be maximized is neither concave nor smooth. We have implemented an adaptive simplex grid method for the solution of this type of problems and report on the results of a numerical study. Levy and Levy (2004) proved that under the assumption of normally distributed returns the CPT efficient set is a subset of the mean-variance (MV) frontier thus portfolio selection can be carried out by maximizing the CPT objective function along the MV frontier. For assessing the robustness of this approach, we compare it with the direct CPT-optimization, for a real life data-set and for several investors and find that the two approaches lead to substantially different portfolios. This difference increases dramatically if we add a call option to our data-set and it diminishes almost completely for a data-set obtained by sampling from the corresponding normal distribution.

Operations Management and Software

[Room 10] Solvers for Stochastic Optimization

Chair(s): Vittorio Moriggia

Francis Ellison (with Suvrajeet Sen, Yifan Liu, Gautam Mitra)

Stochastic Decomposition: Motivation, technology and the challenges that it presents.

Stochastic Decomposition (SD), applied to linear, 2-stage recourse problems, is a way of examining potential solutions statistically with a view to reaching an acceptable solution with a minimum of sampling. Observations of the 2nd stage are obtained by Monte-Carlo sampling - applicable equally to continuous as to discrete distributions. We use these observations one at a time using L-shaped methodology to obtain cuts, and, after a certain minimum period, test every solution for the stability that should ensure a good approximation. For convergence a method of regularisation must be chosen, and this may be critical - particularly as the statistical nature of the method means that multiple runs are needed with different start-seeds for the pseudo-random number sequence. The utility of the method is illustrated by the original regularised decomposition method of Ruszczynski, adapted for SD by Sen. Research remains to be done using the Trust Region approach of Linderoth and Wright, also using the Level Method approach of Lemarechal et al. and Fabian.

Victor Zverovich (with Gautam Mitra, Csaba I. Fábián)

A solver for problems with second-order stochastic dominance constraints

Stochastic dominance provides an important framework of making choice; it is applied increasingly in asset allocation decisions which take into account risk. In particular, second-order stochastic dominance (SSD) captures risk-averse preferences; this is a fundamental assumption underlying investment behavior. It is established as a theoretically sound choice criterion in portfolio selection models. We describe the architecture and implementation of a solver for problems with second-order stochastic dominance constraints. The solver provides an efficient implementation of cutting-plane methods proposed in Fábián, Mitra, and Roman (2009) and Fábián, Mitra, Roman, and Zverovich (2010). These methods have been shown to process problems with a large number of scenarios efficiently and allow regularization by the level method of Lemarechal et al. (1995). The SSD solver described by us can be called from AMPL and other modeling systems that support AMPL solver interface. We illustrate the use of the solver for an exemplar portfolio selection model and report computational results showing that it can solve efficiently very large problems.

Cristiano Arbex Valle (with Gautam Mitra, Victor Zverovich)

A Randomized Metaheuristic for Stochastic Integer Programs with Binary First Stage Variables and Continuous Second Stage Variables

Stochastic Integer Programs (SIP) are well known to be computationally intractable. For a given computing resource many large-scale models cannot be solved to optimality and it becomes necessary to apply heuristics to produce tractable approximate solutions. In our study the motivation is to find better starting points for such
heuristic methods. A VNDS heuristic for Two-Stage SIPs with binary first stage and continuous second stage variables was first proposed by us, Lazic et al (2010). The VNDS is a local search procedure which explores the neighbourhood of an initial solution and as such it might not be able to escape local optima. In this work we propose a Randomized Adaptive Search Procedure that uses the same neighbourhood structure to find different initial solutions, providing diversification and the possibility of escaping local optima. A reduced VNDS is then applied as a local search procedure to each initial solution found. We report the results of our empirical investigation for well known sets of SIP models for the purpose of benchmarking our computational approach.

Christian Wolf (with Csaba I. Fábián, Achim Koberstein, Leena Suhl)

A computational study of on-demand accuracy level decomposition for two-stage stochastic programs

The L-shaped method is used to solve two-stage stochastic programs with recourse. To avoid well-known inefficiencies of the cutting-plane approach, regularization of the expected recourse function can be achieved with level decomposition, which was recently shown to be computationally efficient. The recent introduction of on-demand accuracy oracles for level bundle methods by Oliveira and Sagastizabal allows to benefit from the advantages of the single-cut and the multi-cut approach in the L-shaped method, without suffering from their disadvantages. The dual information from every scenario subproblem is saved, but not added to the master problem directly, to prevent proliferation of optimality cuts. After solving the master problem, it is checked if a new optimality cut can be generated from the saved dual information that substantially improves the recourse function approximation. The subproblems are not solved if this is the case, but the master problem is resolved, which is usually computationally fast, due to the addition of only one single aggregated cut. We present computational results for the on-demand accuracy level decomposition and compare these with the L-shaped method.

Horand Gassmann (with Kipp Martin, Jun Ma)

An open-source solver system for stochastic programming

Stochastic programs are computationally challenging, and specialized solvers tend to be experimental, research oriented, and not widely available. For many production uses of stochastic programming it seems that once the scenario generation is completed, the resulting deterministic equivalent is solved by a commercial solver such as Cplex or Gurobi. This can be expensive. Moreover, a large body of literature has established quite clearly that for large problems specialized techniques are more successful. The goal posts of what constitutes a "large problem" have moved due to extensive development of commercial solvers, while the development of stochastic solvers has remained more or less stagnant. But the advantage of stochastic solvers remains. In the last decade or so open-source projects such as COIN-OR have created freely available code for the solution of deterministic problems. It seems therefore natural to try to develop specialized stochastic solvers making use of these packages as building blocks. This talk describes ongoing efforts at developing a web-aware package that puts together a number of COIN-OR projects to allow decomposition algorithms to be implemented not only locally but also remotely as well as in parallel.
Thursday 10.45-12.50 Parallel Sessions

Advances in stochastic programming and contiguous fields
[Room Galeotti] Stochastic Variational Problems
Chair(s): Roger Wets

Werner Römisch (with Hernan Leovey)

Quasi-Monte Carlo sampling for stochastic variational problems

Monte Carlo (MC) sampling for scenario generation has a long history in stochastic optimization. It has been justified for multi-stage stochastic programs, models with dominance constraints, variational inequalities and equilibrium models, for example. The situation is much different for Quasi-Monte Carlo sampling although it is known that certain randomized lattice rules can be much more efficient than MC for integrands belonging to tensor product Sobolev spaces. We argue that this efficiency may carry over to integrands of the form \( f = h(g(\cdot)) \) with a piecewise linear function \( h \) and a smooth mapping \( g \) if the effective dimension of the integrand is small.
In particular, we show that under some weak geometric condition on a two-stage stochastic program all terms of the ANOVA decomposition of \( f \), except the one of highest order, are sufficiently smooth if the densities are smooth. Hence, the optimal rate of convergence \( O(n^{-1-\delta}) \), \( \delta \in (0,\frac{1}{2}) \), may be achieved for such terms with a constant not depending on the dimension, while the ANOVA term of highest order gets small if the effective dimension is small. We discuss dimension reduction techniques and present numerical experience.

Huifu Xu (with Yongchao Liu, Werner Römisch)

Quantitative Stability Analysis of Stochastic Generalized Equations

We consider the solution of a system of stochastic generalized equations (SGE) where the underlying functions are mathematical expectation of random set-valued mappings. SGE has many applications such as characterizing optimality conditions of a nonsmooth stochastic optimization problem or equilibrium conditions of a stochastic equilibrium problem. We derive quantitative continuity of expected value of the set-valued mapping with respect to the variation of the underlying probability measure in a metric space. This leads to the subsequent qualitative and quantitative stability analysis of solution set mappings of the SGE. Under some metric regularity conditions, we derive Aubin’s property of the solution set mapping with respect to the change of probability measure. The established results are applied to stability analysis of stochastic variational inequality, stationary points of classical one stage and two stage stochastic minimization problems, two stage stochastic mathematical programs with equilibrium constraints and stochastic programs with second order dominance constraints.

Johannes O. Royset (with Roger Wets)

On the use of epi-splines in stochastic optimization

Epi-splines are piecewise polynomial functions that are structurally related to classical splines, but rather than interpolation tools they are primordially approximation tools. They approximate large classes of functions including those of lower and upper semi-continuous functions, which offer significant flexibility in a wide range of applications. The theory that supports their properties is largely anchored in Variational Analysis, with implementations relying on the large number of powerful convex and nonlinear optimization solvers available today. We review epi-splines theory and its application to stochastic optimization, with a particular emphasis on sampling-based methods.

Vladimir Norkin (with Roger Wets)

On the Strong Graphical Law of Large Numbers for Random Semi-continuous Mappings and its Applications

First we review strong graphical Laws of Large Numbers (LLN) and concentration inequalities for random sets, random epi-graphs, and random semi-continuous mappings. The LLNs provide conditions for graphs of sample average mappings to converge to the graph of their expectation mapping with probability one. Then we consider a calculus for graphically convergent sequences of random mappings. It allows establishing almost sure graphical convergence of composite mappings, having almost sure graphically convergent components. Next we consider applications of the graphical convergence and graphical LLN in stochastic variational analysis, including approximation and solution of stochastic generalized equations, stochastic variational inequalities and...
stochastic optimization problems with equilibrium constraints. The nature of these applications consists in sample average approximation of problem expectation mappings, application of the graphical LLN and obtaining from here a graphical approximation of solutions

Pavel S. Knopov (with D.A. Gololobov)

On the method of empirical average in some stochastic optimization and estimation problems

We investigate the method of empirical averages in the case when the functional depends on the homogeneous random field observed on a sphere. We prove the strong consistency of the estimates of the minimal points, and describe their limit distribution is found. The proof of the consistency is based on the limit procedures developed in the works of Jenrich [1], Pfanzagl [2, etc. for the minimal contrast estimates. The essential point of the proof of our result is the result of Yurinskii[3] on the law of large numbers for homogeneous random fields observed on a sphere.


3. Yurinskii V.V. The strong law of large numbers for homogeneous random fields. Mathematical Notes 16(1),(1974), 668-673.

