INTERNATIONAL CONFERENCE ON OPERATIONS RESEARCH

Decision Analytics for the Digital Economy

SEPTEMBER 06 – 08

with program updates (Sept 05)

www.or2017.de
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The print of the book of abstracts was supported by Techniker Krankenkasse.

Editorial work and layout: Charlotte Köhler, David Rößler
Welcome to OR2017!

More than 800 practitioners and academics from mathematics, computer science, economics, engineering, and related fields will participate at the International Conference on Operations Research at the Campus of Freie Universität Berlin.

The conference motto “Decision Analytics for the Digital Economy” takes up the trends that are currently empowering the field more than ever before, opening up new areas of applications in industry and society, and giving rise to exciting scientific challenges.

With 14 plenary and semi-plenary presentations of leading international scientists, more than 600 contributed presentations in 26 parallel streams, five pre-conference workshops, including two Hackathons, 18 exhibition stands, and 22 industrial sponsors, the conference provides ample opportunities to present and discuss the latest OR related developments from theoretical results and algorithmic progress to application-oriented case studies and hands-on training.

The social program features three evening events for networking and relaxing, and four guided tours to interesting OR related spots in Berlin.

Enjoy OR2017 to gain insights, get training in a workshop, participate in a hackathon, share your expertise with others, recruit your next employees, find your next job, or just meet old and make new friends in the intriguing fields of operations research, management science, data science, and analytics.

Have a productive and joyful OR2017 in Berlin!
Natalia Kliwer, Ralf Borndörfer, and Jan Ehmke
Welcome to Freie Universität Berlin!

Dear participants of OR2017,

On behalf of Freie Universität Berlin I would like to welcome you to the International Conference on Operations Research 2017!

I am delighted to say that this is our second time of hosting this distinguished conference at Freie Universität Berlin. The first conference, the 8th DGOR organized by Peter Stahlknecht, was held in 1978 with 400 participants, featuring 125 talks which – a novelty at the time – were organized into parallel streams in order to provide more time for presentation and discussion.

Certainly, many things have changed within the last 40 years. In 1978, to “utilize data availability” was the second case Eberhard Elsasser made in his opening speech adding that “...new methods of data acquisition and storage” would “open a new dimension of data availability”. Yet, he probably could not have imagined the vast potential – but also the risks – of what we call analytics today. The special focus of this years conference lies on the topic “Decision Analytics for the Digital Economy”. Tremendous progress has been and is still achieved in classical application areas of decision analytics such as manufacturing, logistics, transportation, finance, and engineering. In other areas, for example in medicine, life sciences, humanities, and social sciences new application uses are emerging.

Freie Universität Berlin encourages these developments, ranging from fundamental research to the support of seed-stage companies. We are proud to be part of initiatives such as the Einstein Center for Mathematics, the Einstein Center Digital Future, the Research Campus MODAL, and the new Business and Innovation Center.

We are aware that shaping the digital future will only succeed in form of a joint effort. In that sense, the OR2017 conference, organized by the School of Business and Economics, the Department of Information Systems and the Department of Mathematics and Computer Science of Freie Universität Berlin, as well as its participants with their interdisciplinary background, are prime examples of the notion of coming together to shape the future.

Dear participants, I wish you all a successful, productive, and enjoyable conference!

Sincerely,

Univ.-Prof. Dr. Peter-André Alt (President of Freie Universität Berlin)
Welcome to Berlin!

Dear Participants in the OR2017 Conference,

Welcome to Berlin for this prestigious scientific conference in the field of operations research! We are delighted that so many international experts from all over the world have come to Germany’s capital city to discuss and exchange expertise on this year’s special focus ‘Decision Analytics for the Digital Economy.’

You are meeting in a city that is well on the way to becoming a high-tech capital. That goes hand in hand with our ambition to make greater use of the opportunities digitalization offers. Berlin has enormous potential in this area, thanks to a concentration of scientific and academic institutions that is unique in Europe, the digital economy’s countless startups, and the growing number of established industrial companies working in close concert with universities and the startup scene.

As a result, I am confident that Berlin is the ideal setting for an inspiring conference in your field. In addition, the city itself provides inspiration with its wealth of cultural offerings. Anyone attending a conference in Berlin should take advantage of the opportunity to visit one of our many museums, theaters, or concert halls. Another good idea would be to take a stroll through one of our trendy neighborhoods and enjoy the relaxed attitude towards life of our vibrant metropolis.

With all this in mind, I would like to welcome you to Berlin once again and wish you a productive conference and a very pleasant stay that you will long remember.

My thanks go to the German Operations Research Society and the Department of Information Systems in the School of Business & Economics at Freie Universität Berlin for hosting and organizing this important conference.

Sincerely,

Michael Müller (Governing Mayor of Berlin)
CONFERENCE HISTORY

The history of the Annual International Conference of the GOR (Gesellschaft für Operations Research) – sometimes organized cooperatively with other OR societies from Europe – includes the following past stations:

2017 Berlin
2016 Hamburg
2015 Wien
2014 Aachen
2013 Rotterdam
2012 Hannover
2011 Zürich
2010 München
2009 Bonn (EURO)
2008 Augsburg
2007 Saarbrücken
2006 Karlsruhe
2005 Bremen
2004 Tilburg
2003 Heidelberg
2002 Klagenfurt
2001 Duisburg
2000 Dresden
1999 Magdeburg
1998 Zürich

The GOR was founded 1998 as the fusion of DGOR (Deutsche Gesellschaft für Operations Research) and GMÖR (Gesellschaft für Mathematik, Ökonomie und Operations Research).

In 1978, the 8th DGOR Annual Meeting was also hosted by Freie Universität Berlin with 400 participants and 125 talks.
STREAMS AND STREAM CHAIRS

Business Analytics, Artificial Intelligence & Forecasting  
Sven Crone, Alexander Martin, Thomas Setzer

Control Theory and Continuous Optimization  
Mirjam Dür, Stefan Ulbrich

Decision Theory and Multiple Criteria Decision Making  
Jutta Geldermann, Horst W. Hamacher

Discrete and Integer Optimization  
Christoph Helmberg, Volker Kaibel

Energy and Environment  
Dominik Möst, Russell McKenna

Finance  
Michael H. Breitner, Daniel Rösch

Game Theory and Experimental Economics  
Max Klimm, Guido Voigt

Graphs and Networks  
Marc Pfetsch, Jörg Rambau

Health Care Management  
Teresa Melo, Stefan Nickel

Logistics and Freight Transportation  
Stefan Irnich, Michael Schneider

Metaheuristics  
Franz Rothlauf, Stefan Voß

Optimization under Uncertainty  
Rüdiger Schultz, Sebastian Stiller

OR in Engineering  
Ulf Lorenz, Peter F. Pelz

Production and Operations Management  
Malte Fliedner, Raik Stolletz

Project Management and Scheduling  
Dirk Briskorn, Florian Jaehn

Revenue Management and Pricing  
Catherine Cleophas, Claudius Steinhardt

Simulation and Statistical Modeling  
Stefan Pickl, Timo Schmid

Software Applications and Modelling Systems  
Michael Bussieck, Thorsten Koch

Supply Chain Management  
Herbert Meyr, Stefan Minner

Traffic, Mobility and Passenger Transportation  
Sven Müller, Marie Schmidt

Business Track  
Natalia Kliewer, Ralf Borndörfer, Jan F. Ehmke
PROGRAM COMMITTEE

Natalia Kliewer (Chair)
Freie Universität Berlin

Jan Fabian Ehmke (Chair)
Europa-Universität Viadrina

Ralf Borndörfer
Freie Universität Berlin/Konrad-Zuse-Zentrum für Informationstechnik Berlin

Andreas Fink
Helmut-Schmidt-Universität Hamburg

Alf Kimms
Universität Duisburg-Essen

Thorsten Koch
Technische Universität Berlin

Stefan Lessmann
Humboldt-Universität Berlin

Rolf Möhring
Beijing Institute for Scientific and Engineering Computing

Anita Schöbel
Georg-August-Universität Göttingen

Martin Skutella
Technische Universität Berlin
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Freie Universität Berlin

Ralf Borndörfer (Chair)
Freie Universität Berlin/Konrad-Zuse-Zentrum für Informationstechnik Berlin

Jan Fabian Ehmke
Europa-Universität Viadrina

Max Klimm
Humboldt-Universität Berlin

Stefan Lessmann
Humboldt-Universität Berlin

Timo Schmid
Freie Universität Berlin

SUPPORTED BY

Bernard Fortz, Florian Hauck, Charlotte Köhler, Nils Olsen, David Rößler, Alexander Tesch, Clemens Wickboldt, Angelika Wnuk, Lena Wolbeck
As one of the largest capitals in Europe, Berlin is home to almost 3.5 million inhabitants. People living here are known as open-minded and relaxed (although “Berlinerisch”, the German accent in this area, can sound harshly).

Since Berlin was almost completely destroyed after World War II and divided with a wall from 1961 to 1989 into East and West Berlin, it is a city that especially evolved during the last 30 years. Becoming the capital of Germany again in 1990, Berlin has become a hub of politics, science and culture today. There is a big startup scene that makes Berlin also to the tech capital of Germany.

Berlin is a green city and full of lakes, forests & parks. There are a lot of people from different countries and cultures living in Berlin, and this is celebrated each year at the “Carnival of Cultures” in May. You can hear so many different languages when you walk through the streets and each district has its own flair. If you have enough time, don’t miss the famous “Brandenburger Tor”, the former airport Tempelhof, the Jewish Museum, the East Side Gallery with some old pieces of the Berlin wall, the Tiergarten park & Berlin life in Kreuzberg. And on a clear day, you can swim in the lakes or on the “Badeschiff” – a floating swimming pool on the river Spree.
DAHLEM

Dahlem is a district located in the southwest of Berlin. There are many small parks and the neighborhood is characterized by green pines and paving stones, several cafés and beer gardens lining the streets. Being home to Freie Universität Berlin, Dahlem becomes busy and dynamic during the week, when thousands of students come here by train or bike. In 1987, the underground station “Dahlem Dorf” next to the university was voted as the prettiest in Europe. And in 2016, another underground station next to the conference venue was named after the Freie Universität Berlin.

Besides academic research, Dahlem is also an important site for cultural institutions. The Botanical Garden houses one of the most extensive botanical collections in Europe. Dahlem is also known for its diverse museums. One of the well-known museums is the Ethnological Museum and the Museum of Asian Art, which is renowned for its collection of non-European art collections. The “Brücke Museum” houses a broad collection of early 20th-century expressionist art. Near the conference venue is the Allied Museum, where the history of the Western powers from 1945 to 1994 is exhibited – a particular highlight is the British Airlift plane.
Freie Universität Berlin is a leading research institution and it is one of the German universities successful in all three funding lines in the federal and state Excellence Initiative. Freie Universität takes its place as an international network university in the global competition among universities. Development and assessment of research projects takes place within various focus areas, research networks and platforms for interdisciplinary collaborative research.

Freie Universität Berlin was founded on December 4, 1948, by students, scholars, and scientists with the support of the American allied forces and politicians in Berlin. The move was sparked by the persecution faced by students who took a critical eye of the system at the former Universität Unter den Linden, at that time located in the Soviet sector of the divided city. Students and academics wanted to be free to pursue their learning, teaching, and research activities at Freie Universität, without being subject to political influence.

Generous donations from the United States enabled Freie Universität to build some of its central facilities, including the Henry Ford Building. In a nod to the history surrounding the university’s founding, the seal of Freie Universität still features the words truth, justice, and freedom. In 2007, the university dedicated a memorial to the founding students, who were killed by the Soviet secret service. The university also presents its Freedom Award to individuals who have made outstanding contributions to freedom.

CONFERENCE VENUE

OR2017 will be held at and around the Henry Ford Building in Berlin-Dahlem. The Henry Ford Building was erected between 1952 and 1954 according to the plans of the Berlin architects Franz Heinrich Sobotka and Gustav Müller. It was named after Henry Ford II, who arranged the donation of 8.1 million West German marks by the U.S.-American Ford Foundation for the construction of this building complex. The western wing of the Henry Ford Building contains the University Library including reading rooms, offices, and a book stacks tower. The eastern wing holds lecture halls and conference rooms. The building is protected as an historic monument and was completely renovated from 2005 to 2007. Since then, the building complex has been used as lecture halls and, increasingly, as a conference center. Sessions will also take place at the Department of Law and the School of Business and Economics, which are both located near Henry Ford Building.

The conference venue is located at the corner of Gary and Boltzmann Streets (for your navigation system: Garystr. 35, 14195 Berlin), near the U3 subway stop “Freie Universität (Thielplatz)” in the southwestern part of Berlin.
Most of the shops are open Monday to Saturday from 10.00–20.00. Supermarkets usually open at 7.00 or 8.00, and there are many that are open as late as 22.00 or midnight. On Sundays, only a very limited number of (touristic) shops are open. The supermarkets located at the stations in Friedrichstraße, Hauptbahnhof, Ostbahnhof and Zoologischer Garten are also open on Sundays. The streets around Tauentzienstraße and Kurfürstendamm form the most famous shopping area in Berlin. Start at Wittenbergbergplatz (subway U3) with the famous department store KaDeWe. If you are rather looking for small boutiques, you can either walk along the small streets around Savignyplatz in Charlottenburg, north of Hackescher Markt (a trendy and often also steep area in “Mitte”), or visit Oranienstraße (a more alternative style area around Görlitzer Bahnhof, subway U1).

In restaurants and cafés, it is common to give a tip of 5–10%, depending on the quality of service offered. In self-service locations, it is usually not necessary to tip. For taxis, it is the same as for restaurants.

**LITTLE PHRASEBOOK: BERLINERISCH**

Asche – money
ausklamüsern – find out
helle – smart
icke – I
kieken – look
Kiez – district
loofen – walking
Quadratlatschen – big feet
Schlamassel – difficult situation
schnuppe – indifferent
Schrippe – bun
Stulle – bread
GETTING AROUND

BY PUBLIC TRANSPORT

Conference participants receive a public transport ticket, which is imprinted in the personal badge (valid from Tuesday 19.00 until Friday 19.00). The badge allows to use all means of public transport (subways, trams, busses, regional and suburban trains) in Zones “A” & “B” during the conference period at no further cost (after having fetched the badge at the conference desk). Note that in case of ticket checks, a personal ID may be required. For users of mobile devices, connections can be checked at http://www.vbb.de or by using the app “Bus & Bahn”, available for Android and iPhone, or simply by using GoogleMaps. A common way to reach the conference venue by public transport from the city center is to use subway U3 (green line, direction Krumme Lanke) to the stop “Freie Universität (Thielplatz)”. Additionally, from the city center one may also use the suburban train S1 (pink line, direction Wannsee) to the stop “Lichterfelde-West”. From Lichterfelde-West, it takes 15 minutes of walking to the conference venue.

BY TAXI

Getting around by taxi is rather expensive. The taxi fares start from 3.90€ with an additional 2€/kilometer for the first 7 kilometers and 1.50€/kilometer beyond that. A short ride below 2km (“Kurzstrecke” in German) at a flat rate of 5€ is possible when telling the driver in advance. Use the app “Taxi Berlin” or call +49 30 20 20 20.
MAP OF CONFERENCE VENUE
RECHTSWISSENSCHAFT (RVH)
Van’t-Hoff-Straße 8

PARALLEL SESSIONS

GROUND FLOOR
AROUND THE CONFERENCE VENUE

RESTAURANTS

1 Eierschale
International kitchen
(incl. Breakfast)
09.00 – 00.00
Podbielskiallee 50

2 Luise
Berlin kitchen with a nice beer garden
10.00 – 01.00
Königin-Luise-Straße 40

3 Galileo
Italian restaurant at the top of main building of Freie Universität
11.00 – 22.00
Otto-von-Simson-Straße 26

4 Trattoria Romana
Cosy Italian restaurant serving pizza & pasta
11.00 – 00.00
Unter den Eichen 84d

5 Maria & Josef
Bavarian restaurant and beer garden
12.00 – 0.00
Hans-Sachs-Straße 5

CAFÉS

6 Wiener Conditorei
Traditional café
08.00 – 19.30
Clayallee 175

7 Aux Délices Normands
French bakery with outstanding cakes
07.00 – 18.00
Ihnestraße 29

PHARMACIES

8 Oskar Helene
08.30 – 19.00
Clayallee 175

9 Dahlem Dorf
08.30 – 18.30
Königin-Luise-Straße 38

10 Adler
08.30 – 19.00
Drakestraße 44

SUPERMARKETS

11 EDEKA
07.00 – 00.00
Clayallee 175

12 REWE
06.00 – 00.00
Königin-Luise-Straße 37

13 Alnatura (Organic food)
08.00 – 20.00
Hans-Sachs-Straße 4b

ATM

14 Commerzbank
Clayallee 175

15 Sparkasse
Otto-von-Simson-Straße 26

16 Volksbank
Königin-Luise-Str. 44
GENERAL INFORMATION

CONFERENCE DESK

This is the central source of information and assistance for all participants; in particular, you receive your conference material there. It is located at HFB. Luggage deposit and retrieval is possible at the conference desk during opening hours (not overnight). The desk also collects lost and found items.

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<td>Thursday (September 7)</td>
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<td>Friday (September 8)</td>
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LUNCH & COFFEE BREAKS

During the entire conference (Wednesday – Friday), catering is available at the HFB (ground and 1st floor). During the breaks, coffee and snacks/cookies will be served. At lunch breaks, soup (Wednesday & Thursday) or ciabatta (Friday) is available. Coffee and drinks are always served during the day.