Problem formulation and solution algorithms

[Room 5] Scenario generation and Monte Carlo
Chair(s): Vittorio Moriggia

Anna Timonina

Multi-stage stochastic optimization: The distance between stochastic scenario processes

Approximation techniques are challenging, important and very often irreplaceable solution methods for multi-stage stochastic optimization programs. Applications for scenario process approximation include financial and investment planning, inventory control, energy production and trading, electricity generation planning, pension fund management, supply chain management etc. In multi-stage stochastic optimization problems the amount of stage-wise available information is crucial. While some authors deal with filtration distances, we consider the concepts of nested distributions and their distances which allows to keep the setup purely distributional but at the same time to introduce information and information constraints. Also we introduce the distance between stochastic process and a tree and we generalize the concept of nested distance for the case of infinite trees, i.e. for the case of two stochastic processes given by their continuous distributions. We are making a step towards a new method for distribution quantization that is the most suitable for multi-stage stochastic optimization programs as it takes into account both the scenario process and the stage-wise information.

Ronald Hochreiter

How to generate multi-stage scenario trees (if you have to)

The generation of multi-stage scenario trees for stochastic programs is not trivial. Many approaches have been presented in research papers and some methods are available as add-ons to commercial optimization packages or available in the form of a download of binary black box. However, when one faces the threat of having to implement a new multi-stage stochastic programming model, chances are high that she or he has to (re-)implement a new scenario generator, which is undoubtedly a tedious thing to do. In this talk we present an open-source scenario generator, which can be readily used as an extension package for the open-source statistical computing package R. While presenting this package and its implementation a broad array of scenario generation techniques will be shown and explained. A live presentation of the package functionality concludes the talk. After watching the presentation you will be able to generate multi-stage scenario trees immediately.
Tamás Szántai (with Edith Kovács)

On cherry-tree copula based scenario generation

When solving two- or multi-stage stochastic programming problems one has to model the joint probability distribution of the stochastic parameters to be able to generate scenarios. The quality of scenarios highly influences the quality of solutions. There are methods which generate scenarios that match to a given set of univariate marginal distributions and the dependence between them, which is specified by the correlations. Recently it was also recognized that using copulas for describing the dependence structure between the variables is more adequate. In our talk we propose a new method for modeling multivariate copulas. It is based on the construction of multivariate copulas from certain bivariate building blocks and on exploiting some conditional independences between the random variables. Our method has two main advantages. In comparison with the well-known multivariate copula families (Gumbel, Frank and others) which depend on at most 2 parameters and which determine same type of dependences between the marginal distributions, our method gives the possibility to endow different pairs of random variables with different type of dependences. A difference to the regular vine copulas which also use bivariate copulas as building blocks and which have the drawback that contain a large number of conditional copulas and parameters, is that the cherry-tree copulas largely reduce the number of conditional copulas and also the number of parameters involved in the copula construction due to recognizing conditional independences existing between the variables.

Cesar Beltran-Royo (with Laureano F. Escudero, J. F. Monge, R. E. Rodriguez-Ravines)

An Effective Heuristic for Multistage Stochastic Linear Programming

To solve the multi-stage linear programming problem, one may use the expected value approach (deterministic) or a stochastic approach. Their drawbacks are well known: the deterministic approach is unrealistic under uncertainty and the stochastic approach may suffer from scenario explosion. We introduce a new heuristic whose aim is to overcome both drawbacks. The new approach focuses on events instead of scenarios so it is named Multi-stage Event Linear Programming (MELP). For assessing the validity of MELP, a broad test-bed of instances of the network revenue management problem is used. As we show in the computational experiments, the new approach represents a promising compromise between the stochastic and the deterministic approaches, regarding capacity to deal with uncertainty and computational tractability. Some instances in the test-bed have over 75 millions of constraints and variables in the Deterministic Equivalent Model, a state-of-the art LP solver can not provide a solution, and the MELP incumbent one has a quasi-optimality gap smaller than 1% in all instances we have experimented with.

Leonidas Sakalauskas

Stochastic programming handling CVaR in objective and constraints

The Risk Aversion problem, arising in credit and portfolio applications, is considered as a framework of nonlinear stochastic programming with constraints on CVAR of financial instruments. The method of sequential quadratic programming by series of Monte-Carlo estimators is developed to solve the constrained risk aversion optimization problem. The approach considered distinguishes by adaptive regulation of the Monte-Carlo sample size, which ensures convergence with linear rate, and statistical manner for termination of the algorithm.

Energy

[Room 3] Energy policy
Chair(s): Maria Teresa Vespucci

David Wozabal (with Nils Löhndorf)

Stochastic optimization of a gas plant with storage taking into account take-or-pay restrictions

We present a stochastic dynamic model for the joint operation of a gas turbine and a gas storage as well as the optimal use of a long term gas supply contract with a take-or-pay clause. The planning horizon is one year and the model formulation takes into account a stochastic price development on the gas market and uncertain prices for electricity. Decisions about the dispatch of the resources are taken in a hourly resolution. The resulting problem is numerically solved using approximate dual dynamic programming, resulting in a provably near-optimal policy.
Athena Wu (with Andy Philpott)

Optimal capital planning with renewable-induced uncertainty using Markov decision processes

Classical capacity planning models become problematic when evaluating investment facing renewable generation intermittency. We describe a model treating the uncertainty in renewable supplies as a Markov chain and the short-term operation of electricity plant as an average reward MDP. This problem’s LP formulation can be augmented by binary variables defining investment actions, leading to a mixed-integer program. The impact of increasing renewable penetration and project location choice on generation capacity and transmission asset investments are explored.

Jonas Schweiger

Gas Network Extensions for Multiple Scenarios

Gas transmission networks are complex structures that consist of passive pipes and active, controllable elements such as valves and compressors. Today's gas markets demand more flexibility from the network operators which in turn have to invest into their network infrastructure. As these investments are very cost-intensive and long-living, network extensions should not only focus on one bottleneck scenario, but should increase the flexibility to fulfill different demand scenarios. Thereby we consider several ways of extending the network: by new pipes between points without a prior direct connection, by building a pipe next to an existing pipe, or by adding active elements to the network. For new pipes, the optimal selection of diameters is of special importance. In this presentation, we formulate a model for the network extension problem for multiple demand scenarios and all these extension types. We propose a decomposition along the scenarios. We solve MINLP single-scenario subproblems and obtain valid bounds even without solving them to optimality.

Juan Pablo Luna (with Claudia Sagastizábal, Mikhail Solodov)

An Approximation Scheme for Equilibrium Problems with Risk Aversion

Equilibrium models are useful for markets having agents with conflicting interests (gas, electricity). The inclusion of stochastic information in the model makes the representation more accurate, but also renders more challenging the solution: problems become large scale and involve multivalued operators. The later difficulty arises because of the risk-measures used by the agents to hedge against volatility, which makes their problems nondifferentiable. We present a family of approximating single-valued problems, corresponding to agents hedging risk by means of smoothed measures. The corresponding sequence of approximate equilibria provides a solution of the initial problem. We assess the interest of the approach on stochastic risk-averse variants of generalized Nash games and Mixed Complementarity models of equilibria for a real-life case.

Paolo Falbo (with Cristian Pelizzari, Luca Taschini)

Stochastic Programming and Optimal Regulation of EU-ETS

Environmental and energy targets for 2030 are the top priority in the EU community for the next years. Research that helps policy makers in their task of designing 2030 targets will be timely and well received by a wide range of stakeholders. A stochastic programming problem is developed where environmental and energy targets are jointly set subject to economic and physical constraints. A social welfare function is maximized and the policy interactions are investigated by simulating possible future price scenarios (gas, coal, and electricity) and choosing different target levels.

Finance

[Room 4] Financial markets uncertainty modeling

Chair(s): Fabio Bellini

Nima Nooshi (with Young Shin Kim, Marida Bertocchi)

Risk budgeting and portfolio optimization based on ARMA-GARCH non-Gaussian multivariate model

We propose an ARMA (1,1)-GARACH (1,1) model for a 29 dimensional portfolio of selected stocks, with residuals fitted to a multivariate distribution made of standard CTS marginal coupled with student’s T copula. In the context of Markowitz portfolio theory, we first calculate the efficient frontiers, implementing VaR and AVaR functionals as the risk measure. Then we introduce and calculate the marginal VaR, and marginal AVaR as the indicators of risk quality of single portfolio positions. We show that utilizing these quantities as the portfolio...
restructuring guidance in a form of sequential numerical iterations, leads to a series of portfolios which converges to the efficient frontier. Based on the same idea, we propose a portfolio restructuring methodology in time, which implements the marginal VaR information in a daily rebalancing decision tree. Further we analyze the performance enhancement, as well as realized final wealth of the investments in 2008 and 2011, and discuss the key role of restructuring arrangements to minimize the excessive losses of a highly volatile market.