INTERNET ACCESS

Participants of universities and research institutes can use the eduroam wireless internet access points throughout the Freie Universität Berlin campus. In addition, there will be a separate wifi available for all participants. You can access this network with the following information:
Name: conference
Key: u32fhek2
REMARKS FOR SPEAKERS AND SESSION CHAIRS

Lecture rooms are equipped with a computer (please check back with us for special hard- and/or software), projector and microphone (if necessary, usually due to room size). All you need to bring is your presentation on a USB stick (any additional material is up to you), ideally in PowerPoint and/or PDF format. There will be an assistant in each room who can help you if a technical issue occurs.

Each technical session takes 90 minutes. The session chair is responsible for dividing the time into equal parts. This is 22 minutes per speaker in a session with four speakers and 30 minutes per speaker in a session with two or three speakers including discussion. The session chair also facilitates the discussion. Please begin and end each presentation on time and ensure that the presentations are held in the order shown in the program. If a speaker cancels or does not attend, the session chair is asked to have a break of according length. Please refrain from any changes to the schedule to allow people changing sessions to allow participants for session jumping.

CREATE YOUR OWN CONFERENCE PROGRAM

To create your own conference schedule, we provide up-to-date information via the “My Program” functionality of the EURO Conftool website. When you login with your EURO account, you can select the sessions you are interested in. You can view your individual selection online, download a calendar file, or print your individual program. We have already made some recommendations for sessions that may be of interest to you.

https://www.euro-online.org/conf/gor2017/program
SOCIAL PROGRAM

GET-TOGETHER

Tuesday, September 5, 18:00 – 22:00, Forecourt of HFB, Garystraße 35, 14195 Berlin

Before the official opening of the conference, we invite you to an informal Get-Together on Tuesday night. We will welcome you with a barbecue and drinks, so please join us to meet old and new friends and colleagues. Check-in at the conference desk will be open during that evening.

Arrival: Subway U3 to “Freie Universität (Thielplatz)” and walk for 5 minutes.

WELCOME RECEPTION

Wednesday, September 6, Admission: 19:00 (door closes at 19:30!), 19:30 – 22:30, Wasserwerk, Hohenzollerndamm 208a, 10713 Berlin

Please join us for a night at the Wasserwerk Berlin with food and drinks! The reception on Wednesday evening will take place at the machine hall of the Wasserwerk Berlin based in Wilmersdorf in the western part of Berlin. The historic building of industrial architecture is an old pump station, built about 100 years ago. The machine hall impresses with water pumps and cases and will provide a great atmosphere. Admission to the reception is free. Yet, the number of tickets is limited. Please bring your ticket.

Arrival from conference venue: Subway U3 to “Spichernstraße”

Arrival from other directions: S-Bahn (urban train) S5, S7 or S75 to “Zoologischer Garten” and 10 minutes walk.
CONFERENCE DINNER

Thursday, September 7, 19:00 – 23:30, Seminaris CampusHotel Berlin, Takustraße 39, 14195 Berlin

The Conference Dinner on Thursday evening will take place at the Seminaris CampusHotel Berlin in close proximity to the conference venue. The hotel is directly located on the campus of the Freie Universität Berlin. The highly modern hotel will serve as a great location for the last night of the conference. Tickets for the dinner are available at 80€, as long as supply lasts. Please bring your ticket.

Arrival from conference venue: 10 minutes walk
Arrival from other directions: Subway U3 to “Dahlem Dorf”
GUIDED TOURS
The meeting point for all guided tours is in front of the HFB

SUPERCOMPUTER KONRAD AT ZIB
Wednesday, September 6, 16:30 – 17:15*
Massively parallel computing is one of the core activities of the Zuse Institute Berlin (ZIB), which is why the ZIB is operating one of the most powerful computing machines worldwide. ‘Konrad’, which represents the Berlin part of the North German Supercomputing Alliance (HLRN), is a valuable companion of hundreds of scientists in northern Germany for groundbreaking scientific research in Earth Sciences, Fluid Dynamics, Material sciences and many other fields. The HLRN operates a Supercomputer with 90,000 cores, 250 Terabyte of memory and high performance parallel filesystems to fulfill the needs of today’s scientific demands. Take a brief overview in today’s supercomputing through a guided tour at Konrad.

We will meet approximately one hour before the tour starts. Details will be provided on your tour ticket.

BER AIRPORT TOUR
Thursday & Friday, September 7 & 8, 14:00*
The “BER experience” tour begins with the airport company premises in the DIALOG-FORUM building at Berlin-Schönefeld Airport. A bus takes you to the future Berlin Brandenburg Airport and across the airport site spanning 960 hectares. One highlight of the tour involves disembarking at the terminal and touring the check-in area. During the tour, our guides provide information on the new airport and development of aviation in the region.

We will meet approximately one hour before the tour starts. Details will be provided on your tour ticket.

*please find exact information about departure times etc. in your conference kit
VISIT BMW GROUP PLANT BERLIN

Wednesday, September 6, 14:30 – 17:30*

Only half an hour away from the conference venue, car maker BMW runs one of its motorcycle production plants. Rich in tradition, the plant looks back to a long and prestigious history of cutting edge technology enabled manufacturing. Take a look behind the scenes, experience production processes in real-life, and obtain detailed insights from BMW experts. As part of your participation at OR2017, you have the chance to attend a guided tour of BMW Group Plant Berlin organized exclusively for conference delegates.

We will meet approximately one hour before the tour starts. Details will be provided on your tour ticket.

DAHLEM
DISCOVERING "GERMANY’S OXFORD"

Wednesday, September 6, 16:30*

Nuclear fusion, the first uranium reactor, the electron microscope – a surprising number of scientific discoveries and inventions have emerged from Dahlem. From 1912 on, the elegant residential district evolved into a mecca for creative brains from around the world. Unparalleled in Germany, the first modern research campus emerged here on the green field site. Albert Einstein, Otto Hahn, and Lise Meitner were just some of the researchers who worked or lived in Dahlem. The stimulus was provided by the Kaiser Wilhelm Society, the predecessor of the Max Planck Society, which now continues the tradition together with the Freie Universität.

We will meet approximately 15 minutes before the tour starts. Details will be provided on your tour ticket.

*please find exact information about departure times etc. in your conference kit
PRE-CONFERENCE WORKSHOPS

OPTANO

HANDS-ON: OPTANO MODELING
When/Where: Tue, Sept 5, 2017, 15:00* HFB|D, Speakers: Dr. Jens Peter Kempkes and Lars Beckmann

OPTANO Modeling is a .net Modeling API. It supports a wide range of solvers and modeling aspects. Modeling is easy to use, supports code tests and has been downloaded more than 25000 times. In this hands-on demonstration, we will provide an introduction to c#/.net and the OPTANO Modeling API. We’ll use some examples to explain its key concepts and illustrate its rich features. There will be time for questions both during and at the end of this workshop for beginners and experts. The workshop will be held by two advanced developers of OPTANO Modeling.

GUROBI

HACKATHON: GUROBI-TOMTOM OR2017 CHALLENGE
When/Where: Tue, Sept 5, 2017, 12:00 – open end* HFB | Senat, Supervision: Alexander Kröller, Sebastian Schenker, Kostja Siefen et al.

Are you looking for a mathematical optimization challenge? Do you think mobility can be organized in much smarter ways? Then this hackathon is for you! Can you innovate in one day? Do you have the programming skills to make your ideas work? Can you work with real data? Are you interested in getting in touch with leading optimization and mobility companies? Then register for the Gurobi-TomTom Mobility Maximization Mission hackathon (GMT^3). All you need is a laptop with wireless LAN. Real world traffic data, the Gurobi optimization suite, TomTom tool APIs, cloud computing capacity, and help from an expert supervision team will be available (participants must sign a confidentiality NDA). The winners will be selected and awarded a prize in the GTM^3 session WE-12 (Wednesday 16:30-18:00 WGS|BIB). See www.or2017-hackathon.de for more information.

*please note that times can change, participants will be informed via e-mail about beginning and ending of workshops
IBM Analytics - Decision Optimization

IBM Decision Optimization (Prescriptive Analytics) helps organizations
• improve operations - eliminate inefficiencies and capture more value
• manage resources more effectively - better utilize capital, personnel, equipment, vehicles, facilities
• mitigate risk - gain insight into how decisions have business-wide impacts & hedge against data uncertainty
• increase agility - dynamically generate plans and schedules to adapt to market conditions
• improve customer satisfaction - achieve customer expectations for customization and speed.

Learn about IBM Decision Optimization and explore successes achieved by international companies

PART I – THE IBM DECISION OPTIMIZATION SUITE
IBM Decision Optimization Solutions combine form a powerful foundation for decision management:
• IBM CPLEX Optimization Studio - model business problems and solve with IBM Optimizers (CPLEX and CP Optimizer)
• IBM Decision Optimization Center - build, deploy & use optimization-based decision-making applications
• IBM Decision Optimization Cloud - leverage advanced analytics and decision making optimization software on cloud
• IBM Data Science Experience - collaborate on projects, combine machine learning, predictive and prescriptive analytics using the DSX Cloud or On-premises platform

The workshop will walk you through the IBM Decision Optimization Suite and present the latest developments. Enjoy live examples and discuss opportunities with IBM top experts.

Presentations will include
• What's new in CPLEX with a Focus on Modeling assistance and runseeds
• Introduction to Data Science Experience with Predictive and Prescriptive Analytics combined

PART II – BUSINESS CASES
Learn about success stories in Manufacturing, Financial services, Healthcare, and other highly data-intensive industries. During this session we’ll discuss the implementation parts of the projects, difficulties encountered and outcomes achieved. The goal is to share experiences and highlight the value Decision Optimization brings across industry.

For this session of the workshop we’re delighted to welcome three partners companies, Math.TEC, X-Integrate and Atesio who agreed to share some of the use cases they worked on using the IBM Decision Optimization suite.

Half an hour presentations include:
• Evaluating and Planning Gas Network Capacities, pres. by A. Eisenblätter, Atesio
• Innovation through Math in Logistics and Production Industry, pres. by K. Knall & J. Koehl, Math.Tec
• Forecast of Buying Behavior and Sales - Optimize Production, Logistic and Tour Planning – Use Cases of the combination of predictive and prescriptive analytics, pres- by W. Schmidt, X-Integrate

*please note that times can change, participants will be informed via e-mail about beginning and ending of workshops
PART I: AN INTRODUCTION

We start with the basics of GAMS to develop algebraic models, solve them using state-of-the-art algorithms, and introduce the key concepts of GAMS and the fundamentals of the language (e.g. sets, data, variables, equations). We’ll explore some case studies drawn directly from GAMS users in different fields. The largest part of the workshop will consist of an demonstration, where we are going to build a simple optimization based decision support application from scratch. We show how GAMS supports an easy growth path to larger and more sophisticated models, promotes speed and reliability during in the development phase of optimization models, and provides access to all of the most powerful large-scale solver packages. Along the way we will look at some of the data management tools included in the GAMS system and show how to analyze and debug large problems using the various tools available within GAMS.

This workshop requires no or limited knowledge about GAMS.

PART II: ADVANCED HANDS-ON WORKSHOP

This hands-on workshop, which is catered to the requirements of advanced GAMS users and application builders provides a great opportunity to learn about selected topics and best practices like: Use of the GAMS Object-Oriented API’s to integrate GAMS models into different environments, like C#, Python, and Java. | Code embedding in GAMS | Stochastic programming in GAMS | Asynchronous and parallel GAMS models

These sessions are hands-on workshops, so please bring your laptop.

*please note that times can change, participants will be informed via e-mail about beginning and ending of workshops
Solving with Satalia – Our SolveEngine and the Business of Academia

When/Where: Tue, Sept 5, 13:00* (Part I), 15:30* (Part II) HFB1B

The SolveEngine is a cloud-based platform for accessing solvers from the SAT, CP and Mathematical Programming communities and utilises a machine learning layer that will automatically select the best algorithm to solve your problem. For this workshop, we will be showing what the SolveEngine can do and all the ways you can use this solving genie to approach the hardest problems.

Are you interested in learning how to use the SolveEngine to solve problems? In this hackathon you will gain experience connecting your code to the SolveEngine via API.

15.00 – Break

15.30 – 17.00 The Business of Academia: Bridging the academia-industry gap

We will discuss the challenges associated with bringing academic research to market and why academic breakthroughs have a hard time finding acceptance in industry. Based on our research and experience, we will describe how different organisations are attempting to change this for good. We will provide a detailed recommendation for how academic inventions can be translated into industry innovations, and how this can create commercial value for academia and industry alike. Finally, we will take a deep-dive into your own frustrations of working with industry, and seek to discuss actionable solutions that may help to resolve them.

Register here: https://www.satalia.com/conferences/or2017

*please note that times can change, participants will be informed via e-mail about beginning and ending of workshops
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Bring your ticket!
## CONFERENCE STREAMS

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### Session Topics

- **BA**: Business Analytics, Artificial Intelligence, Forecasting
- **CC**: Control Theory & Continuous Optimization
- **DM**: Decision Theory & Multiple Criteria Decision Making
- **DI**: Discrete and Integer Optimization
- **EE**: Energy and Environment
- **FI**: Finance
- **GE**: Game Theory and Experimental Economics
- **GN**: Graphs and Networks
- **HC**: Health Care Management
- **LF**: Logistics and Freight Transportation
- **MH**: Metaheuristics
- **OU**: Optimization under Uncertainty
- **OR**: OR in Engineering
- **PR**: Pricing and Revenue Management
- **PO**: Production and Operations Management
- **PS**: Project Management and Scheduling
- **SI**: Simulation and Statistical Modelling
- **SM**: Software Applications and Modelling Systems
- **SC**: Supply Chain Management
- **TM**: Traffic, Mobility and Passenger Transportation
- **BT**: Business Track
- **O**: Opening, Awards, Plenaries, Closing

For detailed information on streams and session topics, check indices starting on page 109 and 153.
PLENARY SPEAKER
Wed, Sept 6, 9:00 – 10:30 HFB|Audimax

Prof. Richard Eglese  (Lancaster University, UK)

GREEN LOGISTICS: DECISION ANALYTICS FOR SUSTAINABLE TRANSPORTATION

The environmental effects of transporting goods are of increasing concern to managers and policy makers. The use of fossil fuels, such as petrol and diesel oil, in transport produces air pollutants that can have a toxic effect on people and the environment. However, one of the main drivers for the concern over the environmental effects of freight transport has been the potential effects of the production of greenhouse gas (GHG) emissions on climate change from the use of carbon-based fuels.

Research into models for transportation and logistics has been active for many years. Much of the modelling has been with the aim of optimising economic objectives or improving measures of customer service. However, in recent years, more research has been undertaken where environmental objectives have also been considered, so that supply chain and other logistic services can be delivered in a more sustainable way.

For the OR analyst, there are many choices to be made about how to model freight transport operations. Can old models be revised with a simple change of objective or are more radical changes needed? We shall examine some of these choices and illustrate the issues with cases studies to show what contribution can be made to environmental and other objectives through the use of decision analytic models. This will include issues raised by the use of new technologies, such as the use of electric or other alternatively powered vehicles.

Richard Eglese is a Professor of Operational Research in the Department of Management Science at Lancaster University Management School.

He was President of the Operational Research Society in the UK in 2010-2011 and is currently a member of its General Council and Chair of its Publications Committee. He is also now President of EURO (The Association of European Operational Research Societies) until the end of 2018.

His research interests include combinatorial optimisation using mathematical programming and heuristic methods. He is concerned with applications to vehicle routing problems, particularly models for time-dependent problems and for problems in Green Logistics where environmental considerations are taken into account to provide more sustainable distribution plans.
PLENARY SPEAKER
Fri, Sept 8, 13:45 – 15:00 HFB|Audimax

Prof. Dr. Andrea Lodi (École Polytechnique de Montréal, CA)

ON BIG DATA, OPTIMIZATION AND LEARNING

In this talk I review a couple of applications on Big Data that I personally like and I try to explain my point of view as a Mathematical Optimizer – especially concerned with discrete (integer) decisions – on the subject.

I advocate a tight integration of Machine Learning and Mathematical Optimization (among others) to deal with the challenges of decision-making in Data Science.

For such an integration I try to answer three questions: 1. What can optimization do for machine learning? 2. What can machine learning do for optimization? 3. Which new applications can be solved by the combination of machine learning and optimization?

Andrea Lodi received the PhD in System Engineering from the University of Bologna in 2000 and he has been Herman Goldstine Fellow at the IBM Mathematical Sciences Department, NY in 2005–2006. He has been full professor of Operations Research at DEI, University of Bologna between 2007 and 2015. Since 2015 is Canada excellence Research Chair in ‘Data Science for Real-time Decision Making’ at the École Polytechnique de Montréal.

His main research interests are in Mixed-Integer Linear and Nonlinear Programming and Data Science and his work has received several recognitions including the IBM and Google faculty awards. He is author of more than 80 publications in the top journals of the field of Mathematical Optimization.

He serves as Editor for several prestigious journals in the area. He has been network coordinator and principal investigator of two large EU projects/networks, and, since 2006, consultant of the IBM CPLEX research and development team. Finally, Andrea Lodi is the co-principal investigator (together with Yoshua Bengio) of the project "Data Serving Canadians: Deep Learning and Optimization for the Knowledge Revolution", recently generously funded by the Canadian Federal Government under the Apogée Programme.
MARKET DESIGN: A LINEAR PROGRAMMING APPROACH

Market design uses economic theory, mathematical optimization, experiments, and empirical analysis to design market rules and institutions. Fundamentally, it asks how scarce resources should be allocated and how the design of the rules and regulations of a market affects the functioning and outcomes of that market. Operations Research has long dealt with resource allocation problems, but typically from the point of view of a single decision maker. In contrast, Microeconomics focused on strategic interactions of multiple decision makers. While early contributions to auction theory model single-object auctions, much recent theory in the design of multi-object auctions draws on linear and integer linear programming combined with game-theoretical solution concepts and principles from mechanism design. This led to interesting developments in theory and practical market designs.