Ingrida Vaiciulyte

Application of skew t-distribution in the field of investors’ preferences visualization

This work represents how the economic situation is reflected according to skew t-distribution parameter variation. In general, the skew t-distribution is represented by a multivariate Gaussian distribution, which the vector of mean, in its turn, is distributed as a normal distribution and the covariate matrix is depending on the parameter, distributed according to the gamma distribution. In simple terms, it is a mixture of Gaussian and gamma distributions. For evaluation of these distribution parameters, we apply the maximum likelihood method. The parameters of the chosen distributions, calculated on the basis of stock data (Close and Volume) of enterprises, which belong to health-care industry for the 2007-2011 year period. It was a period of an economic depression, which started in 2007 and the years after were recovery time. With a distribution presented we are trying to determine each-year changes in evolution of the field of investors’ preferences. Resulting stocks prices distribution reflects all investors’ opinion about company’s results

Anastasia Markelova (with Aaron Kim, Svetlozar T. Rachev)

An approach of random scaling factor to solve the problem of square root of time and its application in forecasting of asset return

Despite the fact that well-known square-root-of-time rule (SRTR) was proposed as a forecasting procedure in Basel accord and it is widely use in many financial institutions, the accuracy of this rule was proved as questionable. We investigate the problem of “square root-of-time” and propose a new approach of scaling the return. It based on the idea of application of the mixture distributions and the dependence between one-day and N-days parameters of the asset return distributions. In contrast to the standard rule, where scaling factor depends directly from the amount of days, in our approach it is suggested to be a random variable under some distribution. We illustrate the suggested model on the 11-year data from 416 stocks from S&P500 and check it with likelihood-ratio test. Based on the empirical evidence, the model is able to predict future behavior of stocks return in more realistic way

Sofia I. Miranda (with Terry Rockafellar, Johannes O. Royset)

Superquantile Regression with Applications to Buffered Reliability, Uncertainty Quantification, and Conditional Value-at-Risk

We present a generalized regression technique centered on a superquantile (also called conditional value-at-risk) that is consistent with that coherent measure of risk and yields more conservatively fitted curves than classical least-squares and quantile regressions. In contrast to other generalized regression techniques that approximate conditional superquantiles by various combinations of conditional quantiles, we directly and in perfect analog to classical regression obtain superquantile regression function s as optimal solutions of certain error minimization problems. We show the existence and possible uniqueness of regression functions, discuss the stability of regression functions under perturbations and approximation of the underlying data, and propose an extension of the coefficient of determination R-squared for assessing the goodness of fit. We present two numerical methods for solving the error minimization problems and illustrate the methodology in several numerical examples in the areas of uncertainty quantification, reliability engineering, and financial risk management

Audrius Kabasinskas

On k-sample homogeneity tests, when k is large

We analyze aggregated intra-daily data of DAX30 (with interval 10 sec). In this case we have totally 251 observation days of each stock from the DAX30 list. We aggregate raw inhomogeneous intra-daily data into the equally-spaced homogeneous 10 seconds intra-daily time series and we get 3060 intra-daily observations for every stock. Our results show that the distribution of intra-daily log-returns differs every day (Kabasinskas et al, 2012). We have to use some statistical tests to proof that. The problem is that we cannot use traditional tests for continuous distributions since our data are mixed-stable (discontinuous law) distributed. However, even if we apply Anderson-Darling and Kruskal-Wallis tests to analyze DAX30 stock returns takes approximately two
days. To solve this problem a parallel code was developed and tested. For all 29 stocks from the DAX30 list the hypothesis of homogeneity was rejected. This means that intra-daily observations of stock returns have different probability distribution for different days. That is bad news for active stock traders since forecast or even simulation modeling (scenario generation) of stock prices becomes very complicated.

**Operations Management and Software**

[Room 10] Challenges of engineering and environment applications

*Chair(s): Pavel Popela*

Michael Tous (with Martin Pavlas, Radovan Somplak, Pavel Popela)

**Stochastic programming applied to design and operation planning problems in the field of energy systems**

The aim of the presentation is to discuss stochastic programming importance in the area of energy production problems. The erection of a new facility and its operation is a long-term project. The economic feasibility of such a project depends on many parameters, which have uncertain future development. Stochastic programming has proven to be very powerful tool. First, we applied stochastic programming to operation planning of a heating plant utilizing coal and biomass-based fuels. The achieved results showed great potential of this optimization approach. We fully utilized its potential in waste-to-energy facility planning problem. The economic feasibility of the project is very sensitive to waste heating value, gate fee, heat demand, heat price, electricity price etc. However, these parameters have uncertain development. The issue is becoming more difficult if we consider a waste-to-energy facility as a part of complex waste management system. It means that we also consider competing facilities - neighbouring waste-to-energy facilities, land-filling, mechanical biological treatment of waste. The results can provide valuable support for decision makers.

Radomil Matousek (with Pavel Popela, Eva Mrazkova)

**Recent Advances in Stochastic Quadratic Assignment Problems**

The aim of the paper is to introduce various deterministic reformulations of Stochastic Quadratic Assignment Problem (StoQAP) and discuss the solution techniques and present the achieved computational experience. Firstly, the previous papers in the area are listed, interesting StoQAP applications are mentioned and comparison with deterministic QAP is given. Then, the test instances from StoQAPLIB library are introduced and their dataset up is described. The GAMS modelling language with a suitable CPLEX solver is used to obtain results and they are compared with the original meta-heuristic that is also utilized for larger test instances. The impact of the input data dependency structure on the obtained results is described. The GAMS modelling language with a suitable CPLEX solver is used to obtain results and they are compared with the original meta-heuristic that is also utilized for larger test instances. The impact of the input data dependency structure on the obtained results is studied at the end of the paper.

Pavel Popela (with Jan Roupec, Jan Novotny, Dusan Hrabec, Jan Holesovsky, Zuzana Sabartova, Lubomir Klimes, Tomas Mauder)

**Recent Advances in Stochastic Programming Modelling for Engineering Applications**

The aim of the paper is to present and summarize our recent experience obtained from various stochastic programming engineering applications (see e.g. differential-equation constrained programs for design problems in mechanics, continuous casting control by cooling, investment planning and operational control in process engineering and energy production, and traffic-related logistic problems involving pricing) to identify interesting common features of the related models. Specific modelling recommendations coming from the individual application fields are mutually compared and subsequently unified and generalized to support development and enhancement of suitable modelling tools for real-world decision making problems. The realized steps supporting an efficient use of several stochastic programming reformulations are discussed. Selected examples of syntactical model modifications involving existing software tools and original computer code are shown together with possibilities for a combined use of both decomposition algorithms and suitable heuristics.

Tatiana Ermolieva (with Yuri Ermoliev, Petr Havlik, Aline Mosnier, Michael Obersteiner)


The aim of the paper is to discuss robust non-Bayesian probabilistic cross-entropy based disaggregation (downscaling) techniques driven by the need to address local heterogeneities related to secure food, water, energy provisions consistent with available aggregate data and projections of global and national development trends. For example, aggregate land use projections derived from global economic land use planning models give no insights regarding potentially critical heterogeneities of local processes. High spatial resolution land use
and cover change projections are also required as one of the crucial inputs into Global Circulation Models. Many practical studies analyzing regional developments use cross-entropy minimization as an underlying principle for estimation of local processes consistent with available aggregate data. Traditional cross-entropy downscaling relies on a single prior distribution. In reality, prior distributions depend on various "environmental" parameters which may not be known exactly. Therefore in general instead of a uniquely defined prior there is a feasible set of these distributions. In this case, the estimation of local changes consistent with available aggregate data can be formulated as probabilistic inverse (from aggregate to local data) problem in the form of, in general, stochastic non-convex cross-entropy minimization model. Specific reparametrization permits to convexify the model. The duality relations derive numerical procedure for local estimates robust with respect to all priors from the feasible set. The approach will be illustrated by downscaling aggregate regional GLOBIOM (Global Biosphere Management Mode) model projections of land use changes

Mehiddin Al-Baali

On a Limited-Memory Damped-BFGS Method for Large Scale Optimization

In 2011, we extended the damped BFGS method of Powell (1978), which is useful for solving constrained optimization problems that uses Lagrange functions (see for example the books of Fletcher, 1987, and Nocedal and Wright, 1999), to unconstrained optimization. Further extension of this method to the limited memory L-BFGS method of Nocedal for large-scale optimization will be considered. This extension maintains the global convergence property on uniformly convex functions for the L-BFGS method, which uses values of the steplength which satisfy the Wolfe-Powell conditions. Some numerical results will be described to show that an appropriate way for employing the damped technique improves the performance of the L-BFGS method substantially in several cases. Since this technique enforces safely the positive definiteness property of the BFGS update for any value of the steplength, we used only the first Wolfe-Powell condition on the steplength so that (as for the backtracking framework) only one gradient evaluation is evaluated on each iteration.
New Concepts for Stochastic Systems
[Room Galeotti] Equilibrium in a stochastic environment
Chair(s): Roger Wets

Alejandro Jofré (with Terry Rockafellar, Roger Wets)

General economic equilibrium with incomplete markets

Economists have been working on equilibrium models in a stochastic environment for the last fifty years in an effort to take into account the fact that economics’ agents are interested not only in ‘immediate’ rewards (consumption) but also future rewards coming from future consumption, financial contracts and their environment. In such two-stage or more-stage model, the major issue becomes to associate a value to money or any other good that would play a similar role. The classical GEI-models (general equilibrium markets with incomplete markets) are not able to integrate all these fundamental issues. We introduce in this presentation a model that remedies these shortcomings through innovations in goods and the way agents can get utility from them. In particular, all two-party contracts can be viewed in this framework as concerned with deliveries of "goods." Moreover the amounts delivered can depend on future prices, so that diverse types of options can now be covered. Endogenously introduced transaction costs on issuing contracts keep markets from getting out of hand and lead to bid-ask spreads which, in particular, induce a gap in interest rates for lending and borrowing money. On the technical side, equilibrium is given a formulation in variational analysis which brings new tools to the subject and offers better prospects for stability studies and computation. By taking advantage of the explicit introduction of money as a good and a fresh way of proving existence, this formulation also succeeds, where traditional fixed-point reductions would not, in drastically weakening the (unrealistic)survivability assumptions on initial endowments.

Julio Deride (with Alejandro Jofré, Roger Wets)

Computing equilibrium points in an stochastic two-stages economic model

In this paper we propose a new strategy for computing equilibrium points for a two periods incomplete market economic model based in variational techniques. First, equilibrium points are characterized as solutions of a max-min optimization problem in which the excess supply function is relevant. Second, the max-min problem is solved by introducing the "augmented Walrasian function" and by using local and global approximation techniques with multiple start ups, and a progressive hedging approach for stochasticity. Finally, we give some numerical examples showing how powerful is this approach for solving large scale incomplete market equilibrium problems in which an important number of agents, consumption goods and financial contracts are involved.

Michael C. Ferris (with Roger Wets)

Stochastic Multiple Optimization Problems with Equilibrium Constraints

We present a mechanism for describing and solving collections of optimization problems that are linked by equilibrium conditions. We show how to incorporate stochastic information into these systems and give examples of their use and their possible extensions to hierarchical modeling. We demonstrate this mechanism in the context of energy planning problems, specifically for capacity expansion, hydro operation, and transmission line switching. Included in this class are classical models such as the PIES model and agent based formulations arising from Nash Games. We describe some recent extensions of the extended mathematical programming (EMP) framework to facilitate stochastic variational inequalities, including sample average approximations, risk measures and chance constraints.