The talk will first introduce a number of market design applications and show how discrete optimization is used for allocation and payment rules. These markets include industrial procurement, the sale of spectrum licenses, as well as cap-and-trade systems. In addition, we survey a number of theoretical developments and the role of integer and linear programming in recent models and market designs. Models of ascending multi-object auctions and approximation mechanisms will serve as examples. Finally, we will discuss limitations of existing models and research challenges.

Martin Bichler received his MSc degree from the Technical University of Vienna, and his Ph. D. as well as his Habilitation from the Vienna University of Economics and Business. He was working as a research fellow at UC Berkeley, and as research staff member at the IBM T. J. Watson Research Center, New York. Since 2003 he is full Professor at the Department of Informatics of the Technical University of Munich (TUM) and a faculty member at the TUM School of Management.

Martin is a faculty and board member of the Bavarian Elite Master program “Finance and Information Management” and a fellow of the Agora Group on Market Design at the University of New South Wales, Australia. He received an HP Labs eAward, the IBM Faculty Award, and the INFORMS ISS Design Science Award, and holds several patents. Since 2012 he is Editor-in-Chief of Business and Information Systems Engineering and serves on the editorial board of a number of journals including INFORMS ISR. Martin’s research interests include market design, mathematical optimization, game theory, and econometrics.
Prof. Dr. Marco Lübbecke (RWTH Aachen)

OPTIMIZATION MEETS MACHINE LEARNING

Optimization, as a way to make "best sense of data" is a common topic and core area in operations research (OR), in theory and applications. Machine learning, being rather on the predictive than on the prescriptive side of analytics, is not so well known in the OR community. Yet, machine learning techniques are indispensible for example in big data applications. We start with sketching some basic concepts in supervised learning and mathematical optimization (in particular integer programming). In machine learning, many optimization problems arise, and there are some suggestions in the literature to address them with techniques from OR. More importantly, we are interested in the reverse direction: where (and how) can machine learning help in improving methods for solving optimization problems and what is it that we can actually learn? We conclude with an alternative view on this presentation’s title, namely opportunities where predictive meets prescriptive analytics.

Marco Lübbecke is a full professor and chair of operations research at RWTH Aachen University, Germany. He received his Ph.D. in applied mathematics from TU Braunschweig in 2001 and held positions as assistant professor for combinatorial optimization and graph algorithms at TU Berlin and as visiting professor for discrete optimization at TU Darmstadt.

Marco’s research and teaching interests are in computational integer programming and discrete optimization, covering the entire spectrum from fundamental research and methods development to industry scale applications. A particular focus of his work is on decomposition approaches to exactly solving large-scale real-world optimization problems. This touches on mathematics, computer science, business, and engineering alike and rings with his appreciation for fascinating interdisciplinary challenges.
IT-based processes have fostered the rise of shared mobility business models in recent years. In order to play a major role in people’s future transportation, reliable shared mobility services have to be ensured. The availability of a shared vehicle at the point in time and location of spontaneously arising customer demand is recognized as requirement to replace individual vehicle ownership in the long term. Methodological support for shared mobility systems can draw on operations research models originally developed in the field of logistics. We give an overview on optimization models with regard to network design, transportation, inventory, routing, pricing and maintenance that have been adopted to operational support of shared mobility systems.

For instance, the problem of relocating bikes over time in a station-based bike sharing system can be formulated as service network design problem. We show that next to the coverage of routing, the problem formulation incorporates inventory and transportation decisions. The fact that the number of bikes is kept constant over time is depicted by asset management constraints. A matheuristic is proposed to solve this problem to near optimality. Tailored techniques are to be developed in order to cope with these complex problems.

Dirk Christian Mattfeld is full professor of decision support in the business information systems engineering group at Technische Universität Braunschweig, Germany. His research focuses on the efficient use of resources in urban logistics and shared mobility. These interests comprise work in analytics, modelling and optimization. Dirk Christian Mattfeld has graduated from Universität Bremen and has been affiliated with Universität Hamburg and Technische Universität Braunschweig. With respect to GOR, he chaired the GOR working group on logistics and traffic from 2002 to 2010.
SEMI-PLENARY SPEAKER
CANCELLED

Prof. Panos M. Pardalos, PhD (CAO, University of Florida, US)

NETWORK MODELS AND DATA SCIENCES IN FINANCE AND ECONOMICS

Financial markets, banks, currency exchanges and other institutions can be modeled and analyzed as network structures. In these networks nodes are any agents such as companies, shareholders, currencies, or countries, and edges (can be weighted, oriented, etc.) represent any type of relations between agents, for example, ownership, friendship, collaboration, influence, dependence, and correlation. We are going to discuss network and data sciences techniques to study the dynamics of financial markets and other problems in economics.

Panos M. Pardalos serves as distinguished professor of industrial and systems engineering at the University of Florida. Additionally, he is the Paul and Heidi Brown Preeminent Professor of industrial and systems engineering. He is also an affiliated faculty member of the computer and information science Department, the Hellenic Studies Center, and the biomedical engineering program. He is also the director of the Center for Applied Optimization [18]. Pardalos is a world leading expert in global and combinatorial optimization. His recent research interests include network design problems, optimization in telecommunications, e-commerce, data mining, biomedical applications, and massive computing.
NETWORK FLOW PROBLEMS WITH PHYSICAL TRANSPORT

Looking at network flow problems from a combinatorial point of view the flow is typically assumed to be constant in time and flows without additional requirements such as pressure differences. This is no longer true if we look at energy networks such as water or gas networks. To appropriately model the physics of these flows partial or at least ordinary differential equations are necessary resulting even in simplified settings in non-linear non-convex constraints. In this talk we look into the details of such models, motivate them by problems showing up in the transmission of the energy system and present first solution approaches with many hints to future challenges.

Alexander Martin studied Mathematics and Economics at the University of Augsburg. He finished his PhD and habilitation theses at the Technische Universität Berlin and was deputy head of the optimization group at the Zuse Institute in Berlin. From 2000 to 2010 he became professor for discrete optimization at the Technische Universität Darmstadt, where he has been vice president from 2008 to 2010. Ever since he heads the chair on “Economics, Discrete Optimization, Mathematics (EDOM)” at the University of Erlangen-Nuremberg. He has been member of two cooperate research centers, the graduate school of excellence Computational Engineering and several networks supported by German ministries (BMBF and BMWi) and is currently the speaker of the cooperate research center “Mathematical Modeling, Simulation and Optimization using the Example of Gas Networks”. Besides his editorial activities for several international journals he was managing editor for the journal “Mathematical Methods of Operations Research”.

He also received honoury appointments to the BMBF advisory board “Mathematics”. His research areas are the study and solution of general mixed-integer linear and nonlinear optimization problems comprising the development of appropriate models, their analysis as well as the design and implementation of fast algorithms for their solution. The applications result from the engineering sciences and industry including network design, transportation problems and energy optimization.
META-ALGORITHMS

Meta-algorithmics is a subject on the intersection of learning and optimization whose objective is the development of effective automatic tools that tune algorithm parameters and, at runtime, choose the approach that is best suited for the given input. In this talk I summarize the core lessons learned when devising such meta-algorithmic tools.

Meinolf Sellmann received his doctorate degree in 2002 from Paderborn University (Germany) and then went on to Cornell University as Postdoctoral Associate. From 2004 to 2010 he held a position as Assistant Professor at Brown University and was Program Manager for Cognitive Computing at IBM Watson Research. Now he is Technical Operations Lead for Machine Learning and Knowledge Discovery at General Electric. Meinolf has published over 70 articles in international conferences and journals, filed nine US patents, served as PC Chair of LION 2016 and CPAIOR 2013, Conference Chair of CP 2007, and Associate Editor of the Informs Journal on Computing. He received an NSF Early Career Award in 2007, IBM Outstanding Technical Innovation Awards in 2013 and 2014, and an IBM A-level Business Accomplishment Award 2015. For six years in a row, Meinolf and his team won at international SAT and MaxSAT Solver Competitions, among others two gold medals for the most CPU-time efficient SAT solver for random and crafted SAT instances in 2011, the best multi-engine approach for industrial SAT instances in 2012, the overall most efficient parallel SAT Solver in 2013 (at which point portfolios were permanently banned from the SAT competition), and 17 gold medals at the 2013 to 2016 MaxSAT Evaluations.
LAST MILE LOGISTICS

Last-mile logistics providers are facing a tough challenge in making their operations sustainable in the face of growing customer expectations to further decrease lead times to same-day or even same-hour deliveries, and/or to offer narrow delivery time windows. The providers respond to this challenge by investing in their analytic capabilities to make their last mile logistics efficient and intelligent as possible.

In addition, innovative and disruptive business models are currently on trial, e.g. asset-lean start-ups use crowdsourced drivers or drivers on demand-dependent contracts. Several companies are experimenting with delivery drones or robots, and how to collaborate with each other (‘shared economy’). Many of these developments entail exciting new challenges for operations researchers. In this talk, I will review some of the most recent developments and reflect on future research directions.

Dr Arne K. Strauss is Associate Professor of Operational Research at the University of Warwick (UK). He holds a Ph.D. in Management Science from Lancaster University (UK), an M.Sc. in Mathematics from Virginia Tech (USA), and a diploma in Business Mathematics from the University of Trier (Germany).

His main research interests are price optimization, demand modelling and demand management. He worked with various industrial partners including e.g. Lufthansa Systems or the retailer Ocado. He won several prizes for his research including the doctoral prize of the British Operational Research Society for the best PhD dissertation 2009. He is a joint recipient of an IBM Faculty Award in 2015 worth $20,000. Currently, his work focuses on using demand management to improve last-mile logistics. He also leads a team at Warwick on a Horizon 2020-funded project on capacity ordering and price control in the context of air traffic management.
Dr. Hans-Georg Zimmermann (Siemens AG)

DATA ANALYTICS, MACHINE INTELLIGENCE AND DIGITALIZATION AT SIEMENS

Data Analytics, Artificial Intelligence and Digitalization are general megatrends in research and industry. The big data trend was initiated by the increasing computer power and the internet. But data alone are only information about the past, we have to find structures and causalities between the variables. Based on such models we can compute information about possible futures and go on to decision support or control. The view of artificial intelligence is to solve the above problems with human analog methods. Especially neural networks and deep learning play an important role in such an effort. Siemens has a focus on technical and not internet applications, so we call our development machine intelligence instead artificial intelligence.

Finally, digitalization describes the way from physical processes (and production lines) to virtualization, using the digital copy of the processes for optimization and online control.

In a final part of the talk I will show in form of examples, that in an industrial research center research plays an important role: First, we have to confront problems which were unsolved otherwise. Second, the knowledge accumulation in lasting teams opens unique selling points for the company.

Dr. Hans Georg Zimmermann, Study of Mathematics, Computer Science, Economics at University of Bonn (PhD in game theory). Since 1987 at Siemens, Corporate Research in Munich. Founding member of the neural network research at Siemens (starting 1987). Since 2000 Senior Principal Research Scientist, scientific head of the neural network research with applications in forecasting, diagnosis and control. Member of GOR, DMV, DPG, advisor of the National Science Foundation in US, lectures and talks at universities on all continents.
THE RISE OF ARTIFICIAL INTELLIGENCE IN FORECASTING? HYPE VS REALWORLD SUCCESS STORIES

Artificial Intelligence and Machine Learning have become household names, hot topics avidly pushed by the media, with companies like Facebook, Google and Uber promising disruptive breakthroughs from speech recognition to self driving cars and fully-automatic predictive maintenance. However, in the forecasting world, reality looks very different. An industry survey of 200+ companies shows that despite substantial growth of available data, most companies still rely on human expertise or employ very basic statistical algorithms from the 1960s, with even market leaders slow to adopt advanced algorithms to enhance forecasting and demand planning decisions. This reveals a huge gap between scientific innovations and industry capabilities, with opportunities to gain unprecedented market intelligence being missed. In this session, we will highlight examples of how industry thought leaders have successfully implemented artificial Neural Networks and advanced Machine Learning algorithms for forecasting, including FMCG Manufacturer Beiersdorf, Beer Manufacturers Anheuser Bush InBev, and Container Shipping line Hapag-Lloyd. I will leave you with a vision not of the future, but of what’s happening now, and how it can enhance supply chain and logistics planning.

Sven F. Crone is an Assistant Professor in Management Science at Lancaster University, UK, where his research on business forecasting and time series data mining has received over 40 scientific publications and international awards for developing novel forecasting algorithms. As the co-director of the Lancaster Research Centre for Forecasting, one with 15 members the largest research units dedicated to business forecasting, he and his team regularly take state-of-the-art forecasting research and apply it in corporate practice. He has trained over 500 corporate demand planners, and consulted with industry leaders on improving forecasting methods, systems and processes. Sven is also a regular keynote speaker at academic and practitioner conferences, sharing insights from hands-on consultancy projects on research in artificial intelligence and machine learning for FMCG/CPG, Call Centres and Energy Markets.
Dr. Christoph Klingenberg (Deutsche Bahn)

IMPROVING ON-TIME PERFORMANCE AT DEUTSCHE BAHN

This presentation outlines a framework for improving the on-time performance of a public transport provider from a practitioners’ point of view. In setting the goal for the on-time performance we differentiate between the punctuality for the passenger journey including transfer between trains and the punctuality for each service (train). Besides a differentiated goal you need a simple cost estimate per minute delay, again for a passenger minute and a train minute. The basic analytic work is to carry out various comparisons of scheduled versus actual values for travel times between stations, stopping times at stations, transfer times between services, maintenance duration or rotation plans for trains. For each analysis, we filter the erratic component (as represented by the standard deviation) from the systematic ‘plan-error’ component (difference between the mean value and the plan value). This leads to the two basic directions to take for improving the on-time performance: 1. stabilize operations, i.e. eliminate erratic disturbances and 2. adjust the plan to the mean value of actuals or some value close to the mean value. This implies departing from static scheduling as introduced in the 50ies and still employed by most major railways and introducing a dynamic scheduling approach using OR methods. The main obstacle to adjusting the schedule to accommodate the systematic errors is an overcrowded train system with very limited room for time-shifting train paths (schedules). We discuss options to solve this impasse within the given framework through a comprehensive optimization approach (unfreeze the system).

Dr. Christoph Klingenberg studied mathematics and computer science at the universities of Hamburg and Bonn, Germany and spent postgraduate research at the universities of Cologne, Germany and Princeton and Harvard, USA. He then joined McKinsey & Company for a career in top management consulting for 6 years. The major part of his professional life he spent with Lufthansa German Airlines in various strategic, planning and operational positions. In 2014 he joined Deutsche Bahn (German railways) and currently heads the strategic division programs for the group including projects for autonomous driving, European train control systems and improved operational performance.
Prof. Anna Nagurney, PhD (Univ. of Massachusetts, US)

**BLOOD SUPPLY CHAINS: CHALLENGES FOR THE INDUSTRY AND HOW OPERATIONS RESEARCH CAN HELP**

Blood is a unique product that cannot be manufactured, but must be donated, and is perishable, with red blood cells lasting 42 days and platelets 5 days. Blood is also lifesaving. A multi-billion dollar industry has evolved out of the demand for and supply of blood with the global market for blood products projected to reach $41.9 billion by 2020.

Although blood services are organized differently in many countries, such supply chain network activities as collection, testing, processing, and distribution are common to all. In this talk, I will focus on the United States, but the methodological tools can be adapted to other countries. Revenues of blood service organizations have fallen and the financial stress is resulting in loss of jobs in this healthcare sector, fewer funds for innovation, as well as an increasing number of mergers and acquisitions. In this presentation,

I will overview our research on blood supply chains, from both optimization and game theoretic perspectives. For the former, I will highlight generalized network models for managing the blood banking system, and for the design and redesign for sustainability. In addition, a framework for Mergers & Acquisitions (M&A) in the sector and associated synergy measures will be described. A case study under the status quo and in the case of a disaster of a pending M&A in the US will be presented. Finally, a novel game theory model will be highlighted, which captures competition among blood service organizations for donors.

Anna Nagurney is the John F. Smith Memorial Professor at the Isenberg School of Management at the University of Massachusetts Amherst and the Director of the Virtual Center for Supernetworks, which she founded in 2001. She holds ScB, AB, ScM and PhD degrees from Brown University in Providence, RI. She is the author or editor of 13 books, including the new book, "Competing on Supply Chain Quality: A Network Economics Perspective," with Dong Li, more than 180 refereed journal articles, and over 50 book chapters. She presently serves on the editorial boards of a dozen journals and two book series and is the editor of another book series.
SAT Anthetes & Committee Meetings

GOR Board Meeting
Tuesday, September 05, 08:30 – 12:30 HFB|K2

GOR Advisory Board Meeting
Tuesday, September 05, 14:00 – 18:00 HFB|K2

Editorial Board Meeting
Mathematical Methods of Operations Research
Wednesday, September 06, 14:00 – 15:30 HFB|K2

Meeting of the GOR Working Group Heads
Thursday, September 07, 10:30 – 12:00 HFB|K2

Editorial Board Meeting or Spectrum
Thursday, September 07, 12:30 – 14:00 HFB|K3

GOR General Meeting 2017
20. Mitgliederversammlung der GOR e.V.
Thursday, September 7, 16:30 – 18:00 HFB|A
1 - Green Logistics: Decision Analytics for Sustainable Transportation
Richard Eglese

The environmental effects of transporting goods are of increasing concern to managers and policy makers. The use of fossil fuels, such as petrol and diesel oil, in transport produces air pollutants that can have a toxic effect on people and the environment. However, one of the main drivers for the concern over the environmental effects of freight transport has been the potential effects of the production of greenhouse gas (GHG) emissions on climate change from the use of carbon-based fuels.