Andy Philpott (with Par Holmberg, Tony Downward)

Supply function equilibrium models for electricity markets

We review some recent results in the theory of supply-function equilibrium. These have application in electricity pool markets and auctions of divisible goods. The auctions we consider arise in electricity pool markets, where uncertainty plays a key role. We discriminate between ex-post optimal and ex-ante optimal supply function equilibrium (the wait-and-see and here-and-now versions of these models) and show how both these versions of the model arise in different settings.
Incomplete market in stochastic investment equilibrium models

We consider the problem of investing in production equipment in a competitive economy subject to risk. The problem is a partial equilibrium in the sense that some price evolutions (e.g., input) are given while others (output) are endogenous. We show that a risk function optimization model of that problem can be interpreted as a competitive market with complete risk trading. Existence and uniqueness of equilibrium are then easy to establish. The model is however unrealistic because of the assumption of complete risk trading. We then assume that risk cannot be traded: this corresponds to a project finance approach where each equipment is valued on the basis of its own merit. The problem is formulated as a stochastic complementarity model; we discuss existence and local uniqueness. While financial instruments of a sufficient maturity do not exist in these markets it is possible to conclude long-term delivery contracts that provide partial hedging of new plants. We formulate this approach and again study existence and local uniqueness.

New Approaches to Classical Problems

[Room 4] Time consistency in stochastic programming
Chair(s): Alois Pichler

Andrzej Ruszczynski

Introduction to Dynamic Risk-Averse Optimization

We present the concept of a dynamic risk measure and discuss its important properties. In particular, we focus on time-consistency of risk measures. Then we consider two- and multi-stage stochastic optimization problems with measures of risk and discuss optimality conditions. These are used to develop decomposition methods in a nested and scenario forms. Next, we focus on dynamic optimization problems for Markov models. We introduce the concept of a Markov risk measure and we use it to formulate risk-averse control problems for Markov decision models. We present risk-averse dynamic programming equations and solution methods by value or policy iteration, and by convex optimization.

Ozlem Cavus (with Andrzej Ruszczynski)

Computational Methods for Risk-Averse Undiscounted Transient Markov Models

We consider the total cost problem for discrete-time controlled transient Markov models. The objective functional of this problem is a Markov dynamic risk measure of the total cost. We propose two solution methods, value and policy iteration, and analyze their convergence. We illustrate the results on a credit limit control problem.

Birgit Rudloff (with Zachary Feinstein)

Time consistency of risk measures in markets with transaction costs

In markets with transaction costs, when capital requirements can be made in a basket of currencies or assets, risk measures are naturally set-valued functions. Definitions of different time consistency properties in the set-valued framework are given. It is shown that in the set-valued case the recursive form for multivariate risk measures as well as an additive property for the acceptance sets is equivalent to a stronger time consistency property called multi-portfolio time consistency. The recursive form can be seen as a set-valued Bellman's principle and we will show cases where it leads to a sequence of linear vector optimization problems that can be solved with known algorithms. As examples, we consider the superhedging problem in markets with proportional transaction costs and the set-valued average value at risk.

Linwei Xin (with David A. Goldberg, Alexander Shapiro)

Distributionally robust multistage inventory models with moment constraints

We consider a minimax approach to managing an inventory under distributional uncertainty. In particular, we study the associated multistage distributionally robust optimization problem, when only the mean, variance, and distribution support are known for the demand at each stage. It is known that if the policy maker is allowed to recompute her policy choice after each stage (i.e., dynamic formulation), a base stock policy is optimal. In contrast, if the policy maker is not allowed to recompute her policy after each stage, far less is known. If these two formulations have the same set of optimal policies, i.e. the policy maker would choose the same policy
whether or not she has the power to recompute after each stage, we say that the problem is time consistent. We give sufficient conditions for time consistency. We also provide counterexamples, demonstrating that the problem is not time consistent in general. Interestingly, we observe that: (1) time inconsistency can occur even when both formulations have a common optimal basestock policy; (2) time consistency can occur even when the two formulations have different optimal values.

Alois Pichler

Time Consistency of Stochastic Programs

It has been elaborated that some risk measures (risk functionals) are time inconsistent. We insure first that basically all risk measures are not time consistent in a strict sense, and looking at the outcome at different times may totally change the risk perspective. We demonstrate that time inconsistency disappears when defining risk functional in an extended way, adapting the measure over time. The extended, conditional risk functionals introduced allow a temporal decomposition of the initial risk functional in a way, which is consistent with the past and the future. The central result is a decomposition theorem, which allows reassembling the initial risk functional by compounding the conditional risk functionals without losing information or preferences.

Computation and Applications

[Room 3] Computational SP including risk management and energy applications

Chair(s): Csaba I. Fábián

Claudia Sagastizábal

How to exploit oracles with on-demand accuracy in energy problems

Often energy problems are modeled as large-scale stochastic optimization problems exhibiting certain intrinsic structure, related to different generating units, different scenarios, etc. Structure in only revealed after relaxing some coupling constraints or after dealing with "complicating" variables: Lagrangian relaxation and Benders-like decomposition methods are a convenient tool to bring on separability. With both approaches, the success of the iterative scheme put in place relies on how fast is the subproblem solution and how well the subproblem information is coordinated by the "master" program. To be fast, the subproblem solution may be inaccurate, but in a manner that does not escape out of control, to ensure asymptotic solution of the original problem. When the master solution is done via a bundle method, it is possible to handle many types of inexactness, ranging from subproblems totally controlled by the master to totally dumb ones, without losing accuracy in the final solution. We investigate the effect of inexactness on various difficult energy problems that illustrate well the interest of the approach.

Welington Oliveira (with Sergio V.B. Bruno)

Bundle Methods for Multistage Stochastic Capacity Planning Problems

Capacity planning is one of the most important long term managerial decisions. Mathematical programming has been aiding this process for several decades. The growing uncertainty in business around the world is pressing decision makers to account for risk in their planning decisions. Some examples of multistage stochastic programming problems applied to capacity planning exist, but are far from standard, since the dimensionality of these problems is usually prohibitive. In this work we address a special class of capacity planning problems whose structural properties allow the application of specialized decomposition methods. It is known that bundle methods generally cannot be applied to multistage decomposition problems, but we show how to effectively apply it in our approach. We consider an energy capacity planning problem.

Gautam Mitra (with Victor Zverovich, Christian Valente)

Formulation and solver support for optimisation under uncertainty

Algebraic modelling languages are now well established as important tools used both by practitioners and by academics in the field of operational research. Furthermore, the pervasiveness of computing devices allows for embedding of optimisation-based software, and therefore it is most important to have tools and techniques, which allow easy deployment on such devices. Portability and consistency of the development workflow across multiple platforms is of the utmost importance for the same reason. This presentation is focused on development in the AMPL modelling family related to the three areas above. First we analyse established frameworks for modelling under uncertainty and risk, identifying the following important approaches: - stochastic pro-
gramming (SP) with recourse, - chance constraints, - integrated chance constraints, - robust optimisation. In an earlier work Valente et al. introduced extensions of AMPL to support SP formulations, which they called SAMPL. This extended algebraic modelling language allows native representation of two- and multi-stage scenario-based stochastic programming problems in addition to the mathematical problems already supported by the base language. In this paper we describe a set of extensions to SAMPL for representing robust optimisation problems and the additional classes of SP problems listed above. We not only describe syntax and semantics of the extensions but also discuss solver requirements, reformulation techniques and connection between the modelling system and external solvers. In particular, we show that direct representation (as opposed to deterministic equivalent) of some of the modelling constructs not only makes the models easier to understand but also facilitates the use of specialised solution algorithms.

Afroz Ansaripour (with Hillel J. Kumin)

Some Explicit Results for the Distribution Problem of Stochastic Linear Programming

We consider the "wait and see" problem of stochastic linear programming, i.e., we wish to find a closed form expression for the distribution of the maximum value of the objective function in a stochastic linear programming problem where either the objective function coefficients or the right hand side coefficients are continuous random variables with known probability distributions. Explicit results for the distribution of max z(x) are very difficult to obtain; indeed, most analyses rely on approximation techniques or simulation. Results are only known if the right hand side has an exponential distribution and for problems with no more than two constraints. No new results have appeared in almost 40 years. In this paper, we obtain explicit results for problems whose objective coefficients or right hand side coefficients have exponential, gamma, uniform, or triangle distributions. A transformation is presented that greatly reduces computational time.

Csaba I. Fábián

Computational aspects of feasibility issues and risk averse optimization

Computational studies on two-stage stochastic programming problems indicate that aggregate models have better scale-up properties than disaggregate ones, though the threshold of breaking even may be high. We attempt to explain this phenomenon, and to lower this threshold. We present the on-demand accuracy approach of Oliveira and Sagastizabal in a form which shows that this approach, when applied to two-stage stochastic programming problems, combines the advantages of the disaggregate and the aggregate models. Moreover, we generalize the on-demand accuracy approach to constrained convex problems. The generalized approach is applied to handling feasibility issues and risk constraints in two-stage stochastic programming problems.

Finance and Applications

[Room 5] Scenario generation for stochastic programming
Chair(s): Alex Weissensteiner

Stein W. Wallace

Scenario generation: What are the issues?
The purpose of this talk is to set the scene for scenario generation. Why should we care? Why don’t we simply sample enough scenarios?

Michal Kaut

Copula-based heuristic for scenario generation for two-stage stochastic programs

We present a scenario-generation method for two-stage stochastic programs that uses bivariate copulas to describe the dependence between the marginal distributions (rather than the more common correlations). During the talk, we will discuss the theoretical advantages of copulas, outline the structure of the heuristic, and present numerical results illustrating the strength of the new method.

Andrea Consiglio (with Angelo Carollo)

A global optimization approach to generate multi-asset, arbitrage-free, scenario trees

Simulation models of economic and financial factors are widely used to support decisions or to assess risk exposures. There exists an extensive literature on scenarios generation models whose main aim is to describe the
true stochastic process with the least number of scenarios, as to overcome the "curse of dimensionality". There is, however, an important issue that is usually overlooked or, worse, ignored: the no-arbitrage restriction. No-arbitrage scenarios are essential if pricing options. But, even for portfolio optimization the absence of arbitrage is a key property, since its presence can yield biased solutions. Among the various methods proposed in literature, the moment matching approach is the one that is more suitable to account for the no-arbitrage restriction. This is possible by explicitly adding a set of constraints such that the expected value of each asset, under the martingale probability measure, is equal to the risk free rate. Thus, the scenarios generation problem turns out to be the solution of a set of non-linear equations, where the variables represent the assets returns, the objective and the martingale probabilities. A major drawback of the moment matching approach is its inherent non-convex nature. Moreover, the variables of the problem can grow substantially even for a modest number of assets and scenarios. The aim of our analysis is to re-formulate the moment matching problem with arbitrage restrictions as a global optimization problem. We then focus on new convex lower bounding techniques to provide a more stable and reliable approach to stochastic tree generation.

Alex Weissensteiner (with Alois Geyer, Michael Hanke)

No-Arbitrage Bounds for Scenarios and Financial Optimization

We derive no-arbitrage bounds for expected excess returns to generate scenarios used in financial optimization. The bounds allow to distinguish three regions: one where arbitrage opportunities will never exist, a second where arbitrage may be present, and a third, where arbitrage opportunities will always exist. No-arbitrage bounds are derived in closed form for a given covariance matrix using the least possible number of scenarios. The same setting is also used in an algorithm to generate discrete scenarios and trees. Numerical results from solving two-stage asset allocation problems indicate that even for minimal tree size very accurate results can be obtained.

Michael Hanke (with Alois Geyer, Alex Weissensteiner)

A Simplex Rotation Algorithm for the Factor Approach to Generate Financial Scenarios

Scenarios to be used for financial optimization must be free of arbitrage opportunities. We start from a factor approach, which is explicitly designed to generate arbitrage-free scenarios while exactly matching the assets' expected excess returns and covariances. We present an algorithm to implement the factor approach which is based on rotations of simplexes. This algorithm offers two major computational advantages: First, it does not require any orthogonalization procedure, but uses a deterministically constructed simplex as its starting point. Second, instead of (potentially frequent) re-sampling, it ensures no-arbitrage for every single run by purposefully rotating this simplex. Hence, the proposed algorithm completely avoids any need for checking scenarios for arbitrage. We derive the theoretical relation between the number of states and the size of (no-)arbitrage regions. As a by-product, the derivation of the rotation algorithm provides interesting geometrical insights.
Advances in stochastic programming and contiguous fields

Room Galeotti Chance constrained stochastic programming

Chair(s): René Henrion

Vincent Guigues (with René Henrion, Andris Möller)

Joint dynamic chance constraints with projected linear decision rules for some multistage stochastic linear programs

We consider multistage stochastic linear optimization problems where the underlying stochastic process follows a generalized linear model with noises that are (i) truncated normal or (ii) Gaussian. In case (i), we consider policies which are affine functions of past values of the process and use robust versions of the hard constraints. In case (ii), hard constraints are satisfied almost surely using policies given by projections of affine functions of past values of the process on the set defined by the hard constraints. In both cases, joint dynamic chance constraints are used to allow the approximate policies to satisfy the remaining set of random soft constraints with a given probability. We show that these joint chance constraints can be written as a joint static chance constraint depending on a Gaussian random vector and on new decision variables. We provide explicit formulas for computing the gradient and the Hessian matrix of the probabilistic function corresponding to this joint static chance constraint. Finally, the methodology is applied to the control of a hydro-thermal system corresponding to the North-East region of Brazil.

Andris Möller

Derivative Formulae for Linear Chance Constraints under Gaussian Distribution

In the talk stochastic programs with joint linear chance constraints of the type \( P(T(x))\xi\leq\beta(x)\geq p \) are considered where \( \xi \) is a Gaussian random vector, \( P \) is a probability measure and \( p\in[0,1] \) is the required probability level. Such constraints arise, for example, from portfolio optimization or blending problems. In the context of solving stochastic programs, the main task consists in the computation of function values and gradients of the probability function \( \varphi(x)=P(T(x))\xi\leq\beta(x) \). It is shown how both of these computations may be led back to the computation of values of Gaussian distribution functions. Consequently efficient (existing) codes for the latter may be exploited to deal with linear Gaussian chance constraints when the matrix depends on the decision variable. Numerical results for selected applications will be reported.

Wim van Ackooij (with René Henrion)

Gradient formulae for nonlinear probabilistic constraints with Gaussian and Gaussian-like distributions

Chance constrained programming is the branch of stochastic programming dealing with optimization problems under chance constraints. Such constraints request that a constraint mapping of the decision vector and a multivariate random vector satisfies a specific inequality system with pre-given probability level. Many, if not most, resolution methods yielding ultimately an (locally) optimal solution require gradients. Therefore, for an efficient resolution of chance constrained programs it is convenient to dispose of an easy way to compute such gradients. Efficient gradient formulae are available for several specially structured chance constraints. In this work we will show how we can obtain an efficient gradient formula for chance constraints of a continuously differentiable map that is convex in the argument represented by a multivariate Gaussian random variable. In order to derive this formula we will use the spherical-radial decomposition of a Gaussian random variable. This will allow us to represent the gradient as an integral over the multi-dimensional unit-sphere. An efficient Monte-Carlo sampling scheme has been provided by Déak for such integrals. The key advantage of the obtained formula is that the same sampling procedure can be used to provide chance constraint values and gradients simultaneously.

Jianqiang Cheng (with Erick Delage, Abdel Lisser)

Distributionally robust stochastic knapsack problem

This paper considers a distributionally robust version of a quadratic knapsack problem, which we refer to as distributionally robust stochastic knapsack problems. In this model, a subset of items is selected to maximize the total profit while obeying that a set of knapsack constraints are satisfied with high probability. Contrast to
the stochastic optimization, we assume that only part of information on random data is known, i.e., the first and second moment of the random variables. As for the binary constraints, special interest is given to the corresponding semi definite program (SDP for short) approximation. Two different solving method are presented for SDP approximation and their optimal values are an upper bound and a lower bound respectively. An extensive computational study is given to illustrate the strengths of our proposed methods and distributionally robust approach.

Siqian Shen (with David Escott)

**Problems in Chance Constrained Network Interdiction**

We consider Network Interdiction Shortest Path problems with probabilistic chance constraints. The problem is formulated as a Stackelberg game between a network operator who must choose the shortest path in a network damaged by an adversary. Unlike standard Network Interdiction problems the adversary does not simply seek to maximize the minimum path length, but rather may seek to keep the minimum path length above a fixed threshold with large probability, or for fixed probability maximize the associated threshold. We identify different chance constrained formulations and applications, and develop valid inequalities for those formulations. We also explore the connections between these probabilistic chance constrained formulations and robustly feasible solutions.

**Problem formulation and solution algorithms**

[Room 5] Stochastic integer programming methods and applications

*Chair(s):* Lewis Ntaimo

Christopher D. Hagmann (with Nan Kong, Pratik J Parikh)

**Integrated Warehouse-Inventory-Transportation Planning under Uncertainty: A Stochastic Integer Quadratically-Constrained Programming Approach**

Warehouses play a vital role in mitigating variations in supply and demand, and in providing value-added services in a supply chain. However, warehousing decisions are typically not integrated when developing distribution plans in supply chain practice. This lack of integration has resulted in a substantial variation in workload (50%-150%) at our industry partner’s warehouse costing them millions of dollars. To address this challenge, we introduce the warehouse-inventory-transportation problem (WITP) to determine optimal distribution plans from vendors to customers via warehouses such that the total distribution cost is minimized. However, such an investigation of the three-way interaction between warehousing, inventory, and transportation decisions under demand uncertainty results in a two-stage stochastic integer quadratically-constrained program (SIQCP), which is computationally demanding. In this talk, we propose a scenario-wise decomposition-based algorithm for these SIQCPs. In this algorithm, lower bounds are obtained by solving the Lagrangian dual with relaxation of the non-anticipativity constraints. A global optimization framework is developed to manage the derived subproblems. The correctness of the algorithm is shown and its efficiency is presented with results from modest sized instances.

Michelle M. Alvarado (with Lewis Ntaimo)

**A Stochastic Integer Programming Extended Attack Response Model for Large-Scale Wildfires**

Extended attack response involves dispatching firefighting resources to suppress escaped wildfires, that is, fires that have exceeded initial attack capabilities. On average, over 76,000 wildfires took place in the U.S. each year from 2001 to 2011, which annually burned almost 7 million acres of lands and cost several hundred million dollars in federal wildfire suppression alone. In this talk, we present an integrated simulation-optimization methodology for extended attack response planning. We formulate the problem as a multi-period two-stage stochastic integer program to determine the location and firefighting strategies of resources in the first-stage, and the relocation of the resources in the second-stage after fire behavior is revealed. The decisions are made at each decision period in a rolling horizon fashion. Fire behavior and suppression simulation is used to generate scenarios at each decision period to provide information on how the fire will spread in the next period based on uncertain weather. Preliminary results based on cases from the Texas Forest Service will be presented.
Guglielmo Lulli (with Luca Corolli, Saravanan Venkatachalam, Lewis Ntaimo)

A Stochastic Integer Programming Model for the Stochastic ATFM problem

Air traffic Flow Management (ATFM) under uncertainty is now attracting a lot of interest from the research community. Some approaches have already been proposed to attack this problem highlighting the importance of keeping a balance between the complexity of the model and its representation of reality. In this talk, we present a two-stage stochastic integer programming formulation for the problem, which takes into account both uncertainty and the network structure of the problem. We also discuss a decomposition approach that takes advantage of the underlying structure of the problem and allows us to solve realistic instances in a reasonable computational time.