Research into models for transportation and logistics has been active for many years. Much of the modelling has been with the aim of optimising economic objectives or improving measures of customer service. However, in recent years, more research has been undertaken where environmental objectives have also been considered, so that supply chain and other logistic services can be delivered in a more sustainable way.

For the OR analyst, there are many choices to be made about how to model freight transport operations. Can old models be revised with a simple change of objective or are more radical changes needed? We shall examine some of these choices and illustrate the issues with cases studies to show what contribution can be made to environmental and other objectives through the use of decision analytic models. This will include issues raised by the use of new technologies, such as the use of electric or other alternatively powered vehicles.

2 - Globalized Gamma-Robustness
Andreas Bärmann, Christina Büsing, Lena Maria Hupp, Frauke Liers, Manu Kapolke

We extend the notion of “globalized robustness”, introduced by Ben-Tal and Nemirovski, to the case of polyhedral Gamma-uncertainty sets. The globalized robust counterpart to an uncertain linear program that is considered here allows for the immunization of the solution against Gamma-many changing parameters in a given row, as studied by Bertsimas and Sim. In addition, it allows to “smoothen” the behaviour of the solution for parameters outside of the prescribed Gamma-uncertainty-set. If more than the Gamma-many specified parameters change, or they change by more than was initially specified, the violation in the corresponding constraint or in the objective function will remain moderate, dampened by a suitable penalty term.

In this talk, we focus on the global robustification of the objective function, deriving compact linear formulations and complexity results. The tractability of our formulations and the quality of the obtained solutions will be tested for uncertain variants of several combinatorial optimization problems.

3 - Blending robust and stochastic optimization of two-stage problems
Fabian Mies, Britta Peis, Andreas Wierz

Uncertainties in two-stage problems are typically described by either robust or stochastic models. The former aim to optimize the worst case performance of a solution, whereas the latter consider the expected cost with respect to some probability distribution. While the stochastic perspective allows for a greater modeling flexibility, it suffers from an increased model size since all possible scenarios need to be considered. On the other hand, robust models can often be solved adaptively by only considering relevant scenarios. In this talk, we present a flexible modeling framework to combine the advantages of
robust and stochastic optimization. By specifying the probability distribution of the uncertainty set only up to a given level of granularity, our method can be interpreted as to interpolate between a robust and a stochastic objective, containing both approaches at its extremes. We highlight that by restricting the supplied amount of information about the uncertainty, the suggested compromise is less susceptible to misspecification. In particular, if the probability distribution is estimated based on historical data, solutions are less prone to overfitting, as made precise by tighter risk bounds.

1 - Optimizing in the Cloud - Deploying Optimization Models on the cloud with Web Services REST API's
Bjarni Kristjansson
Over the past decade the IT has been moving steadfastly towards utilizing software on clouds using Web Services REST API's. The old traditional way of deploying software on standalone computers is slowly but surely going away.

In this presentation we will demonstrate the soon-to-be-released MPL REST Server which allows optimization models to be easily deployed on the cloud. By delivering optimization through a standard REST API, which accepts data in either JSON or XML formats, the optimization becomes purely data-driven. Client applications can now be implemented relatively easily on different platforms such as mobile/tablets or web sites, using just standard HTML/CSS with Javascript, or any other preferred programming language.

Google and Amazon have among been of the leading software vendors in the area of Web Services and publish several REST API's which can be quite useful for deploying optimization applications. On the server side, optimization models can easily access online data using for example the Google Sheets API and Amazon DynamoDB. On the client side, libraries such as the Google Maps API and the Google Visualization API can be used to provide rich user experience. We will be demonstrating mobile web applications which utilize the MPL REST Server and the Google/Amazon REST API's for deploying optimization models.

2 - Cloud Strategies for Optimization Modeling Software
Robert Fourer
Modeling languages and systems for optimization first appeared online 20 years ago – not long after web browsers came into widespread use – and have continued to evolve through the development of what came to be known as software as a service and cloud computing. In comparison to solver services that compute and return optimal solutions, cloud services for building optimization models and reporting results have proved especially challenging to design and deliver; a collaboration between local clients and remote servers often provides the best environment for model development. This presentation will start with the pioneering free NEOS Server, will compare more recent commercial offerings such as Gurobi’s updated Instant Cloud, and will conclude with a description of the QuanDec service for creating web-based collaborative applications from MPL models.

3 - Solving routing and scheduling problems using LocalSolver
Julien Darlay
LocalSolver is a heuristic solver for large-scale optimization problems. Having modeled your optimization problem using common mathematical operators, LocalSolver provides you with high-quality solutions in short running times. Combining different optimization techniques, LocalSolver scales up to millions of variables, running on basic computers. One of the strengths of LocalSolver is its rich yet simple modeling framework. Indeed, most usual mathematical operators are available, including arithmetical expressions (sum, product, trigonometric functions) or logical expressions (comparisons, conditional terms, array indexing). As a consequence, there is no need to linearize the considered problem: the user can model it directly and naturally. Initially this modeling power was based on numerical decision variables only (binary, integer or continuous). A significant extension to this approach was brought in 2015 with the introduction of high level decision variables, inspired from ”set-based variables” introduced in Constraint Programming. Many optimization problems involve sequencing or ordering concepts: scheduling, routing, network design. For these problems, a new type of variables yields even simpler and more compact models. The value of such a variable is not a number but a collection of numbers. More precisely, a list variable list(n) represents a sub-permutation of the set {0,1,2,…,n-1}. We will show in this presentation how this new kind of variables allows building very simple and very effective models for a number of optimization problems, including routing and scheduling problems.

4 - OPTANO Modeling
Jens Peter Kempkes, Lars Beckmann
OPTANO Modeling, formerly known as Optimization.Framework, is a.NET Modeling API. During the past year we have put a lot of thought and work into supporting more modeling aspects, better documentation and support for even more solvers. It seamlessly integrates into applications, leads to testable models and can easily be used in continuous integration pipelines - in short: OPTANO Modeling is enterprise ready.

This talk will show recent advances of OPTANO Modeling and the OPTANO eco system. It will address both users and optimization software developers.

Location Planning
Stream: Logistics and Freight Transportation
Parallel session
Chair: Tim Kammann

1 - Multi-objective capacitated facility location problem: A case study of Tehran earthquake
Mahdi Shavarani
Facility location problems are commonly used to select a predetermined number of facility locations among a set of potential locations. In this study, each candidate location is considered with a specific capacity and opening cost. It is supposed that the demand is uniformly distributed along the edges. A mathematical model is developed to minimize the aggregate costs for the construction of facilities, aggregate travel distance and unsatisfied demand. Since the network problems are NP-hard, a Non-dominated sorting genetic algorithm II (NSGAII) is developed to solve the proposed model. The number of selected locations is a decision variable; thus an approach is proposed to deal with the changing length of the chromosomes. To demonstrate the applicability of the developed mathematical model, a case study is performed to find the best location of shelters in response to a major earthquake in Tehran.

2 - 2-Echelon Optimization Model for Urban E-Grocery Operations
Tim Kammann, Agathe Kleinschmidt, Sören Schindler, Max Leyerer, Marc-Oliver Sonneberg, Michael H. Breitner
This paper, we address an innovative business concept for e-grocery operations by using an urban network of refrigerated Foodstations. Regarding the last mile delivery, consumers collect orders by themselves or ordered goods are delivered by means of electric cargo bicycles. To determine the locations of the Foodstations and both the routes from the warehouse to the stations and the routes from the stations to the consumers, we propose a 2-echelon optimization model minimizing costs and traffic volume. We present a Location Routing Problem (LRP) and a rich variant of a Vehicle Routing Problem (VRP) considering multiple products, compartments, time windows, and a split delivery. With our approach, we contribute to the concept of e-grocery allowing for less pollution and a more sustainable city environment.
3 - Determining the influence of truck appointment systems at container terminals on truck arrival patterns of related logistics nodes

Ann-Kathrin Lange, Anne Schwientek, Carlos Jahn

Due to the increasing size of container ships, the related amount of containers to be handled for each ship in one port is growing as well. This leads to high peak situation for truck arrivals at logistics nodes and especially container terminals. In peak situations the gate and yard areas at container terminals are often strained to deal with the high amount of arriving trucks causing high costs for the terminals and long waiting times for the trucks. One much discussed method to mitigate the strain caused by peaks is to introduce a truck appointment system. The effects of this system on terminal performance and on truck waiting times have been analyzed widely in past studies with varying results. Other related logistics nodes in the port such as empty container depots, custom services or packing stations are rarely considered in spite of their importance for the port's efficiency and their role in drayage processes. To cover parts of this research gap, the focus of this paper is on the influence of truck appointment systems at container terminals on the truck arrival patterns of subsequent logistics nodes. A discrete event simulation model based on real-world data of the port of Hamburg is used to study the impact of different TAS' characteristics, e.g. the length of the time windows for each truck to pick up or drop of a container or the distribution of the time windows during the day, on the different actors involved in drayage processes in Hamburg. For the truck arrival patterns restricted opening hours of the logistics nodes and limited working times for the truck drivers are considered.

WB-04

Graphs and Complexity

Stream: Graphs and Networks

Parallel session

Chair: Stephan Schwartz

1 - A Graph Theoretic Approach to Solve Special Knapsack Problems in Polynomial Time

Carolin Rehs, Frank Gurski

The knapsack problem is a well-known NP-hard problem in combinatorial optimization. We introduce a graph theoretic approach in order to solve a large number of knapsack instances in polynomial time. For this purpose we apply threshold graphs, which have the useful property, that their independent sets correspond to feasible solutions in respective knapsack instances. Presenting a method to count and enumerate all maximal independent sets in a threshold graph in polynomial time and expanding this method for k-threshold graphs, allows to solve every knapsack instance with equivalent threshold graph as well as every multidimensional knapsack instance with equivalent k-threshold graph for fixed number of dimensions in polynomial time. Furthermore, our results improve existing solutions for the maximum independent set problem on k-threshold graphs.

2 - The Graph Segmentation Problem

Stephan Schwartz, Leonardo Balestrieri, Ralf Bomdörfer

We study a novel graph theoretical problem arising in the automatic billing of a toll network. The graph segmentation problem (GSP) is to cover a family of user paths in a given network with a set of disjoint segments (which are also paths). We investigate structural properties of the problem and derive tight bounds for the utility of an optimal segmentation. While the GSP is NP-hard in general, special cases can be solved in polynomial time. We also give an integer programming formulation that benefits from the results of our structural analysis. Computational results for real-world instances show that in practice the problem is more amenable than the theoretic bounds suggest.

WS-05

Location of Charging Stations for Electric Vehicles

Stream: Traffic, Mobility and Passenger Transportation

Parallel session

Chair: Brita Rohrbeck

1 - Decision Support for Location Planning of Electric Vehicle Recharging Infrastructure

Paul Göpfert, Stefan Bock

To leverage the adoption of electric vehicles for day-to-day use is one of the main aims of contemporary environmental politics. But the usefulness of electric vehicles is limited as long as an adequate recharging infrastructure is missing. Without the possibility to recharge on the way, people usually do not consider electric vehicles for traveling on long distance relations.

In this talk we consider a decision support system for a recharging infrastructure provider in order to facilitate the creation of an efficient network of recharging stations for long distance traveling. The underlying optimization problem is based on the routing and refueling location model (Yildiz et al. 2016). We propose heuristic filtering rules making the set of possible stations small enough to apply relaxations of exact approaches for the aforementioned model. Furthermore, the performance of simple insertion heuristics as well as a tabu search approach is tested on a realistically sized network for the federal republic of Germany.

2 - Location Planning of E-Taxi Charging Stations

Gregor Godbersen, Rainer Kolisch

We are considering the problem of allocating charging stations to cater a fleet of electric taxis in a metropolitan area. Despite recent work on allocation of charging stations for private e-cars, this problem has not been fully treated in the literature. Unique aspects are high mileages and 24-hour shifts with short breaks which ask for broader coverage of charging stations. We model the problem as mixed-integer program (MIP) optimizing charging infrastructure investment costs. Since the MIP cannot be solved for large real-world instances, we present an adaptive large neighborhood heuristic. Experimental results and managerial insight for a real-world data set from a German metropolitan area with 1.5 million inhabitants are presented.

3 - Location Planning of Charging Stations for Electric City Buses Considering Battery Ageing Effects

Brita Rohrbeck, Kilian Berthold, Felix Hetich

In the context of global warming and effective energy usage, electrification of traffic is one important pillar of forward-looking behaviour. This affects not only private cars, but also freight vehicles as well as public transportation, hence buses. A cost-minimal network configuration for electric city buses, including battery ageing effects, is the focus of this presentation.

Electric city buses with stationary charging technology follow the trend of sustainable technologies and unburden cities from greenhouse gases and noise emissions. However, their technology and charging infrastructure is still costly, and a cost-optimal solution strongly depends on the batteries’ capacities as well as on the number and locations of charging stations. The capacity of a battery is again greatly influenced by ageing effects due to time and usage. The objective is to find a set of locations for the charging stations that keeps the overall costs minimal.

In our talk we discuss the parameters influencing the battery performance and deduce a capacity decay function to incorporate the impact of battery ageing. We introduce a mixed integer model with multiple periods that gives a cost-optimal solution. We enhance the model by a battery ageing function and extend it towards a network of bus lines.

We give an overview of our results obtained from real world data of the bus network of Mannheim. To prove the quality of our solutions, we contrast them with the present configuration used in Mannheim and analyse them within the framework of a simulation.
Atherosclerosis is a very complex issue and the use of Petri nets for its modeling and analysis allows to systematize existing knowledge about this phenomenon and for new discoveries. This is especially important because the studied process is very common, the mechanisms that contribute to it are still studied and therefore new data is coming. Based on it, models of this process have been created and then analyzed in detail. Analysis of the models expressed as Petri nets can be based on clustering of t-invariants. In addition, identification of MCT sets, i.e., sets containing transitions corresponding to extreme points as well as an outer description in terms of inequalities and, given publicly available data, create probability distributions of this phenomenon studied using Petri nets. This research has been partially supported by the National Science Centre (Poland) grant No.2012/07/B/ST6/01537.

The pooling problem is a classic non-convex, nonlinear problem introduced by Haverly in 1978. In a nutshell, the task is to route flow through a network taking material qualities and bounds on these qualities into account. The point is that at each node of the network, the arriving material gets blended and therefore, the attribute qualities have to be tracked across the network which introduces bilinear terms into the model. We propose a novel convex relaxation that strengthens the state-of-the-art relaxation for the pooling problem. Being small enough for in-depth study, it still captures the essential structure of the problem. We provide a complete inner description in terms of the extreme points as well as an outer description in terms of inequalities defining its convex hull (which is not a polyhedron). We show that the resulting valid convex inequalities significantly strengthen the standard relaxation of the pooling problem.

Travel itineraries between many origin-destination (OD) pairs can require multiple legs, such as several trains, shared rides or flights, to arrive at the final destination. Travelers expect transparent reliability information to help improve decision-making for multi-leg itineraries. We focus on airline travel and making a priori decisions about flight itineraries based on the reliability of arrivals and bounds on the travel time budget. We model the reliability of multi-leg itineraries and, given publicly available data, create probability distributions of flight arrival and departure times. We use these values in our reliability calculations for the entire itinerary. We implement a stochastic network search algorithm that finds the most reliable flight itinerary (MRFI). We also implement several ideas to improve the efficiency of this network search. Computational experiments help identify characteristics of the MRFI for a diverse set of OD pairs.

Facility layout is a well-known operations research problem that arises in various applications. In this presentation we consider the following NP-hard row layout problem that has been recently suggested by [P. Hungerländer: The Checkpoint Ordering Problem. Optimization, to appear, 2017.]: The Checkpoint Ordering Problem (COP) asks for an optimal arrangement of one-dimensional departments with given lengths and weights such that the total weighted sum of their distances to a given checkpoint is minimized. Furthermore we consider the well-known Multi-Row Facility Layout Problem (MRFLP), where the task is to determine the optimal placement of one-dimensional departments with given lengths and weights for each pair of departments on a given number of rows. The MRFLP is a very challenging optimization problem as the currently largest multi-row instances solved to optimality have only 16 departments. We extend both the dynamic programming algorithm and the integer linear programming approach for the COP such that they now can handle an arbitrary but fixed number of checkpoints. We also suggest a heuristic for the COP that is based on our dynamic program. Additionally we propose how to use these methods in order to get high-quality bounds for the MRFLP. Finally we demonstrate the efficiency of our exact methods and heuristics for both the COP and the MRFLP on a variety of benchmark instances from the layout literature.

In this talk we consider the NP-hard Double Row Facility Layout Problem (DRFLP). Given a set of departments with positive lengths and pairwise (symmetric) transport weights between them, the DRFLP asks for an assignment of the departments to two rows and for horizontal positions of the departments such that the departments do not overlap. The aim is to minimize the weighted sum of the distances between the departments where usually only the center-to-center distances are regarded. We extend the model and the solution approach presented in Fischer et al. (2015) in various directions. Our new model is capable of asymmetric transport weights as well as individual in- and output positions of the departments. Clearance conditions between the departments can be taken into account. Moreover, given not only the lengths but also the widths of the departments, the used area for placing the departments can be restricted or optimized. In real-world instances there are often several departments of the same type. We show how to exploit this in the solution process. In the currently best DRFLP approach one iterates over all possible row assignments. We can significantly reduce the number of row assignments that have to be checked in the case of identical departments. Furthermore we illustrate additional constraints to break the symmetry of departments of the same type. So we are able to solve realistic instances with up to 21 departments in reasonable time. Without respecting the types of the departments the largest instances solved to optimality in reasonable time contained only 16 departments.