Luca Corolli (with Guglielmo Lulli, Lewis Ntaimo)

The Time Slot Allocation Problem under Uncertainty

In the air traffic industry, strategic decisions involve determining flight schedules at airports. These schedules are defined by assigning time slots to flights so that they can operate their departures and arrivals. The problem of optimally assigning time slots given airline requests is known as the Time Slot Allocation (TSA) Problem. In this talk, we propose a two-stage stochastic integer programming model for TSA that captures the uncertainty involving this problem, considering capacity restrictions that may be imposed on the day of operation of flights due to bad weather. We show two alternative formulations for TSA, and provide the results obtained by evaluating the models on a set of real instances. The results show that this approach can lead to relevant benefits for airlines.

Shabbir Ahmed

A distributed scenario decomposition algorithm for stochastic 0-1 optimization

We propose a version of the dual or scenario decomposition algorithm for stochastic combinatorial optimization problems that exploits the binary nature of the first stage variables to recover optimal primal feasible solutions. The scheme is applicable to quite general problem structures and can be implemented in a distributed framework. Illustrative computational results on a class of standard two-stage stochastic integer programming test problems is presented.

Energy

[Room 3] Renewable sources
Chair(s): Patrizia Beraldi

Marius Radulescu (with Constanta Zoie Radulescu)

Stochastic programming models for optimal location of renewable energy power plants

In this paper portfolio theory is applied in order to obtain optimal locations for renewable energy power plants. A geographically dispersed set of wind farms and solar power plants provide a more stable energy than the energy provided in the case the renewable energy plants are concentrated in a small area. Two single period portfolio selection models for optimal location of renewable energy power plants are presented. The models belong to the class of stochastic programming models. One of them is a safety first model and the other one is a chance constrained model. Decisions of investment in renewable energy power plants are connected with land use decisions and the development of the grid infrastructure. Some of the variables of the models are non-negative integers and others are binary variables. Input data in the models are represented by wind data sets and solar data set collected from sites geographically dispersed. In order to solve the models heuristic algorithms and computer simulation must be used.

Abdelsalam Eajal (with Kumaraswamy Ponnambalam)

Optimal Power Generation Scheduling in Microgrids Using Stochastic Programming

Power generation scheduling is a short-term operational planning problem. It can be divided in two main stages. The first stage concerns with determining which generating unit can be committed and for how long. The second stage is to determine the power output of the committed unit for each time interval. In large-scale power systems, the power scheduling problem is a deterministic linear/nonlinear mixed-integer optimization problem. The main objective of the system operator is to determine the optimal power schedule for the committed
units such that the demand at any given time is met at minimum cost. However, with the increasing penetration of renewable energy units, a new concept in power systems has emerged and that’s microgrids. The microgrid can be defined as a small portion of the main grid which has its own generation and loads. The generating units in microgrids can be classified as dispatchable units such as diesel and gas turbines and non-dispatchable units such as photovoltaic (PV) and wind units. The intermittent nature of renewable energy imposes a challenge to the microgrid operator when scheduling the power generation among the committed dispatchable units. In this study, the power scheduling problem in microgrids is investigated taking the uncertainty in wind power into account. The problem is formulated as a stochastic mixed-integer linear optimization problem with the objective being minimizing the total microgrid expenses. The objective is subject to a set of operational constraints imposed on the generating unit itself and the system. A two-stage stochastic programming method is applied to find the optimal power generation schedule of a microgrid. The developed approach was implemented in General Algebraic Modeling System (GAMS) platform. The developed method is tested on a microgrid consisting of eight dispatchable units and a wind farm with a capacity of 1.1 MW. To demonstrate the savings due to uncertainty modeling, the value of the stochastic solution (VSS) is used to compare the stochastic power schedule obtained with the deterministic one.

Michael Pascal Nielsen (with Pierre Pinson, Henrik Madsen)

A reliable - and flexible power system ensured through demand response

Flexibility as a single mean is not sufficient for securing a reliable and efficient operation of the power system since it requires energy in form of electricity, and generation- and transmission capacity. Flexibility in the power system is as essential as energy and capacity - power plants must therefore carry additional reserves to maintain the reliability in the case should an unexpected drop in wind power occur. The stochastic nature of the wind requires sufficient capacity both in generation - and the transmission grid. Adding more variability and unpredictability to the power system will lead to an increased number of start-ups, ramping and periods of operation at low load levels. Suppliers in the electricity markets respond to prices that change hour by hour, but consumers rarely respond to price changes. Demand response is a mean to encourage lowering the electricity consumption. Demand response can be motivated by giving the costumers an incentive to reduce their loads at times when either the electricity price is high or the system reliability is at stake.

Ali Koc (with Jayant Kalagnanam, Innocent Kamwa, Louis Delorme)

Integrating wind power into a pure hydro power system via a two-stage stochastic program

We address the daily generation and transmission planning of a pure hydro-power system with large-scale wind power integration. Hydro-power stations do not usually suffer from generator (turbine) start-up or shut-down times, or from delays in ramping up and ramping down the generators, as in the case of thermal power stations. However, the interaction between the reservoirs in the hydro network complicates the ability to rapidly react to wind power fluctuations. Hence, a seamless integration of wind power into a hydro power system requires keeping significant load-following reserves. We propose a two-stage stochastic program that addresses the wind power intermittency and aim to reduce the reserve levels. We also investigate the benefit of demand dispatch in alleviating the effect of wind power uncertainty. We present examples from the Quebec Interconnection.

Arild Helseth

A stochastic optimization model for long-term hydropower scheduling

In hydropower dominated systems, long-term scheduling (3-5 years) of resources is important for expansion planning, price forecasting etc. In the Nordic power system, comprising more than 1000 hydro reservoirs, this scheduling has traditionally been solved by aggregating reservoirs. However, with the future upgrades in transmission capacity between the Nordic and other European electricity markets, and with the increased volatility and stochasticity introduced by more renewable energy in the systems, the traditional scheduling methods are challenged. The flexibility of the hydropower system will play a more important role in this future. Thus, it is important that future scheduling models realistically capture the constraints that limits this flexibility. In this context, ideas and work in progress to design a new fundamental hydro-thermal scheduling model will be presented. This model should comprise both a detailed hydropower representation and constraints limiting the utilisation of the power grid. In all, the problem may be classified as a large-scale multi-stage stochastic optimization problem, and will have to rely on massive parallel processing.
On Solving Dual Level Scenario Tree for the Energy Commercialization Problem in Brazil

Dual level scenario trees have a particular modeling structure in which there are strategic and operational nodes. In the strategic node, the most important decisions are taken, such as investments or commercialization strategies for the next year or some time period. In the operational nodes, the consequences of the strategic decisions are assessed as well as some additional adjustments may be taken into account. The dual level scenario tree reduces the size of the traditional scenario trees yielding a decrease in the computational burden. In this paper we discuss this strategy for solving the proposed scenario tree and we compare it to the traditional one in an energy commercialization problem. The case study considers the problem of a hydro company and the regulatory framework of the Brazilian energy market.

A Markov Chain Method to Bootstrap Multivariate Continuous-Valued Stochastic Processes

Models for energy markets involve the maximization of expected profits of producers. The estimation of expected values often requires a joint simulation of the stochastic processes driving prices and quantities of fuels and electricity. Such task is extremely complex, due to the peculiar properties of the series (jumps, stochastic volatility, spikes, regimes). We advance a data driven algorithm to bootstrap multivariate continuous-valued stochastic processes based on Markov chains. We choose the partition of the continuous support of the process by means of a Tabu Search heuristic.

Two-Stage Portfolio Optimization with Higher-Order Conditional Measures of Risk

Optimization of a portfolio with an option to rebalance over multiple periods from is a major problem in modern portfolio theory. In this research, different forward and backward scenario tree generation techniques are applied on multivariate GARCH-generated scenarios to construct scenario trees. Then, Monge-Kantorovich transportation model is developed to compare the probability distribution of the GARCH-generated scenarios with the probability distribution in the constructed scenario trees. Next, mean-semideviation risk function with higher-orders is used to formulate the two-stage portfolio problem in which there are two periods and an option to rebalance between those two periods. Simulation analysis will be done to measure the performance of this method with the stated risk functions is evaluated on the scenario tree which is constructed in the previous part.

Practical scenario tree reduction methods for dynamic portfolio management problem

To properly describe and efficiently solve dynamic portfolio optimization problems, we propose a practical scenario tree reduction algorithm under the financial decision setting. The algorithm refines existing single-node reduction methods and overcomes their deficiencies. To further increase the efficiency of the scenario tree reduction process, we extend the above single-node reduction method to a multi-node reduction algorithm, which could reduce multiple nodes at one iteration. In addition, no-arbitrage condition is considered in our scenario tree reduction methods, and the reduced scenario tree obtained from our algorithms is arbitrage-free, which is important for financial optimization problems. A series of numerical experiments are carried out and reduced scenario trees are applied to the multi-period portfolio management problem, the results show the practicality and high performance of two methods, especially for the multi-node reduction algorithm. What is more important, based on the reduced scenario trees, it becomes much easier to solve the dynamic portfolio selection problem, and the obtained optimal trading strategies are more reasonable and robust.
Luca Taschini (with Santiago Moreno-Bromberg)

** Tradable Permits Schemes and New Technology Adoption**

This paper investigates technology adoption behavior under no-anticipation of new technology and imperfect competition in a tradable permits scheme (rents market). The inter-dependence between the incentive to adopt a new technology and the allowance price (scarcity market) is explicitly modelled. The incentive depends on the expected value of scarcity rents. Future rents reflect the expected level of uncovered pollution emissions (permits demand), the expected level of offered emission permits (permits supply), and the current technological status. The aggregate supply is the solution of a non-cooperative game that possesses a pure-strategy Nash equilibrium. This condition is also satisfied when a price support instrument is introduced to induce a long-term incentive to adopt a new technology. The paper examines, both theoretically and numerically, the impact of the price support contract on the scarcity rent value and on the technology adoption behavior.

Operations Management and Software

[Room 10] Networks and transportation

*Chair(s): Alexei A. Gaivoronski*

Chefí Triki (with Simona Oprea, Patrizia Beraldi, Teodor G. Crainic)

**Bid Generation in Combinatorial Auctions for the Transportation Procurement under Stochastic Winning Prices**

We deal with the generation of bundles of loads to be submitted by carriers participating in combinatorial auctions in the context of truckload transportation services. We develop a probabilistic optimization model that integrates the bid generation and pricing problems together with the routing of the carrier’s fleet. We propose two heuristic procedures that enable to solve models with up to 400 auctioned loads. The main features of our contribution consists in: - Considering the bundle price as a decision variable instead of a parameter; - Representing the auction clearing prices as random variables; - Including the dynamic aspect of the routing problem; - Determining the routing of the trucks over the whole temporal horizon by solving a fleet management problem; - Enclosing the pickup/delivery time windows related to every load; - Studying novel techniques for computing the synergies between the loads.

Shima Shahbazi (with Kasper Klitgard Berthelsen, Esben Høg)

**Optimizing RFID tagging in the aviation industry**

Every year, many passengers are affected by baggage mishandling. Mishandling costs the aviation industry 2,580,000,000 USD in 2011 according to Specialists in International Society of Aeronautical Telecommunications (SITA) baggage report at 2012. Thus, the aviation industry faces the challenge to solve the problem of mishandled bags. To study and solve the mishandling problem, some airports/airlines have used the Radio Frequency Identification (RFID) technology to tag, read and track the bags. RFID tags are attached to the bags at check-in in the departing airport and they are read during their journeys by RFID readers. The read data include the times when a bag passes the readers in the RFID network. The data is used to estimate baggage handling quality daily in each step of this network. Although using the RFID technology is beneficial in studying and solving the mishandling problem at the aviation industry, it has only been implemented in a few number of airports. One reason for the limited extent of RFID implementation is due to its tagging cost. In order to reduce the cost of tagging in the aviation industry, we consider the minimum extent of RFID tags needed to ensure a reliable insight into the statistical analysis of RFID data. It leads to a discrete optimization problem with an objective function formed as a penalty function. Due to the variability of the number of the bags which are tagged daily and the number of the bags which are handled in different steps of the network, we define the above optimization problem as a stochastic problem with an expected value objective function and a chance constraint. Not only, the objective function of the mentioned problem does not have a closed form, but also its chance constraint is not a separable simple chance constraint. To deal with these difficulties, we use the well-known Sample Average Approximation method (SAA). The main idea of this method is that it defines an approximated optimization problem by the sample average functions corresponding to the stochastic objective function and the chance constraint and then solves the approximated problem instead of the true problem.
Paola Zuddas (with Massimo Di Francesco, Alexei A. Gaivoronski)

Container transportation problem under uncertain demand and weather conditions

We consider multiperiod planning of maritime container transportation of goods with uncertain demand on the amount of requested empty containers in scheduled ports. Loading/unloading decisions must be taken before exact demand and availability of containers is known. In addition, weather conditions that affect loading/unloading operations are subject to unforeseeable changes. We develop stochastic optimization techniques for solving this problem based on combination of simulation and optimization, which allows to choose the optimal parameters of loading/unloading decision rules.

Alexei A. Gaivoronski (with Abdel Lisser)

Bilevel stochastic network problem

We consider a network with communication/transportation demands between different nodes. Both demand and connection costs/travel times on links are described by random variables. The network is managed by Network Operator who places charges/tolls for communication/transportation on links. The demands are served by Service Provider who decides the optimal routing that depends on link costs and tolls. This situation gives rise to stochastic bilevel network problem where the upper level is constituted by Network Operator who decides the tolls and the lower level by Service provider who, knowing tolls, decides what part of demand to satisfy and how to route it. We develop numerical techniques for solution of this problem that belongs to the family of stochastic gradient methods and exploit the network structure. This enabled us to investigate how the optimal solution depends on the level of uncertainty. In particular, we show that stochastic problem with continuous distributions possess considerably better properties compared to deterministic bilevel problem. We have observed that deterministic solution degrades substantially in the presence of even small uncertainty, a phenomena not known in single level optimization problems.
**New Concepts for Stochastic Systems**

[Room Galeotti] Stochastic programming and stochastic control

Chair(s): Michel De Lara

Michel De Lara (with Pierre Carpentier, Jean-Philippe Chancelier)

**Information constraints and discretization puzzles in stochastic optimal control**

We first shed light on the two main new issues in stochastic optimal control (SOC) in comparison with deterministic optimal control: the handling of risk attitudes and of online information. Then, we stress the importance of so-called information constraints (including non-anticipativity constraints) in the formulations and the possible resolution of stochastic optimal control problems. Third, working out a toy example, we discuss issues and puzzles in the discretization of SOC problems. We highlight the point that scenario trees link randomness and information discretizations. We propose a discretization scheme where randomness and information are discretized independently, and we provide proper convergence results.

Pierre Carpentier

**Variational approaches in stochastic optimal control**

When dealing with the numerical solution of stochastic optimal control problems, dynamic programming and stochastic programming are two standard approaches. But the first one is subject to the curse of dimensionality, whereas the second approach (scenario tree method) usually does not deliver a sufficiently accurate information to deliver a feedback law "outside of the tree". An alternative is to write down the optimality conditions of the optimal control problem. For the numerical resolution of those optimality conditions, an adaptive mesh discretization method is used in the state space in order to provide information for feedback synthesis. This mesh is naturally derived from a bunch of sample noise trajectories which need not to be put into the form of a tree prior to numerical resolution. Results of experiments with a hydroelectric dam production management problem are presented, as well as with a more realistic problem in order to stress the effectiveness of the method for high dimensional problems.

Jean-Philippe Chancelier (with Jean-Philippe Chancelier, G. Cohen, Michel De Lara, P. Girardeau, Pierre Carpentier)

**Dynamic Consistency for Stochastic Optimal Control Problems**

Stochastic Optimal Control (SOC) is concerned with sequential decision making under uncertainty. As the time evolves, observations are made on the system, and it is generally profitable to adapt the decisions to the available information. Our aim in this presentation is to enlighten the role of information in the time consistency notion. We will show that a sequence of problems may be consistent for some information structure while inconsistent for a different one. We will consider a standard stochastic optimization problem solvable using Dynamic Programming, and will observe that a sequence of subsequent problems formulated from the original one are time consistent. We will show that adding a probabilistic constraint involving the state at the final time brings time inconsistency, in the sense that optimal strategies based on the usual state variable have to be reconsidered at each time step. In addition to the classical difficulties regarding probabilistic constraints a new matter arises in the dynamic case. We will establish that time consistency can be recovered provided an adequate state variable is chosen.

Jean-Christophe Alais (with Pierre Carpentier, Vincent Leclere)

**Decomposition-coordination methods in stochastic optimal control.**

We focus on large scale stochastic optimal control problems, known to suffer from the curse of dimensionality. We start by giving a short overview of the main ideas and mechanisms of decomposition / coordination methods -- with respect to time, randomness and space -- in the stochastic case. Then, we present the Dual Approximated Dynamic Programming method. To end, we address the hydroelectric production management of interconnected dams and we present numerical results on a real case based instance.
Modelling energy transmission is a very important issue for any electric utility in Europe. It is strategic for utility companies to be able to plan the energy exchange evolution up to 30 years ahead. This prospective is used for example in deciding which capacity we need to expand over the next years. The way the prices of commodities evolve and an accurate forecasting of the consumption load are related issues. Due to the time horizon of these problems one should take into account the uncertainty in order to provide reliable decisions. Furthermore, due to computational issues (curse of dimensionality), one can think about computing decentralized strategies for long term investments and daily power production. This turn out to be sub-optimal for most of network configurations and we need elaborated coordination schemes in order to approach optimality. Thus we consider addressing the issue of numerical resolution of network multistage stochastic optimization problems. We will particularly focus on different decomposition schemes and present different coordination algorithms approximating optimal strategies in a stochastic framework.

New Approaches to Classical Problems

[Room 4] Integer Programming Based Approaches for Chance-Constrained SPs
Chair(s): Shabbir Ahmed

James Luedtke (with Yongjia Song, Simge Kucukyavuz)

Recent Advances for the Solution of Sample-Average Approximations of Chance-Constrained Stochastic Programs

By using sample average approximation, a general chance-constrained stochastic program (CCSP) can be approximated by a CCSP in which the distribution has finite support. Solving the resulting CCSP requires determining which subset of the sampled constraints should be satisfied, a task which is NP-hard in general. We present some recently developed integer programming and decomposition techniques that can be used to solve several classes of such problems. For chance-constrained network design and packing problems, which have binary decision variables, we find that it is important to take advantage of the combinatorial structure of these problems. By doing so, we are able to extend techniques that are successful for the deterministic versions of these problems to the chance-constrained counterparts, and obtain formulations that scale well with the number of scenarios used to approximate the distribution. Time permitting, we will also present results of our recent efforts to solve CCSPs with a huge number of scenarios.

Simge Kucukyavuz (with Xiao Liu)

A Decomposition Algorithm for a Chance-Constrained Program with Recourse

We consider a class of two-stage stochastic optimization problems. In the first stage, a set of decisions must be made before random parameters, with finite support, are revealed. In the second stage, after the realization of uncertain parameters, recourse decisions are made at an additional cost such that a certain service level is met with high probability. We propose a finite decomposition algorithm for this class of problems, and report our computational experiments with it.

Yongpei Guan (with Ruiwei Jiang)

Data-driven Chance Constrained Stochastic Program

Chance constrained programming is an effective and convenient approach to control risk in decision making under uncertainty. However, due to unknown probability distributions of random parameters, the solution obtained from a chance constrained optimization problem can be biased. In addition, instead of knowing the true distributions of random parameters, in practice, only a series of historical data, which can be considered as samples taken from the true (while ambiguous) distribution, can be observed and stored. In this paper, we derive stochastic programs with data-driven chance constraints (DCCs) to tackle these problems and develop equivalent reformulations. For a given historical data set, we construct two types of confidence sets for the ambiguous distribution through nonparametric statistical estimation of its moments and density functions, depending on the amount of available data. We then formulate DCCs from the perspective of robust feasibility, by allowing the ambiguous distribution to run adversely within its confidence set. After deriving equivalent reformulations, we provide exact and approximate solution approaches for stochastic programs with DCCs under both moment-based and density-based confidence sets. In addition, we derive the relationship between the
conservatism of DCCs and the sample size of historical data, which shows quantitatively what we call the value of data.