In this talk, we will present a framework for creating quick-and-dirty heuristics while maintaining the hallmarks of an optimisation problem. That is, we should be able to guarantee we can find a feasible solution if one exists; and, what we “know” about the optimal solution should inform the search direction. The resulting framework is an informed decomposition that can be thought of as an approximate Benders scheme.
1 - Structure-based Decomposition for Pattern-Detection for Railway Timetables

Stanley Schade, Thomas Schlechte, Jakob Witzig

We consider the pattern detection problem from the context of timetable analysis and rotation planning. Given a large-scale timetable that contains all trips of long-distance railway vehicles for one year, we want to identify weekly patterns in the timetable that are invariant. These patterns are interrupted by singular events like public holidays, which usually cause adaptations in the timetable, and interim changes for construction periods that require the redirection of vehicles. In a previous work we presented a Mixed Integer Linear Programming (MILP) approach to tackle and solve this pattern detection problem. In this paper, we look more closely at the problem specific properties and develop structure-based techniques. We propose a dual reduction technique which allows for the decomposition of the problem. In practice, the resulting subproblems are very small such that there is no need for using a MILP solver anymore. Furthermore, we analyse different heuristic approaches. Computational results for real world instances demonstrate that our methods are able to produce optimal solutions as fast as standard MILP solvers.

2 - Timetable Sparsification by Rolling Stock Rotation Optimization

Boris Grimm, Markus Reuther, Stanley Schade, Thomas Schlechte

Planning rolling stock movements in industrial railway applications is a long-term process that gains accuracy the closer the day of operation comes. This process is regularly affected by man-made impediments like strikes. Even then, some employees may still be available, e.g., since they are not organized in a union. Consequently, a strike of a single union is more a heavy decrease of capacity than a complete lock down of the railway system. In such events the timetable, rolling stock rotations, maintenance plans, and crew schedules have to be adapted. Optimization methods are particularly valuable in such situations in order to maintain a best possible level of service using the resources that are still available. Finding new or revised cyclic tours of rolling stock vehicles (rotations) through the timetable after disruptions is a well studied topic in the literature, see Cacchiani et al. (2014) for an overview. Usually, a rescheduling based on a timetable update is done, followed by the construction of new rotations that reward the recovery of parts of the obsolete rotations. We consider a different, novel, and more integrated approach which, to the best of our knowledge, has not been described in the literature before. The idea is to guide the cancellation of the trips of the timetable by the rotation planning process, which is based on mixed integer programming. The goal is to minimize the operating costs while cancelling a trip inflicts opportunity costs, which are based on an estimation of the trip priority. The performance of the algorithm is presented as a case study of the German ICE train network of DB Fernverkehr AG for the strike period in May 2015.

3 - On the Benefit of Preprocessing And Heuristics for Periodic Timetabling

Christian Liebchen

We consider the computation of periodic timetables, which is a key task in the service design process of public transportation companies. We are aware of only one collection of instances, the so-called PES-Pib. In the present paper, we aim at providing good solutions for the smallest and the largest of its instances (R1L1 and R4L4). We run a standard MILP solver (CPLEX) on a very elementary problem formulation. To come up with MILP sizes that fit better for standard MILP solvers, we propose to simplify the instances first, by invoking some basic preprocessing, parts of which having a heuristic character. Doing so, we improve the previously best-known objective value for R1L1 from 37,338,904 down to 33,711,523, and for R4L4 from 47,283,768 down to 43,234,156, i.e. by 9.7% and 8.6%, respectively.

1 - Modular Detection of Model Structure in Integer Programming

Michael Bastubbe, Marco Lübbecke

Dantzig-Wolfe reformulation applied to specially structured mixed integer programming models is well-known to provide strong dual bounds, though one of many requirements for implementing this method is structural problem knowledge. This is typically a reordering of the coefficient matrix to singly bordered block diagonal form. While searching such forms we pursue two goals: (a) try to retrieve what the modeler had in mind when building the model, and (b) find a vast variety of promising decompositions to facilitate studies on decomposition quality measures. In this talk we present a new modular, iterative algorithm to detect model structures in general mixed integer programming models aiming for these goals. After a pretection step, where constraints and variables are classified in various ways, we iteratively build a tree of successively more completed (refined) decompositions where each leaf is a complete decomposition. We demonstrate manifold refinement procedures, based on the pretested classifications, isomorphism detection algorithms, (hyper-)graph partitioning algorithms, and user given meta data. Finally we present computational results of our implementation integrated in the generic branch-and-price solver GCG.

2 - Learning when to use a decomposition

Markus Kruber, Marco Lübbecke, Axel Parmentier

Applying a Dantzig-Wolfe decomposition to a mixed-integer program (MIP) aims at exploiting an embedded model structure and can lead to significantly stronger reformulations of the MIP. Recently, automating the process and embedding it in standard MIP solvers have been proposed, with the detection of a decomposable model structure as key element. If the detected structure reflects the (usually unknown) actual structure of the MIP well, the solver may be much faster on the reformulated model than on the original. Otherwise, the solver may completely fail. We propose a supervised learning approach to decide whether or not a reformulation should be applied, and which decomposition to choose when several are possible. Preliminary experiments with a MIP solver equipped with this knowledge show a significant performance improvement on structured instances, with little deterioration on others.

3 - Refining column generation subproblems using Benders’ cuts

Jonas Witt, Marco Lübbecke, Stephen Maher

When solving the linear programming (LP) relaxation of a mixed-integer program (MIP) with column generation, columns might be generated although the MIP admits an integer optimal solution that can be expressed without these columns. Such columns are called redundant and the dual bound obtained by solving the LP relaxation is potentially stronger if (some) redundant columns are not generated. To avoid generating redundant columns, we introduce a sufficient condition, which can be checked by solving a compact LP. If the sufficient condition is fulfilled, we can use a dual solution of this compact LP to generate classical Benders’ cuts that eliminate redundant columns from the column generation subproblem. We implemented this refinement of the column generation subproblem in the branch-price-and-cut solver GCG and present computational results on structured as well as unstructured MIPs from the literature. Furthermore, we analyze the effect of this approach and discuss promising applications.
1 - Integrity Gaps of Integer Knapsack Problems: Bounds and Expected Value
Iskander Aliiev

We obtain optimal lower and upper bounds for the (additive) integrality gaps of integer knapsack problems. In a randomised setting, we show that the integrality gap of a “typical” knapsack problem is drastically smaller than the integrality gap that occurs in a worst case scenario.

2 - Discrete quantitative Helly numbers
Stefan Weltge, Gennady Averkov, Bernardo González Merino, Matthias Schymura

Given a subset $S$ of $\mathbb{R}^n$ and a nonnegative integer $k$, what is the largest number of convex sets with exactly $k$ points of $S$ in common, but every proper subfamily of these sets has more than $k$ points of $S$ in common? For $k = 0$, this refers to the classical Helly number of $S$. In this work, we study its quantitative generalization (for general $k$) and provide a geometric interpretation of this number. This allows us to strengthen bounds recently obtained by Aliiev et al. (2014) and Chestnut et al. (2015) for the case of $S$ being the integer lattice.

3 - Approximation of corner polyhedra with families of intersection cuts
Joseph Paat

The corner polyhedron provides a framework for deriving cuts for general mixed-integer linear programs. An inequality description of the corner polyhedron can be obtained by using the family of intersection cuts, which are derived from lattice-free sets. However, classifying lattice-free sets is a difficult endeavor, and therefore it seems intractable to access the entire family of intersection cuts. In light of this difficulty, we develop conditions for a family of intersection cuts to closely approximate the corner polyhedron. We examine the geometry of the lattice-free sets that generate these cuts, and in doing so, we characterize “strong” approximations based upon the number of facets of the lattice-free sets. This work was done in collaboration with Gennady Averkov from the University of Magdeburg in Germany and Amitabh Basu from Johns Hopkins University in the USA.

2 - Stowage planning: A benchmark and a novel heuristic
Rune Larsen, Dario Pacino

With the ever-growing size of container vessels and the fact that the liner shipping industry is surviving off marginal revenue, using advanced planning methods has never been more relevant. One of the main revenue drivers in liner shipping is vessel utilization. A number of scientific articles tackle this problem on a strategic or tactical level by optimizing fleet size and composition or optimizing the design of the shipping network. On an operational level, the capacity of a vessel and its efficiency at port is dictated by the so-called stowage plan. A stowage plan describes the arrangement of the containers on the vessel. Stowage plans are not easy to produce. This is not only due to the large number of containers that needs to be planned, but also due to a complex set of physical restrictions that govern the balance and stability of a vessel. Research on stowage planning has been plagued by missing data and by not having a common problem definition. In this talk we will introduce the first publicly available benchmark on stowage planning. The data collected for the benchmark is based on a real vessel, where simplifications have been made to make the problem more accessible to an academic audience. A novel large neighborhood search has been implemented to solve the stowage planning problem. Details about the algorithm and preliminary results on the new set of benchmark instances will be showcased during the talk.

3 - The Stochastic Liner Shipping Fleet Repositioning Problem with Uncertain Container Demands
Stefan Kuhlemann, Kevin Tierney

The repositioning of vessels is a costly process for liner shipping companies. During repositioning, vessels are moved between services in a liner shipping network to adjust the network to the changing demands of customers. A deterministic model for the Liner Shipping Fleet Repositioning Problem (LSFRP) exists, but many input parameters to the LSFRP are uncertain. Assuming these parameters are deterministic could lead to extra costs when plans computed from the deterministic model are realized. To get more realistic repositioning plans, uncertainties regarding influences on the travel time or the number of available containers must be considered. We introduce an optimization model for the stochastic LSFRP, focusing first on the uncertainty involving container demands. This model is evaluated with several scenarios originating in the industry. We then discuss business insights related to considering uncertainty during planning.
2 - Impact of efficient algorithm implementation on the performance of heuristic optimization
Michael Feichtenschlager
The inola Advanced Optimization Core is a reliable, self-learning, heuristic optimization technology which is particularly useful for solving practical complex constrained operations research problems. Generic heuristic optimization methods have the disadvantage of not being able to provide evidence for global optimal solutions, so the computed solution should be delivered fast and of high quality. In the presentation, the importance of efficient algorithm implementation will be demonstrated by means of practical routing tasks, which has been implemented with the inola AOC. Using different algorithm designs, the impact on performance will be analyzed by pre-post comparison. Small changes in just parts of selected algorithms can lead to a significant improvement in the application’s performance. In addition to the importance of efficient algorithm implementation another aspect, why heuristic optimization methods can fail, is the lack of a proper solution space exploration. The optimization method shall only cut-off areas of the solution space, in which the optimum will never be found, which is by default a challenge of optimization.

3 - Research in operations - the aircraft maintenance, repair and overhaul market
Michael Frank
For maintenance, repair and overhaul (MRO) of aircrafts, used parts from other airplanes are used. The sell, loan and exchange of used aircraft parts is a big market. MRO providers offer flat rate deals to airlines that cover all expenses of MRO operations. These deals require a lot of operations research: Demand for spare parts need to be forecasted, values for spare parts in various conditions must be determined and most efficient economical use of existing stock calculated. The presenter will give a brief insight in a solution for a big MRO provider. Applied methods include forecasts based on stochastic processes for demand prediction. Additionally a combination of various regression models are used for value determination. Optimization models support buy/sell decisions and the most efficient use of stock parts. The models itself are of interest not only due to their complexity but also due to the enhancements to handle all kind of missing data cases. The solution for this MRO order is tailor made. The presentation will show examples for other custom-made OR solutions. That should support the thesis that successful OR implementations are mostly tailor made.

WB-13

Wednesday, 11:00-12:30 - RVH I
Forecasting Neural Network Specification
Stream: Business Analytics, Artificial Intelligence and Forecasting
Parallel session
Chair: Sven F. Crone
1 - Visually Supported Parameter Tuning and Feature Engineering for Artificial Neural Networks
Dennis Eilers, Cornelius Köpp, Michael H. Breitner
A successful application of artificial neural networks in practical business analytics applications mainly depends on how well the available data represent the problem statement and the model capabilities to learn the dependencies in the presented patterns. Engineering the right features (independent variables) and tuning the model parameters is therefore a major challenge and requires technical expertise as well as domain knowledge about the investigated problem. In this study, we show how heat map visualizations of model errors can be used to assess the suitability of selected network properties and features. The proposed heat map approach visualizes the performance of the models in a two-dimensional feature space which allows a local representation of the accuracy to identify misprediction or necessary adjustments. Experiments with different network topologies and feature representations show how location dependent error visualizations can provide a more comprehensive quality criterion than a single performance measure like the root-mean-square error. The gained insights help to find adequate parameters like the number of hidden layers/neurons in a feed-forward neural network. Moreover, additional features can be constructed and evaluated based on their influence on the error distribution. We also discuss practical as well as theoretical implications based on the observed phenomena.

2 - Learning uncertainty of predictions by neural networks with regression
Pavel Gurevich, Hannes Stuke
In the talk, we discuss a general flexible approach to uncertainty quantification for predictions performed by deep neural networks. It is based on the simultaneous training of two neural networks with a joint loss function. One of the networks performs regression and the other quantifies the uncertainty of predictions of the first one. Unlike in many standard uncertainty quantification methods, the targets are not assumed to be sampled from an a priori given probability distribution. We analyze how the hyperparameters affect the learning process and show that our method allows for better predictions compared to standard neural networks without the uncertainty counterpart. Finally, we establish a connection between our approach and the mean variance estimation method and the mixture density networks.

WB-14

Wednesday, 11:00-12:30 - RVH II
Class and Score Prediction
Stream: Business Analytics, Artificial Intelligence and Forecasting
Parallel session
Chair: Thomas Setzer
1 - Consumer’s sport preference as a predictor for his/her response to brand personality
Friederike Paetz, Regina Semmler-Ludwig
Within a purchase decision process consumer often tend to choose that branded product, which arouses the most positive brand affect, rather than taking certain product attributes into account. Brand personality - human characteristics associated to a brand - is known as a central driver for affective brand loyalty. Recent studies already revealed, that consumers prefer those brands, which are in line with their own personality traits. Because brand personality is created by organization’s communication mix, organizations may therefore explore the personality traits of their target market segments and attach the corresponding personality to their brand. However, focusing on consumers’ personality traits is not directly observable. Hence, linking personality traits to variables, which are easily observable, may reduce organization’s communication effort. Within our study, we explore the personality traits of sportsmen from several sport clusters, e.g., sport players, sport fighters etc. To measure sportsmen’s personality, we used the popular Big Five approach, which describes personality by five factors, i.e., extraversion, neuroticism, agreeableness, consciousness and openness. We found evidence that the considered sport clusters significantly differ within certain personality traits. E.g., nature sportsmen turned out to be most extravert and open, while fitness sportsmen are most conscious. Hence, consumer’s choice of a specific kind of sport may be used as a predictor for his/her response to brand personality, i.e., affective brand loyalty. Sport organizations may use these results to simplify their communication strategies.

2 - Credit Scoring based on Neural Networks
Ralph Grothmann, Hans Georg Zimmermann
For financial institutions, credit risk assessment is key to their business success and as it is also vital for the economy as a whole, the prediction models attract high attention from regulators. Despite substantial developments in the area of machine learning recently, most banks still rely on traditional methods like logistic regression. Since data is expensive to obtain, most publications which applied machine learning techniques to credit scoring have used datasets with less than 1,000 observations. Another common shortcoming is that problems with heavily imbalanced data are often bypassed by using an artificially high default rate of around 50 percent whereas the share in banks’ credit portfolios usually is around 1 to 3 percent. We used a real-world dataset of 183,000 observations with 1.39 percent defaults and applied seven different machine learning techniques including ensemble learners. Our results give clear indication that especially state of the art techniques like boosting algorithms outperform traditional risk models significantly.
3 - Customer Churn Prediction using Temporal Patterns in Support Contact Data

Katerina Shapoval

The telecommunications industry is characterized by a strong price competition and high annual churn rates of about 30%. Furthermore, the acquisition costs per customer are about seven times higher than the retention costs. These circumstances make accurate churn prediction a crucial task for telecommunications companies in order to sustain in the market. Usually, the data available to the company includes records about the support history of a customer. To date, multiple approaches to predict churn exist, however, support data and its impact on churn prediction quality did not get a wide attention among scientific publications. This work aims at analysis and extraction of temporal patterns from support contact history of a customer (e.g. channel with the corresponding number of contacts and high-level description of its reason) as well as subsequent integration of these into churn prediction models. In particular, the predictive value per contact channel and the respective attributes with respect to the predictive power of a following churn event is investigated. A further challenge is the reduction of temporal patterns with respect to the history length and event variety in a multi-channel setting to a concise attribute set. For this purpose, a temporal discounting is employed, which weights the information with the assumption that the latest event has the highest importance.

A simulation is specified. It compares four scenarios for integrating frailty-related data into predictive models for churn.

1 - A case study of simulating the surgical process flow in an Indian healthcare setting

Rakesh Verma, Sudhanshu Singh

The use of simulation has increase over the years, moreover so after the tremendous gains in computing power since the 1980s. Organizations use simulation modelling to assess, evaluate the alternatives and for testing new solutions which may not too complex for analytical modelling. Simulation software has developed its capability in parallel with the growth in computing power since the 1980s. Simulation lets us visualize situations which have not really happened but what could happen. We present a simulation study to bring enhanced understanding of the surgical process in an Indian hospital. The results indicate the need to have tighter control on activities that are related to patient readiness for better throughput of the surgical process. This approach brings in more clarity and makes decision makers more realistic on what could be done.

2 - Toward an Agent-based Simulation of Incentives and Disincentives for Sharing Frailty-Related Information in Perioperative Care

Daniel Farstenau, Felix Balzer, Martin Gersch, Claudia Spies

Elderly patients undergoing surgical interventions are prone to develop frailty-related complications that may go far beyond the index hospitalization. Yet, biological aging-relevant information are currently not fully integrated into hospitals’ perioperative processes. This study combines research on frailty and economics of standardization in a novel way by asking: What is the best design regarding patient data compilation that aligns incentives of involved actors in order to reduce frailty-related complications?