Siqian Shen (with Miguel A. Lejeune)

**Mixed-Integer Programming Models for Optimizing Risk Parameter in Chance Constraints**

We consider a joint-chance-constrained program variant where the risk parameter is variable. Associated with the risk, there is a monotone increasing cost function that can be interpreted as the cost of reputation. The goal is to trade off the reputation cost and the original cost via risk and decision optimization. For programs with random technology matrices, we employ results of cut points and threshold Boolean functions to reformulate equivalent MIPs, in which we replace the risk parameter by representations in binary variables. We compare the strengths of several MIP reformulations and demonstrate the computational efficacy on randomly generated instances with linear reputation functions. The paper develops valid inequalities and bisection algorithms for improving the computational results. We test instances of the portfolio management problem with variable risk tolerances in chance constraints for bounding returns of multiple funds. Managerial insights are derived via minimizing the variance of the overall portfolio and the reputation cost yielded by chosen risk tolerances.

Ricardo Fukasawa (with Ahmad Abdi)

**Improved MIP models for chance-constrained problems with probabilistic right-hand sides**

In a recent work (Abdi and F., 2012), we studied the mixing set with a knapsack constraint, a substructure that arises in Integer Programming reformulations of chance-constrained mathematical programs with random right-hand-sides. We present further developments and understanding of that structure, analyzing what are the possibilities and limitations of our knowledge of the polyhedral structure of such set. In essence, we show that any polyhedral knowledge of the knapsack set can be translated into polyhedral knowledge of the given set. We also comment on issues that arise when using our results to separate valid inequalities via linear programming and propose solutions for them.

**Computation and Applications**

[Room 3] Progressive hedging applied to mixed-integer and nonlinear SPs

*Chair(s): David L. Woodruff*

David L. Woodruff

**Progressive Hedging Applied to Mixed-Integer and Non-Linear Stochastic Programs**

In this introduction, we provide a tutorial overview of Progressive Hedging (PH) from a computational perspective with an eye toward applications to mixed integer (MIP) and non-linear (NL) problems, including a brief survey of literature concerning applications. We also survey literature concerning algorithmic and tuning innovations to support the effective solution of MIP and NL using PH. We describe the PySP open-source software that supports continuing research at many locations on innovations for, and applications of, PH.

Yankai Cao (with Daniel P. Word, Jia Kang, Jean-Paul Watson, David L. Woodruff, Carl D. Laird)

**Progressive Hedging for Non-Linear Models that Arise in Parameter Estimation Problems**

In this work, we consider the efficient solution of a broad class of stochastic nonlinear programming problems, that of model parameter estimation. Parameter estimation is vital in chemical engineering to determine appropriate model parameters for physical systems such as rate constants for kinetic models, heat transfer coefficients for cooling jackets, or mass transfer coefficients in distillation columns. We exploit a fundamental, unexplored equivalency between stochastic nonlinear programming and parameter estimation problems. Specifically, parameter estimation problems can be expressed as nonlinear stochastic programs, as they share multi-stage decision structure and the associated block-angular matrix form. The latter suggests that it may be possible to exploit advances in decomposition techniques for solving stochastic programs in order to yield significant accelerations in the solution of parameter estimation problems. Further, parallelization of the decomposition strategy is likely to yield further, significant run-time reductions. We use Sandia's Pyomo package to model general nonlinear parameter estimation problems. Decomposition strategies for stochastic programming, specifically Rockafellar and Wets' Progressive Hedging algorithm, are employed for problem solution. Specifically, we use Sandia’s PySP software library for stochastic programming. Ipopt is used to solve individual sub-problems.
Jean-Paul Watson (with David L. Woodruff, Roger Wets, Cesar Silva Monroy, Sarah M. Ryan, Dinakar Gade)

Progressive Hedging for Stochastic Unit Commitment

Market management systems (MMSs) determine which generation resources should be used to securely and optimally service expected load on the electricity grid. At the heart of a modern MMS is a mixed-integer unit commitment (SCUC) optimization model. The growing penetration of intermittent renewable generation necessitates a shift to stochastic variants of the SCUC, to deal with inherent uncertainty in power production. We will describe the stochastic programming SCUC formulations and algorithms that are currently being developed under an effort funded by the US Department of Energy, for eventual use in commercial MMSs. Using Progressive Hedging as implemented in Sandia National Laboratories' PySP library for stochastic programming, we devise upper-bounding procedures to facilitate identification of near-optimal solutions to ISO-sized instances within reasonable computation times. The proposed algorithms leverage and are deployed on modest-scaling parallel computing resources. We discuss challenges and solutions to the parallelization of scenario-based decomposition algorithms, including asynchronous computation and scenario bundling strategies.

John D. Siirola (with Zev Friedman, Cesar Silva Monroy, Jean-Paul Watson)

Progressive Hedging for Stochastic Economic Dispatch with AC Power Flow

Economic dispatch, the process of setting minimal-cost generator output levels in an electrical grid, is solved in practice as a deterministic linear program. Specifically, loads are assumed fixed, and a DC power flow approximation is employed in the problem formulation. However, especially in the context of high renewables penetration, the real problem is both stochastic (due to uncertainty in wind and solar plant production) and non-linear (due to AC power flow). We investigate the use of progressive hedging to solve the stochastic, non-linear economic dispatch problem with AC power flow. Sub-problems are solved with the open-source non-linear solver Ipopt. Computational experiments on standard IEEE benchmarks are discussed, in addition to parallelization on modest-scale compute clusters.

Sarah M. Ryan

A New Lower Bound from Progressive Hedging

In convex problems, progressive hedging (PH) is guaranteed to converge to an optimal solution but restrictions on computation time may require early termination in large-scale instances. In stochastic mixed-integer programs, the duality gap implies that the cost of the solution found by PH is an upper bound on the optimal cost. A tight lower bound can provide reassurance on the quality of the PH solution. We describe a new method to obtain lower bounds using the information prices generated by PH as well as an implementation of this new lower bounding functionality in the Coopr PySP software. We show empirically, using these lower bounds, that for large-scale non-convex stochastic unit commitment problems, PH generates extremely good solutions. These observations are also verified by lower bounds obtained from dual decomposition.

Finance and Applications

[Room 5] Asset allocation and ALM for long term investors
Chair(s): Giorgio Consigli

Woo Chang Kim (with John M. Mulvey)

Improving Diversification in an Era of Contagion: Optimizing over a Set of Assets and Special Tactics

For a variety of reasons, the correlations in asset returns in areas such as stocks, commodities, and currency markets have increased over the past decade, especially during crash periods. Thus, achieving a reasonable level of diversification has become more difficult. We develop a methodology for improving risk adjusted performance by constructing systematic tactics, along with traditional asset categories. These tactics can be readily securitized by means of exchange traded products. We illustrate the process via a new family of commodity indexes developed for FTSE
Lorenzo Mercuri (with Giorgio Consigli)

**Factor Models for Scenario Construction in Long Term Asset Allocation.**

The aim of this work is to analyse the empirical results of a multi-objective dynamic stochastic programming ALM model for an insurance company using different statistical models to capture the main features of asset returns. In such context, we consider two alternative approaches. In the first one the statistical behavior of asset returns is explained using observable variables and emphasizing the role of macroeconomics variables. In the second approach we explain asset returns using the smallest possible number of linear combination of specified random variables and relying on probability mixtures able to capture long term returns behavior. Approximation results for large scale stochastic programs are presented under the different statistical assumptions.

Thomas Bauerfeind (with John M. Mulvey)

**Practical Examples: Optimizing Dynamic Asset Allocation Strategies with Approximate Dynamic Programming**

Multistage Stochastic Programming approaches suffer some deficits when it comes to find solutions for problems where more complex management and evaluation rules have to be represented. Thus Approximate Dynamic Programming with decision or policy rules is commonly used in consulting practise nowadays instead. Their standard design for asset allocation problems with one so called fixed mix portfolio vector does regularly not meet the investor’s requirement for advice on dynamic strategies depending on certain individual state variables. Some practical examples are shown where in addition to a portfolio vector the optimization within a decision rule structure does also give answers regarding the design and parameterization of conditional rebalancing rules identifying among other aspects the appropriateness of cyclical versus anti-cyclical investment decisions.

Massimo di Tria (with Giorgio Consigli)

**Relevant short-medium-long term decision criteria for optimal Property & Casualty portfolio selection**

Large institutional investors have a long and established experience in solving portfolio allocation problems across a wide spectrum of asset classes, whose underlying valuation models may be rather complex. Increasingly over the last few years Property & Casualty portfolios have been affected by significant pressure on their technical business due to growing claims per unit premium. Furthermore, due to the new regulatory framework for insurance companies, the need to comply with binding risk capital constraints also affected optimal portfolio choices. In the paper we present a dynamic decision model integrating those views and highlighting the historic step away from static approaches for long term institutional portfolio management.

Koray Deniz Simsek (with Woo Chang Kim, Min Jeong Kim, John M. Mulvey)

**Longevity Risk Management for Individual Investors using Multi-stage Stochastic Programming**

The uncertainty in the life expectancy plays a critical role in the individual financial planning. Utilizing a multi-stage stochastic program, we model and solve the optimal asset allocation problem of a retired couple with uncertain lifetime in the presence of a term life insurance policy, as an extension of the simulation-based model in Kim et al. (2012). In the base case, we find optimal policies assuming no longevity risk (i.e., life time scenarios are based on a fixed life expectancy on the retirement date). Next, we introduce longevity risk in the scenario generation stage through either a shift in the expected lifetimes or an unexpected cut in retirement income. We find that optimal asset allocation policy depends on the presence and the type of these risks as well as the relative price of insurance and the percentage cut in pension benefits. Finally, we show that our results are superior to generalized linear policies, yet can provide insights to improve them.
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