A simulation is specified. It compares four scenarios for integrating frailty-related data into perioperative processes. First, general practitioners, second, decentralized ambulatory clinics within the hospital, third, the hospital’s emergency room, and forth (baseline), the anesthesia unit compiles the data. Our simulation uses the case of perioperative care provided by Charité’s department of anesthesiology. Frailty-related incentive data was collected from 13 interviews, observations, and further documents.

Qualitative analysis suggests that (1) there is general willingness by all parties to participate in data sharing, (2) the earlier the compilation the better, (3) unbalanced cost/utility structures hinder implementation. Calibration with actual cost and outcome data is ongoing.

By focusing on frailty-related data exchanges and using agent-based simulation, the study directly addresses biological aging-related processes. Increasing problem awareness is shown by the fact that Charité has implemented a special track for elderly patients scheduled for elective surgery. This solution could perhaps be extended.

Simulation promises to explicate better decision processes in healthcare and test designs to improve health-related outcomes.

3 - Evaluating intra-day quantity risk of wind power production

Lars Ostmeier, Sven Kolkmann, Christoph Weber

We aim at developing a multivariate model of wind power forecast errors reflecting the economic characteristics of the short-term markets as well as the physical characteristics of wind power forecasts and updates. First theoretical hypotheses are formulated for later empirical validation. Then a multivariate specification is proposed reflecting forecast errors as a function of delivery period and time to maturity. Hypothesis 1 starts from the assumption that the forecasts fully reflect the information available at the forecasting time. Then the updates of forecasts are a consequence of new information. We hypothesize that this new information leads to random changes in forecasts (no autocorrelation between subsequent forecast updates). Hypothesis 2 is reflecting the assumption that changed observations in the underlying physical system will affect monotonously forecasts for different time horizons. In line with numerous studies on probabilistic wind power forecasting, we first specify univariate distributions for forecast updates for single forecast horizons and then we apply copula to describe multivariate processes. Having calculated the forecast errors as defined above, we choose a non-parametric approach to estimate the cumulated distribution function (CDF) of the forecast updates for different time horizons. Therefore, we avoid limitations due to the predefined form of a specific distribution function. Following literature on wind power forecasts, we consider inter alia Support Vector Machines, kernel density estimation and quantile regression. Next, a multivariate Gauss-Copula is fitted to the cumulated distribution functions. The fitted multivariate distribution may then be used for Monte-Carlo simulations of future infed scenarios.

WB-16
Wednesday, 11:00-12:30 - RBM|I102

Finance I

Stream: Finance Parallel session
Chair: Michael H. Breitner

1 - Decoupled Net Present Value - An Alternative to the Long-Term Asset Value in the Evaluation of Ship Investments?

Philipp Schrader, Jan-Hendrik Piel, Michael H. Breitner

The aftermath of the financial crisis has threatened the stability of several financial institutions over the past years. Most heavily hit were banks with a notable exposure to ship finance, who saw the collateral value of many loans being diminished. Industry observers trace back the rare occurrence of actual defaults of ship loans to the use of the Long-Term Asset Value (LTAV), a valuation method explicitly designed for ship investments. As the LTAV is based on a discounted cash-flow approach, it accounts for investment risks in the discount rate. Consequently, the LTAV bundles the time value of money and risk in a single value, which begs the question if this method oversimplifies the incorporation of risk in the evaluation of ship investments. In the context of infrastructure investments, the Decoupled Net Present Value (DNPV) has recently been proposed as an alternative method that addresses the problem of using risk-adjusted discount rates. It separates
the time value of money from risks by quantifying risk factors individu- ally and treating them as costs to the investment. We provide a proof-of-concept regarding the applicability of the DNPV in the context of ship investments. To this end, we develop a DNPV valuation model and instantiate a prototype in Python. We then perform a simulation study that evaluates a ship investment using both the LTAV and the DNPV. The outcomes of our study confirm the applicability of the DNPV to ship investments and point to both its advantages and limitations compared to the LTAV.

2 - The Innovator’s Dilemma revisited: Investment Timing, Capacity Choice, and Product Life Cycle under Uncertainty
Stefan Kupfer, Elmar Lukas
Innovative industries like the semiconductor or flat-panel industry have been a driving momentum of global growth for decades. However, global competition, constant decline of output prices, rocketing costs, and shorter life-cycles put great stress on making the right investment policy. By means of a Markov-regime switching model we model the simultaneous choice of optimal investment timing and capacity under uncertainty in continuous time. Our results indicate that, the threat of disruptive technological change lead to install less capacity later. If uncertainty in the demand regime are different, we find that both optimal capacity and timing threshold become ambiguous. For low degrees of uncertainty in the decline regime, an increase of uncertainty leads to an increase of the investment threshold and a decrease of the optimal capacity in the growth regime.

WB-17
Wednesday, 11:00-12:30 - RBM|2204
Data-driven Healthcare Services
Stream: Health Care Management
Parallel session
Chair: Melanie Reuter-Oppermann

1 - Data-based Location, Relocation and Dispatching Approaches for the German EMS System
Melanie Reuter-Oppermann
In the last couple of years more and more papers have been published that present approaches for determining ambulance relocations and that show the benefit of applying those approaches, for example in the Netherlands. Nevertheless, ambulance locations in Germany are still mostly static. Ambulances are usually waiting for a call at their home base and they are sent back there after an emergency rescue. In addition, always the closest ambulance is assigned to an emergency independent of the severity and the current status of the system, even though researchers have shown that this is not always optimal for the overall system. The question arises if ambulance relocations and different dispatching rules can be applied in German practice in order to improve the performance, i.e. reduce response times. Therefore, promising approaches proposed for the Dutch EMS system were adapted to the German system and tested for several instances. The most important adaptations model the facts that emergency doctors are affected by bad data, raise as well. Reasons for bad data are, for example, miskeying, communication, wrong entry and fraud entry of data. Data Verification is a process, in which data is checked for inconsistencies and accuracy. The goal of Data Verification is to detect invalid and faulty data. Usually, the data is checked after Data Migration and not while entering new data. We propose a novel approach for extending the usual usage scenario of Data Verification by introducing N3 for checking for invalid data stored in a system. While N3 rules are typically used to infer new knowledge, based on the information stored in a knowledge base, we formalize verification checks in N3 rules and apply them on the saved data. The outcome of the inferred information can be used to check if the entered data is consistent. As a use-case scenario, we formalize conformity checks from a hospital information system in N3. The formalized N3 rules can also be used to automatically suggest entry values. We define multiple test scenarios to evaluate the expressivity and applicability of our approach. We also show that our approach is not limited to a certain use-case scenario but can be applied to further domains beyond healthcare.

3 - Appointment planning data - between desire and reality
Anne Zander, Melanie Reuter-Oppermann, Stefan Nickel
The literature offers many models to improve the appointment planning of a medical practice. Unfortunately, the implementation of those models often fails due to the unavailability of certain data. One reason for this is that medical practices often use software that is designed to comply with the billing regulations but not to collect data in order to plan better. In this talk, we will first summarize the most important data that is needed to implement the appointment models from the literature. The models we cover range from intra-day appointment planning with a focus on direct waiting times to inter-day appointment planning with a focus on indirect waiting times (access times). In the second part of the presentation, we investigate the appointment data we obtained from several medical practices. We then discuss what models (with their corresponding objectives) can be applied using this data. Subsequently, we will discuss what kind of data is not available. We show how the medical practices could benefit from collecting this data trough applying the corresponding models.

WB-18
Wednesday, 11:00-12:30 - RBM|2215
Scheduling and Sequencing
Stream: Project Management and Scheduling
Parallel session
Chair: Stefan Bock

1 - Tabu search algorithms for scheduling tasks with ready times on a single machine with limited availability
Jakub Pietruczuk, Piotr Formanowicz
In classical scheduling theory it is usually assumed that machines are continuously available for processing tasks. However, in many real life situations this assumption is not fulfilled. There are many reasons making machines not available in some periods of time, e.g., the limited availability may result from maintenance activities, from overlapping of time horizons in rolling time horizon planning algorithms or it may be due to scheduling of tasks with various priorities. In general, in deterministic scheduling two cases are considered, i.e., the starting points of the non-availability periods are known in advance or they should be determined to meet some requirements (when they correspond to maintenance - in this case both, tasks and maintenance have to be scheduled). In this work problems of scheduling tasks with ready times on a single machine with many non-availability periods are considered. The starting times and lengths of these periods are a part of the problem instance and the optimality criteria are minimization of the makespan and minimization of the sum of completion times. Since the problems are computationally intractable, tabu search algorithms solving them are proposed. The quality of the algorithms has been verified in extensive computational experiments whose results are reported.

2 - A branch and bound procedure for a scheduling problem with fixed delivery departure dates
David Bachtkenkirch, Stefan Bock
In many practical scheduling problems completed jobs are assumed to be delivered to another production stage or delivered to a customer at the point of completion. Scheduling problems with fixed delivery departure dates model cases where completed jobs must be held in inventory until delivery is available at certain points in time. Such circumstances are often found in the industry when a manufacturer relies on third party logistics providers to ship products to customers.
In this talk we present an optimization problem which focuses on minimizing holding and transportation costs for a set of jobs from multiple customers where jobs can only be delivered at certain fixed delivery departure dates. A job needs to complete production and must be assigned to a departure date before its deadline is exceeded. Completed jobs are held in inventory until transportation starts. Jobs can be delivered in batches at customer specific delivery departure dates by means of a direct delivery method.

Properties of the problem are investigated and used to construct an exact branch-and-bound solution procedure. We propose an enumeration scheme which partitions jobs into production blocks, derive an efficient subproblem evaluation method and present dominance criteria making use of the underlying problem structure. Additionally lower and upper bounds are presented. We give a brief overview of the computational results, comparing the branch and bound procedure and a standard MILP solver.

3 - A pseudo-polynomial solution approach for optimally solving the acyclic TSP with multiple congestion scenarios and soft due date restrictions
Stefan Bock

In this talk, an acyclic TSP with multiple congestion scenarios and soft due date restrictions is considered. In order to adequately map unreliable transportation data, multiple congestion scenarios are integrated. Each scenario may be derived from past data and determines congestion-dependent travel times. The problem pursues a hierarchical objective function. As the primary target, the total weighted tardiness for all defined congestion scenarios is minimized. The secondary objective is the minimization of the weighted makespan. The resulting problem is strongly NP-hard if either the number of congestion scenarios or the number of routes are allowed to increase linearly with the number of requests. Moreover, this is also true if non-zero unloading times at the delivery locations are integrated. However, if all three aforementioned cases do not apply, the problem is binary NP-hard, but can be solved to optimality in pseudo-polynomial time. By integrating an efficient dominance rule and tight lower bounds, a best-first Branch&Bound algorithm is proposed. Its high practicality is evaluated for various scenarios by a computational study.
has two stages with environmental issues. At the first stage, Fuzzy Analytic Hierarchy Process (FAHP) with interval type-2 fuzzy sets is used to handle experts’ subjective judgments. It is more meaningful to use interval type-2 fuzzy sets in MCMD problems because of easy of usage, lower computational time and effort. At the second stage, a fuzzy multi-objective linear programming model is developed to determine what the optimal order quantity is and which suppliers should be selected. In the application part, proposed integrated approach is applied to select the green suppliers and determine order quantity with respect to different experts’ judgments. A numerical example is presented to demonstrate the effectiveness of the proposed approach.

2 - Coordination of grading in reverse supply chains

Gerrit Schumacher, Moritz Fleischmann

In reverse supply chains, the quality condition of used products is a critical issue. Therefore, grading and the subsequent disposition decision are essential. These two processing steps fundamentally distinguish forward and reverse supply chains. Yet acquisition and grading are commonly subcontracted, i.e., executed by a different firm than the one eventually reprocessing and reselling the used products. In this presentation, we address potential incentive conflicts arising from this supply chain setup. Specifically, we present a model for the depicted situation with the goal to overcome the incentive conflicts with a coordination mechanism.

3 - Sustainable sourcing with recycled materials: A contribution towards circular economy

Patricia Rogetzer, Lena Schernau, Werner Jammernegg

Recycling rates for certain materials like aluminum are high, but often far below to fully meet an economy’s total demand. As the demand for raw material experiences a steady increase, the use of recovered raw materials can help to pave the way towards a circular economy, i.e. the integration of recycled material into the sourcing strategy plays a crucial role. This could be beneficial not only in terms of the environment and the society, but is also economically relevant. We address such an issue faced by a manufacturer who finds its optimal strategy by sourcing from two suppliers: one delivering virgin material, the other offering recycled material with uncertain yield and price. The focus of this work is to discuss how the integration of recycled material impacts a manufacturer’s economic performance. Depending on the price difference between virgin and recycled material, we want to explore which sourcing strategy is most desirable from an economic point of view. This is analyzed for a short life-cycle product in a single-period inventory model framework. As the delivery quantity of the recycler does not necessarily equal the order quantity, the following sourcing strategies are considered: 1. single sourcing from the recycler, 2. single sourcing from the virgin material supplier, 3. dual sourcing from recycling and virgin material supplier, 4. dual sourcing with recycling material as a main source and an emergency option of virgin material. For every sourcing strategy the optimal order quantities are provided that maximize manufacturer’s expected profit. Our preliminary results indicate that for a certain range of prices from the recycler the dual sourcing approaches will lead to higher profits compared to single sourcing.

2 - Modeling variants for the Multiple Traveling Salesmen Problem with Moving Targets

Anke Stieber

The multiple traveling salesman problem with moving targets (MTSPMT) is a generalization of the classical traveling salesman problem, where the targets are moving over time on arbitrarily shaped trajectories. Additionally, for each target a visibility time window is given. The task is to find routes for several salesmen so that each target is reached exactly once within its visibility time window and the sum of all traveled distances of all salesmen is minimal. The targets and the salesmen are assigned a certain speed value. Then an arc between two targets for two certain times exists, if the distance between the positions at the respective times of both targets can be traversed by a salesman at its maximum speed value. Applications of the described problem class can be found, e.g., in supply logistics and in the defense sector. Such instances can be very large in the number of variables and therefore time consuming to solve numerically. In handling the time aspect in different ways we present distinct modeling approaches for the MTSPMT. Firstly we use discrete time steps and embed the problem in a time-expanded network. Secondly, we use additional continuous variables to present a time-continuous model. This variant yields more accurate objective function values. Finally a time-free approach is proposed. In this so-called master problem the time aspect is relaxed completely and then time feasibility is ensured by solving a number of subproblems, that incorporate the two former model variants. Computational results for randomly generated test instances to compare all different modeling approaches were carried out.

3 - Domain Specific Pre-Analysis and Generation of Optimization Problems

Benjamin Saul, Wolf Zimmermann

Mixed-integer linear programs can be used to solve different problems. However, many methods need understanding of complex mathematical models. Using a domain-specific language to formulate the specification makes these methods available to more users. In our work we implemented a language for optimal pumping systems, a graph based selection problem. The mixed-integer linear program is then generated from the domain-specific model. The model can be analyzed to emit user feedback wrt. feasibility and numerical stability. Analysis results can be used to reduce the solution space by removing variables and tightening bounds.
Deutsche Post DHL is gradually electrifying its vehicle fleet by substituting diesel cars by LDEV. In the area of Bonn, they operate around 170 LDEV, using various LDEV models with a few diesel cars being kept as reserves. Drivers have been using LDEV on a daily work basis for 3-4 years, which allows us to analyze long-term user acceptance.

By conducting a cross-sectional survey at Deutsche Post DHL, we examine to what extent drivers accept the substitution of diesel cars by LDEV. Specifically, we investigate drivers’ LDEV acceptance from two perspectives. First, are the drivers more satisfied with the LDEV than with the diesel vehicle? Second, does the EV increase perceived productivity? Combining these two perspectives, our working hypothesis states that the greater the drivers’ overall satisfaction with the LDEV, the higher their perceived productivity.

We modeled our hypothesis by means of latent measures, such as perceived usefulness and perceived ease of use, using adaptations of Davis’ Technology Acceptance Model and Rogers’ Diffusion of Innovation theory. Preliminary findings suggest that, on average, drivers are slightly more satisfied with their assigned LDEV than with the available diesel cars. If drivers were able to choose the preferred vehicle the majority of them would favor LDEV.

2 - Airline fleet planning with CO2 emission targets under consideration of retrofit options
Karsten Kieckhäuser, Christoph Müller, Thomas Spengler

The global framework for aviation is given by growth expectation (growth rates of 3-5% p.a.) in combination with the challenge to reduce the environmental impact. Especially airlines are under increasing pressure due to ambitious mid- and long-term CO2 reduction targets. To reduce fleet emissions significantly, airlines can purchase new and more fuel efficient aircrafts. However, due to the long use phase of aircrafts, technology improvements in new aircrafts generally take a long time to percolate into the fleet in sufficiently large numbers. Contrary, retrofits at the existing fleet (e.g., winglets) can be a viable alternative in a short to medium timeframe. Decisions on these alternatives are part of airline fleet planning where the development of fleet size and composition is determined. Focusing on the transition towards energy-efficient aviation, we develop a novel optimization model for airline fleet planning. The model determines the fleet composition which maximizes the net present value in the planning horizon under consideration of retrofit options such that a certain CO2 emission target is satisfied. Based on real-world data, the model is applied to two major European airlines (full service network carrier vs. low cost carrier) to study the impact of different CO2 emission targets on the fleet composition. The results indicate that retrofits can make a significant contribution to achieving short term emission targets. The study provides insights for policy makers when setting CO2 emission targets for airlines and developing mechanisms to encourage environmental commitment.

Decision making in real-world routing applications is generally conducted under incomplete information. Vehicle dispatchers deal with uncertainty in travel times, service times, customer requests, and customer preferences. The information is only revealed successively during the execution of the routing. Technological advances allow dispatchers to adapt their decisions dynamically to new information. Nevertheless, current decision-theoretic approaches to allocation problems do not sufficiently address the need for anticipating future events in current decision making. Even though the work on dynamic vehicle routing problems (DVRPs) is manifold, anticipatory approaches are still not established. The aim of this work is to give guidance on how to model DVRPs and how to achieve anticipation. For modeling dynamic vehicle routing problems, we propose the use of a Markov decision process (MDP). For the integration of stochasticity in dynamic decision making, methods of approximate dynamic programming (ADP) are established in many applications fields. Until now, the application of ADP-methods to DVRPs is limited due to DVRPs’ complexity. We extend and combine general methods of ADP to match the characteristics of DVRPs. A comparison with conventional state-of-the-art benchmark heuristics for a DVRP with stochastic customer requests proves the ADP-methods to be highly advantageous.

2 - Game-theoretic Approaches to Allocation Problems in Coopetitve Routing
Igor Kuznetzky

This thesis studies allocation problems arising in horizontal cooperations on the example of cooperative routing problems using the methods of cooperative game theory and operations research. The main contribution of this study lies in the developed methodology to deal with allocation problems in multi-objective cooperative situations with one common objective and individual objectives for all players. This extension leads to an allocation problem, where for every player two payoffs are of importance: the value of the utility, and the amount allocated from the common objective. To handle this problem a knowledge from cooperative game theory is extended and two solution concepts, based on the idea of the core and the Shapley value for non-transferable utility games, are developed. For implementation of these concepts two allocation approaches are introduced. Besides the multi-objective scenario a cost allocation problem with an application to cooperative traveling salesman problem is also studied and concepts of the Shapley value and the core are applied. In the implementation of these solution concepts (as well as in the thesis in general) special attention is addressed to the reduction of computational effort combined with them.

3 - Methodological Advances and New Formulations for Bilevel Network Design Problems
Pirmin Fontaine

This thesis proposes a Benders decomposition algorithm to solve discrete-continuous bilevel problems to optimality. The efficiency of the method is shown on existing problems from the literature - namely the Discrete Network Design Problem, the Decentralized Facility Selection Problem and the Hazmat Transport Network Design Problem. Depending on the problem structure, the convergence of Benders decomposition is improved by using the multi-cut version or pareto-optimal cuts. For the Discrete Network Design Problem, a linearization of the convex objective function is used. The run time is improved by more than 60% compared to the mixed-integer linear program. Moreover, the Discrete Network Design Problem is extended to a multi-period model for planning maintenance work in traffic networks.

Further, we show on the Decentralized Facility Selection Problem and on the Hazmat Transport Network Design Problem run time improvements of more than 90% compared to the mixed-integer linear program. To include risk equity in hazardous material shipment, a population-based risk definition is introduced and the Hazmat Transport Network Design Problem is extended to a multi-mode model. The numerical results show a better distribution of risk compared to classical models in the literature and a convex relation between risk equity and risk minimization.

4 - Handling Critical Tasks Online: Deadline Scheduling and Convex-Body Chasing
Kevin Schewior

Completing possibly unforeseen tasks in a timely manner is vital for many real-world problems. For instance, in hospitals, emergency patients may come in and require to be treated, or self-driving cars need to avoid obstacles appearing on the street. Under the hard constraint of timely fulfilling these tasks, one still usually wishes to use resources as efficiently as possible. In this thesis, we develop various online algorithms for handling critical tasks that improve upon previously known bounds on the resource usage, and thereby we answer long-standing questions.
We consider the above applications in the form of two fundamental mathematical problems. First, in online deadline scheduling, jobs arrive over time to be scheduled on a machine until their deadline. We present the first algorithm that uses a number of machines bounded in the offline-optimal one, which we complement with an impossibility result when jobs cannot be migrated between machines. Further, we investigate the power of using faster machines. Second, in convex-body chasing, an agent needs to immediately serve tasks located within convex regions and minimize the total travelled distance. We simplify known results and introduce the first competitive algorithms for dimensions larger than two.

1 - Dynamic programming approach for bidding problems on day-ahead markets
Jérôme De Boeck, Martine Labbé, Étienne Marcotte, Patrice Marcotte, Gilles Savard

In several markets, such as the electricity market, spot prices are determined via a bidding system involving an oligopoly of producers and a system operator. Once time-dependent price-quantity bids are placed by each producer for its production units, the system operator determines a production schedule that minimizes the marginal production cost. Fampa et al. have considered the problem faced by a profit-maximizing producer, whose bids depend on the behaviour of the system operator, as well as the stochastic nature of final demand, and that can be cast within the framework of stochastic bilevel programming. In this presentation, we consider an enhanced model that embeds two key features, namely the uncertainty related to competitors’ bids, as well as the impact of spot prices on demand. Our aim is to develop efficient solution algorithms for addressing instances involving a large number of scenarios. Under the assumptions that production costs are linear and that demand is piecewise constant, the bilevel model can be reformulated as a large mixed integer program. Although this problem becomes numerically intractable as the number of scenarios increases, it becomes much simpler when producers are allowed to place different price-quantity bids for a given generator. This relaxation of the original problem can then be solved in polynomial time by a dynamic programming algorithm. This algorithm can then be adapted to heuristically solve the original problem, yielding very quickly feasible solutions characterized by small optimality gaps. The performance of the method has been tested on instances inspired from the Brazilian Electric System National Operator.

2 - Comparative exemplary application of different zonal configuration algorithms for the case of market splitting in Germany
Dirk Hladik, Dominik Möst

As progress is beginning to be made in the coupling of European electricity markets in the midst of increasing shares of renewable energy, congestion management is gaining in importance. One main driver of grid congestion results from inappropriately market zones, in which the underlying grid structure leads to physically infeasible market results. These mounting irregularities are a consequence of the ongoing transformation of the energy system, whereby particular generation capacities are being shifted spatially. Thus, a reconfiguration of market zones remains a much-discussed topic and a number of algorithms are proposed in the extant literature. However, there is no “golden rule” to determine the optimal zonal configuration. Approaches range from a distinct cluster basis like nodal prices and Power Transfer Distribution Factors (PTDF) to diverse cluster algorithms, time resolutions and different degrees of incorporating uncertainty. This contribution aims to comparatively apply two common approaches based on a hierarchical clustering of nodal prices and PTDF as well as a third, which tries to combine the advantages of both. These three approaches are applied to the German transmission grid where bordering countries are considered as well using the electricity load flow model ELMOD. The current DE-AT-LU price zone provides a prime application given the current high volumes of curative congestion management. The future increase in wind generation and the nuclear phase-out by 2022 accompanied by delays in grid expansion measures may exacerbate the spatial imbalances. Therefore, this work resolves to determine which one of the three algorithms proves to be preferable to use in the context of market splitting in Germany and assumes a mid-term perspective up to 2025.

3 - Evaluating alternative market designs in electricity markets: a mixed-integer multilevel optimization model and global solution techniques
Thomas Kleineit, Frauke Liets, Martin Schmidt

Mathematical modeling of market design issues in liberalized electricity markets often leads to mixed-integer nonlinear multilevel optimization problems that are intractable in general. Furthermore, no general-purpose solvers exist. We consider the task of simultaneously deciding on network expansion plans, together with the splitting of the market area into a given number of price zones, such that welfare-optimal solutions emerge. This task leads to a challenging multilevel problem that contains a network-design problem and a highly symmetric graph-partitioning model with multi-commodity flow connectivity constraints. Furthermore, proper economic modeling leads to nonlinearities. We develop different problem-tailored solution approaches that yield globally optimal solutions. In particular, we present a KKT transformation approach, an outer approximation approach that exploits strong duality of convex programming, and an approach based on nested generalized Benders decomposition. We present methods for enhancing the solution approach by techniques, such as symmetry breaking and effective primal heuristics. We evaluate the computational behavior on academic and realistic networks. It turns out that our approaches lead to effective solution methods for these challenging optimization tasks arising in electricity markets.
While preference-based explanations play an increasing role in economics the accurate measurement of social preferences deserves more attention. Most laboratory experiments measure social preferences by studying the division of "cake that nobody had to bake" (Güth and Kliemt, 2003). We report results of an ultimatum game experiment with bargaining over waiting time. The experiment was created to avoid effects of windfall gains. In contrast to donated money, time is not endowed by the experimenter and implies a natural loss to subjects. This allows for a better measurement of the inherent conflict in the ultimatum game. We implemented three anonymity conditions: one baseline condition, one condition with anonymity among subjects and one double-blind condition in which the experimenter did not know the division of waiting time. While we expected to observe less other-regarding behavior in ultimatum game bargaining over time, our experimental results rather confirm previous ultimatum game experiments, in which people bargained over money. The modal offer was half of the waiting time and only one offer was rejected. Interestingly, anonymity did not change the results significantly. In conclusion, our experiment confirms other-regarding behavior in the ultimatum game.

3 - An Experimental Comparison of Ultimatum Bargaining Over Positive, Negative and Mixed Outcomes
Thomas Neumann, Stephan Schosser, Bodo Vogt
Experimental economists typically focus on distribution problems that take place in a gains domain. Many real-life situations, e.g. budget allocation within universities or the negotiation of insurance companies over compensation for damages, etc., highlight the relevance of the distribution challenge and also how, in many situations, it is not only positive outcomes that needed to be divided, but also negative or mixed. In this experimental study, we compare the behavior of players in an ultimatum game that takes place in a negative domain with that in a positive domain and with that in a mixed domain. We find that the division of outcomes is different across treatments.
and capacities. The results show that the presented method leads to the optimal solution for all considered instances with a good performance.

**WC-02**

**Wednesday, 13:30-15:00 - WGS|102**

**Modeling Systems II**

Stream: Software Applications and Modelling Systems

Parallel session

Chair: Mike Steglich

**1 - Building and Solving Optimization Models with Python**

Kostja Siefen

Python is a powerful and well-supported programming language that’s also a good choice for mathematical modeling. It has special features that make it easy to build and maintain optimization models. The Gurobi Python interface combines the ease and expressiveness of a modeling language with the power and flexibility of a programming language. In this talk we will show how to build large-scale, high-performance optimization applications through an interactive development process involving actual models as examples.

**2 - Embedded Code in GAMS - Using Python as an Example**

Lutz Westermann

This talk is about a recent extension of the General Algebraic Modeling System (GAMS): the "Embedded Code" facility. GAMS uses relational data tables as a basic data structure. With these, GAMS code for parallel assignment and equation definition is compact, elegant, and efficient. However, traditional data structure (arrays, lists, dictionaries, trees, graphs, ...) are not natively or easily available in GAMS. Though it is possible to represent such data structures in GAMS, the GAMS code can easily become unwieldy, obfuscating, or inefficient. Also, in the past it was not easy to connect libraries for special algorithms (e.g. graph algorithms, matrix operations, ...) to GAMS without some data API knowledge (GDX) and some disk I/O.

To overcome these issues, the Embedded Code facility was introduced recently. It allows the use of external code (e.g. Python) during compile and execution time. GAMS symbols are shared with the external code, so no communication via disk is necessary. It provides a documented API and additional source code for common tasks so that the user can concentrate on the task at hand (e.g. computing shortest paths) and not the mechanics of moving data in and out of GAMS.

**3 - Optimization Modelling for Data Scientists in IBM Data Science Experience**

Sebastian Fink, Hans Schlenker

More and more companies rely on data scientists to turn company data into real business value. Data scientists explore and excavate business data, extract valuable data sets, combine them with 3rd party data, and apply the most advanced analytics approaches to the data to derive real and often very precious business value from that data. Data scientists typically use methods such as data mining, visualization, or machine learning. Mathematical optimization is not yet widely used in this community, but this can be changed: Powerful language APIs for solvers like CPLEX, for data scientists’ preferred programming languages, and their integration into data science tools, simplify the useability of math programming for data scientists. This not only adds yet another technology to the data scientist’s toolsets, but it also empowers them to build much richer analytics pipelines, allowing them to combine optimization with approaches like forecasting, segmentation, or classification. In this talk we present: How Python and Notebooks can be used together with CPLEX to build full math programming and constraint programming models, how this can be used to model and solve real world optimization problems, and how these models can be analyzed and validated in public, hybrid and private cloud environments.

**4 - Implementing and solving decision problems with SolverStudio/Cmpl and CmplServer**

Mike Steglich

Companies or other organisations which are faced with decision problems to be solved using operations research methods have to embed them in their ICT systems.

This talk shows how open-source software tools like SolverStudio/Cmpl and CmplServer can be used by presenting real examples. SolverStudio is an add-in for Excel on Windows that allows to build and solve optimisation models in Excel using selected modeling languages. One of the languages is CMPL (<Coliop|Coin> Mathematical Programming Language).

After an overview of the main functionalities of SolverStudio, the main aspects of CMPL’s integration with SolverStudio will be described. Real decision problems often need to be solved on high-performance hardware but controlled on a notebook or desktop computer. Therefore, it will be shown how CMPL models can be solved using CmplServer which is an XML-RPC-based web service for distributed and grid optimization.

**WC-03**

**Wednesday, 13:30-15:00 - WGS|103**

**Cancelled: Terminal Operations**

Stream: Logistics and Freight Transportation

Parallel session

Chair: Ann-Kathrin Lange

**WC-04**

**Wednesday, 13:30-15:00 - WGS|104**

**Online Optimization**

Stream: Graphs and Networks

Parallel session

Chair: Yann Disser

**1 - Tight Competitive Analysis for Online TSP on the Line**

Miriam Schlöter, Yann Disser, Jan Hackfeld, Christoph Hansknecht, Kevin Schewior, Leon Stougie, Antje Bjelde, Julie Meißner, Maarten Lipmann

We consider the online traveling salesperson problem (TSP), where requests appear online over time on the real line and need to be visited by a server initially located at the origin. We distinguish between closed and open online TSP, depending on whether the server eventually needs to return to the origin or not. While online TSP on the line is a very natural online problem that was introduced more than two decades ago, no tight competitive analysis was known to date. We settle this problem by providing tight bounds on the competitive ratios for both the closed and the open variant of the problem. In particular, for closed online TSP, we provide a 1.64-competitive algorithm, thus matching a known lower bound. For open online TSP, we give a new upper bound as well as a matching lower bound that establish the remarkable competitive ratio of 2.04. Additionally, we consider the online Dial-A-Ride problem on the line, where each request needs to be transported to a specified destination. We provide an improved non-preemptive lower bound of 1.75 for this setting, as well as an improved preemptive algorithm with competitive ratio 2.41. Finally, we generalize known and give new complexity results for the underlying offline problems. In particular, we give an algorithm with running time $O(n^2)$ for closed offline TSP on the line with release dates and show that both variants of offline Dial-A-Ride on the line are NP-hard for any capacity $c=2$ of the server.

**2 - Anonymous Graph Exploration with Binoculars**

Jérémie Chalopin

We investigate the exploration of networks by a mobile agent. It is long known that, without global information about the graph, it is not possible to make the agent halt after the exploration except if the graph is a tree. We therefore endow the agent with binoculars, a sensing device that enables the agent to see the graph induced by its neighbors. We
show that, with binoculars, it is possible to explore and halt in a large class of non-tree networks. We give a complete characterization of the class of networks that can be explored using binoculars using standard notions of discrete topology. This class is much larger than the class of trees: it contains in particular chordal graphs, plane triangulations and triangulations of the projective plane. Our characterization is constructive: we present an Exploration algorithm that is universal; this algorithm explores any network explorable with binoculars, and never halts in non-explorable networks.

3 - Online bipartite matching in offline time

Anna Zych-Pawlewicz, Bartłomiej Bosek, Dariusz Leniowski, Piotr Sankowski

A bipartite graph G between n clients and n servers is revealed online. The clients arrive in an arbitrary order and requests need to be matched to a subset of servers. In our model we allow the clients to switch between servers and want to maximize the matching size between them, i.e., after a client arrives we find an augmenting path from a client to a free server. Our goals in this model are twofold. First, we want to minimize the number of times clients are reallocated between the servers. Second, we want to give fast algorithms that recompute such reallocation. As for the number of changes, we propose a greedy algorithm which for each server has its client reassigned O(sqrt(n)) times. This gives an O(n^{3/2}) bound on the total number of changes, what gives a progress towards the main open question risen by Chaudhuri et al. (INFOCOM’09) who asked to prove O(n log n) upper bound. We also show that by introducing proper amortization we can obtain an incremental algorithm that maintains the maximum size matching in total O(sqrt(nm)) time. This matches the running time of one of the fastest static maximum matching algorithms that was given by Hopcroft and Karp (SIAM J. Comput’73).

3 - Dynamic bi-modal ridesharing using optimal passenger-vehicle assignments

Tai-yu Ma

Existing mobility-on-demand service has a major inefficiency for its operating policy design by disregarding the opportunity in cooperation with other transportation networks. In this work, a dynamic bi-modal vehicle dispatching and routing algorithm is proposed to address real-time operating policy of ride-sharing (feeder) services with the presence of other public transportation networks. We consider a real-time on-demand feeder service supported by one operator. The operator uses a fleet of homogeneous capacitated vehicles and designs its routing and dispatching policy. The addressed problem is a typical first/last mile problem. We propose an optimal passenger-vehicle assignment algorithm based on the concept of shareability graph (Alonso-Mora et al. 2017). Firstly, we compute which requests can be paired combined and which vehicles can serve the requests by satisfying the constraints in terms of passengers’ maximum waiting time, maximum delay and vehicles’ capacity. We combine possible pre-post transit trip requests as groups based on the pairwise request-vehicle graph. Then we compute which feasible trips (a set of requests) can be served by which vehicles. Finally, optimal trip-vehicle assignment is determined by solving an integer linear program problem. Efficient rebalancing strategy for idle vehicles is proposed to reduce users’ waiting times.

The numerical study is conducted on a realistic bi-modal transportation network located in Luxembourg and cross-border area. We test the influence of demand intensity, fleet size, waiting time on passengers’ delay and on vehicle occupancy rates. The proposed methods can be applied to operating policy design of mobility-on-demand service to increase the utilization of public transportation service.

Car Pooling & Sharing

Stream: Traffic, Mobility and Passenger Transportation
Parallel session
Chair: Tai-yu Ma

1 - Carpool formation along high-occupancy vehicle lanes

Stefan Schwedtfege, Nils Boysen, Dirk Briskorn, Konrad Stephan

High-occupancy vehicle lanes are restricted traffic lanes reserved for vehicles with multiple car occupants. Depending on the current number of passengers a driver has to either travel slower on the general purpose lane or is allowed to access the faster HOV lane. This paper treats optimization approaches for matching supply and demand when building carpools along HOV lanes. In current applications, carpools are rather spontaneously formed at slugging areas where potential passengers queue up. Internet-enabled mobile phones, however, allow for dynamic carpool formation based on sophisticated scheduling procedures. We investigate different versions of the carpool formation problem. An indepth analysis of computational complexity is provided and suited solution procedures are developed. These procedures are then applied to quantify the benefit of an optimized carpool formation process. In a comprehensive computational study we compare our optimization approaches with spontaneous ride sharing.

2 - Optimal Integration of Autonomous Vehicles in Car Sharing

Marcus Kaiser

This work is about the potential impact of autonomous vehicles on car sharing. More specifically, estimations on the change of necessary fleet size and of arising cost are given compared to the current situation. For that purpose, a deterministic model relying on historical data of customers’ car rentals is created. The resulting mixed-integer linear program is the extension of a vehicle scheduling problem by the possibility of refueling for the vehicles and the consideration of public transport. The focus then lies on an alternative formulation gained by a Dantzig-Wolfe decomposition, and an exact solution method based on branch-and-price. This involves the examination of a column generation using a heuristic as well as an exact algorithm for the emerging subproblems.

3 - Dynamic bi-modal ridesharing using optimal passenger-vehicle assignments

Tai-yu Ma

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Selected Topics

Stream: Graphs and Networks
Parallel session
Chair: Stephan Westphal

1 - On a technique of finding running tracks of specific length in a road network

David Willems, Stefan Ruzika, Oliver Zehner

Many sport events, especially endurance sport competitions, take place in urban spaces. In the past years, fun runs or obstacle runs gained public attention with growing participant numbers. Labels like XLETIX, Tough Mudder, Strongman, Minz Sportkonzept or B2Run emerged due to the popularity of such events. For example, 17,500 athletes are expected to participate in the upcoming Minz Firmenlauf in Koblenz. For a mid-sized city like Koblenz, this constitutes an immense interference into traffic for each afternoon the run is being carried out. Often, those competitions are reoccurring on an annual basis and have grown to an extent that their running track disrupts the local traffic situation. Traffic participants may encounter road closures and long waiting times. Until now, event organizers have to propose a potential track at the corresponding municipal administration office. This includes technical details as start and finish point as well as legal requirements for the track. In this talk, we address the problem of finding a path of given length in a network, examine its complexity and present a pseudopolynomial algorithm to solve the problem. Especially organizers of running events benefit from this method of finding such paths and cycles as this algorithm is applicable to road networks. As a result, this approach constitutes a simplification tool in the decision-making process of finding adequate running tracks. Since the algorithm returns various paths, it is possible for an organizer to choose the track that meets most desired requirements either by hand or by the application of an additional step of optimization.

2 - A simulation-based framework for competitive analysis of online scheduling problems

Martin Dahmen

A common scheduling problem is given by a set of jobs that must be assigned to a set of machines and different timeslots, under the restriction of various constraints. In our case, we add an additional online characteristic to our scheduling problems. This means that jobs will appear subsequently and as soon as a job appears an online algorithm has to decide which machine it will be assigned to, without knowledge.
Various Aspects of Discrete Models

Stream: Discrete and Integer Optimization
Parallel session
Chair: Steffen Goebbels

1 - Mathematische Optimierung in der Schule
Alexander Schulte


2 - A Linear Program for Matching Photogrammetric Point Clouds with CityGML Building Models
Steffen Goebbels, Regina Pohle-Fröhlich, Philipp Kant
We match photogrammetric point clouds with 3D city models in order to texture their wall and roof polygons. Point clouds are generated by the Structure from Motion (SfM) algorithm from overlapping pictures and films that in general do not have precise geo-referencing. Therefore, we have to align the clouds with the models’ coordinate systems. We do this by matching corners of buildings, detected from the 3D point cloud, with vertices of model buildings that are given in CityGML format. Due to incompleteness of our point clouds and the low number of models’ vertices, the standard registration algorithm “Iterative Closest Points” does not yield reliable results. Therefore, we propose a relaxation of a Mixed Integer Linear Program that first finds a set of correspondences between building model vertices and detected point cloud corners. Then, in a second step, we use a Linear Program to compute an optimal linear mapping based on these correspondences.
1 - A modified Benders method for the single and multiple allocation p-hub median problem

Hamid Mokhtar, Mohan Krishnamoorthy, Andreas Ernst

We consider the well-known uncapacitated p-hub median problem with multiple allocation (UMApHMP), and single allocation (USApHMP). These problems have received significant attention in the literature because while they are easy to state and understand, they are hard to solve. They also find practical applications in logistics and telecommunications network design. Due to the inherent complexity of these problems, we apply a modified Benders decomposition method to solve large instances of the UMApHMP and USApHMP. The Benders decomposition approach does, however, suffer from slow convergence mainly due to the high degeneracy of subproblems. To resolve this, we apply a novel method of accelerating Benders Method. Our approach outperforms existing results in the literature by more appropriately choosing parameters for the accelerated Benders method, and by solving subproblems more efficiently using minimum cost network flow algorithms. We implement our approach on well-known benchmark data sets in the literature and compare our computational results with existing results. The computational results confirm that our approach is efficient and enables us to solve larger single- and multiple-allocation hub median instances.

2 - Variants of the Traveling Salesman Problem with additional ordering constraints

Achim Hildenbrandt

The traveling salesman problem (TSP) is probably the most studied problem in combinatorial optimization. In the field of disaster logistics you often face tasks which can be modeled as a TSP with additional ordering constraints. In this talk we therefore want to consider four different variants of the TSP. The first one is Clustered TSP (CTSP) where all nodes are partitioned into clusters and all nodes of one cluster have to be visited in a row. The second one is the ordered clustered TSP (OCTSP) which is a CTSP where an additional ordering in which the clusters must be visited is given. We also want to consider the precedence constrained TSP (PCTSP) where we are given a list of mandatory precedence relations telling which node must be visited before which other. The last problem is the target visitation problem where an additional preference matrix is given. The objective cost of a tour is then computed as the difference of the cost of all fulfilled preferences and the traveling costs. For each of these four problems we discuss different IP models and examine the connections between them. We also want to present a branch-and-cut algorithm which can solve these problems to optimality. For the TSP a new way of solving is presented which uses lazy cuts.

New Solution Approaches for Applications from Real-World Projects (i)

Stream: Discrete and Integer Optimization
Parallel session
Chair: Anja Fischer

1 - A comparison of reinforcement learning and heuristics for the Dynamic Container Relocation Problem

Paul Alexandru Bucur, Philipp Hungerländer

In maritime port operations there exist areas, known as storage bays, in which containers are stacked in tiers on top of each other in several columns. In such a storage system, containers may only be retrieved one-by-one if they are the highest in their column. In the Container Relocation Problem (CRP), given an initial configuration of the bay and an a-priori known departure sequence, the goal is to retrieve the wanted containers in the predefined order, while keeping the number of container relocations inside the bay to a minimum. The Dynamic Container Relocation Problem (DCRP) introduces a dynamic aspect by also considering arriving containers. In our presentation we explore the use of problem-specific heuristics and reinforcement learning for the DCRP. The main advantage of reinforcement learning techniques is that they do not necessarily require a model of the problem. Hence they are able to continuously ‘learn’ by interacting with the unknown environment. We compare reinforcement learning techniques to problem-specific heuristics, and show how problem-specific heuristics can enhance the learning process by guiding the exploration of the state-action space. We suggest both new competitive approaches for solving large-scale DCRP instances, as well as flexible approaches which allow to account for possible online extensions. In particular we consider three algorithms: Q-learning, Monte Carlo Tree Search and an extension of the well-known Beam Search approach from literature. In our computational experiments we first benchmark our solvers against the traditional literature instances. Then we suggest new benchmarking instances and compare our solvers on this new benchmark set.

2 - A Mixed-Integer Linear Program for the Traveling Salesman Problem with Structured Time Windows

Christian Truden, Philipp Hungerländer

The NP-hard Traveling Salesman Problem with Time Windows (TSPTW) is concerned with visiting a set of customers within their assigned time windows such that a given objective function is minimized. The TSPTW has several applications in its own right and additionally also appears as subproblem within the more general capacitated Vehicle Routing Problem with Time Windows (cVRPTW).

We introduce the Traveling Salesman Problem with structured Time Windows (TSPSTW). The difference between the TSPTW and the standard TSPTW is the special structure of the time windows: structured time windows can hold several customers and are non-overlapping. This special structure of the time windows is motivated by an online grocery shopping application in the context of a large international supermarket chain that builds their vehicle’s tours as new customers come in. In this application, the structure of the time windows is set by the supplier who provides the customer with a selection of time windows to choose from. Hence in this application, these special structural features neither impose substantial restrictions to the supplier nor to the customer.

We suggest a simple but nonetheless very efficient mixed-integer linear program (MILP) for the TSPSTW that can be easily and quickly implemented by practitioners. Finally in a computational study we showcase that our MILP is highly competitive compared to our MILPs for the TSPTW from the literature.

3 - On the Slot Optimization Problem in On-Line Vehicle Routing

Philipp Hungerländer, Andrea Rendl, Christian Truden

The capacitated vehicle routing problem with time windows (cVRPTW) is concerned with finding optimal tours for vehicles that deliver goods to customers within a specific time slot (or window), respecting the maximal capacity of each vehicle. The on-line variant of the cVRPTW arises for instance in online shopping services of supermarket chains: customers choose a delivery time slot for their order online, and the fleet’s tours are updated accordingly in real time, where the vehicles’ tours are incrementally filled with orders.

In this paper, we consider a challenge arising in the on-line cVRPTW that has not been considered in detail in the literature so far. When placing a new order, the customer receives a selection of available time slots that depends on his address and the current (optimized) schedule. The customer chooses his preferred time slot, and his order is scheduled. The large the selection, the more likely the customer finds a suitable time slot, leading to higher customer satisfaction and a higher overall number of placed orders. We denote the problem of determining the maximal number of feasible time slots for a new order as the Slot Optimization Problem.

We propose several heuristics for both determining feasible and infeasible slots. Our approaches combine local search techniques with strategies to overcome local minima and iterative linear programs for selected sub-problems. In an experimental evaluation, we demonstrate the efficiency of our approaches on a variety of benchmark sets and for different time restrictions that are motivated by varying customer request rates.
1 - Towards Dynamic Pricing in Liner Shipping with Accurate Vessel Capacity Models
Mai Ajstrup, Rune Jensen

A recent study by McKinsey estimates a loss in liner shipping due to non-dynamic pricing of more than $4B per year. A challenge for introducing dynamic pricing, however, is that the free capacity of a container vessel is highly dependent on the composition of the type of containers to stow. For example, stowing many light reefer-containers often makes it impossible to stow heavier containers, even if it is within the ship’s nominal capacity w.r.t. TEU, reefer slot and weight. Capacity models that accurately describe the feasible cargo compositions are therefore needed; these can then be applied in cargo flow simulations used to compute the residual capacity of the shipping network, which is the basis for dynamic pricing. In this work, we address the described problem by deriving accurate and compact capacity models from the detailed but linear stowage optimization models recently published by Dedotto et al. This is done by abstracting away the unnecessary information, such as the specific location of each container in the cargo. For this purpose, we have developed a hierarchically decomposed and parallel version of the Fourier-Motzkin elimination method, which projects the feasible solutions in a large dimensional space into a space of smaller dimension. Our results show that our projected models are two orders of magnitude smaller than the initial stowage capacity models and makes the cargo flow simulations more scalable without significant loss of accuracy. Further, we obtain more accurate results expected Marginal Seat Revenue method, originally developed for airline models and makes the cargo flow simulations more scalable without significant loss of accuracy. Further, we obtain more accurate results compared to only using upper bounds on the nominal TEU, weight and reefer-capacities, which is what currently is done.

2 - Uptake Management in Liner Shipping - Industry Challenges and a Solution Approach
Stefan Guericke

Today, more than 6000 active container vessels enable the global merchandise trade. Out of these, the majority of assets are deployed on liner services, serving carriers, and stow the given ship’s nominal capacity w.r.t. TEU, reefer slots and weight. Capacity models that accurately describe the feasible cargo compositions are therefore needed; these can then be applied in cargo flow simulations used to compute the residual capacity of the shipping network, which is the basis for dynamic pricing. In this work, we address the described problem by deriving accurate and compact capacity models from the detailed but linear stowage optimization models recently published by Dedotto et al. This is done by abstracting away the unnecessary information, such as the specific location of each container in the cargo. For this purpose, we have developed a hierarchically decomposed and parallel version of the Fourier-Motzkin elimination method, which projects the feasible solutions in a large dimensional space into a space of smaller dimension. Our results show that our projected models are two orders of magnitude smaller than the initial stowage capacity models and makes the cargo flow simulations more scalable without significant loss of accuracy. Further, we obtain more accurate results compared to only using upper bounds on the nominal TEU, weight and reefer-capacities, which is what currently is done.

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4 - Designing and optimizing an LNG supply chain using LocalSolver
Clément Pajean

This talk deals with the optimization of the sizing and configuration of a Liquefied Natural Gas (LNG) supply chain. This problem is encountered at ENGIE, a French multinational electric utility company which operates in the fields of electricity generation and distribution, natural gas and renewable energy. Having described the industrial problem and its stakes, we show how to model and solve it efficiently using set-based modeling features of LocalSolver, a new-generation hybrid mathematical programming solver. In the process, we combined ENGIE Lab CRIGEN business knowledge and mathematical modelling skills with LocalSolver agile design thinking and powerful solver components to tackle advanced routing & scheduling problems. The resulting software OptiRetail is now used by ENGIE to carry out design studies of LNG supply chains. Several onshore customers need to be supplied with natural gas from LNG sources. The demand of each client is known for every time step. Different transportation means such as vessels or trucks are available to supply LNG from sources to customers, possibly using intermediate hubs. Each carrier is characterized by its storage capacity and its costs as well as the list of sites that it can visit. A tour is a distribution travel starting from a source with full capacity and visiting a certain number of sites, unloading a fraction of the capacity at each site, and finally getting back to the starting source. A planning is a set of tours over the horizon. The cost of the planning is composed of fixed costs and operating costs. The objective is to minimize this cost over a long-term horizon, typically 20 years.

WC-13
Wednesday, 13:30-15:00 - RVH|I
Forecasting Energy and Commodities

Stream: Business Analytics, Artificial Intelligence and Forecasting
Parallel session
Chair: Ralph Grothmann
Chair: Sven F. Crone

1 - Short-term zero flow forecasting in gas networks
Milena Petkovic

Natural gas is the cleanest fossil fuel since it emits the lowest amount of CO2. Over the years, lower prices and better infrastructure lead to significant increase of natural gas usage in transportation, residential and industrial sectors. Accurate forecasting of natural gas flows is crucial for maintaining gas supplies, transportation and network stability. The main goal of the work we present is to compute accurate forecast for zero gas flow for the 24 upcoming hours in order to support other forecasting methods and, furthermore, operational decisions. The proposed methodology for dealing with the problem of short-term natural gas flows forecasting in gas transmission networks for nodes with high percentage of zero flow hours is based on Nonlinear Autoregressive Neural Network with exogenous inputs (NARX). We used NARX neural network with 24 outputs which represent the prediction of 24 hours of gas flow. For exogenous inputs several different parameters were chosen based on a sensitivity analysis. The errors of forecast calculated as accuracy of predicting occurrence of zero flows one-day ahead shown to be on a very small level so we concluded the proposed methodology can be used for supporting other forecasting methods.

2 - Wind power forecasting using Gaussian process state-space models
Tobias Jung

Accurately forecasting the power generated by a wind farm at day-ahead and intraday timescales is the key problem owners and operators of wind farms face and necessary for trading, dispatch, but potentially also other, innovative applications such as offshore maintenance scheduling. As forecasts are directly used for decision-making (be it by a human or a machine), and bad decisions can lead to potentially large financial losses, “forecasting” has to provide a full view on how much power will be generated: being only provided with point-estimates is not desirable for a decision-maker as it does not inform about model uncertainty and hence allow a proper quantification of risk. Existing commercial solutions typically create forecasts for a site from a physical (i.e., meteorological) model, correct it by some black-box statistical method (e.g., a neural network), and add “uncertainty” by some ad-hoc scheme—and often more as an afterthought. To address these shortcomings, we develop a new approach based on a fully probabilistic model which connects pieces of information in a more transparent way and produces posterior distributions coming naturally from the model itself.

We consider the scenario where we want to forecast a single site over a horizon of up to 16 hours ahead. The target quantity, power produced, is formulated as a time-series object in a Bayesian state-space setting with exogenous information, where the underlying unobservable weather dynamics is modeled by a non-linear, non-parametric Gaussian process (e.g., [Frigola, 2015]). Inferring the posterior distribution is done via PGAS, a particle-based MCMC procedure. To perform inference, we consider variational (cf. [Frigola et al., 2014]) and reduced-rank (cf. [Svensson et al., 2016]) approximation.

WC-14
Wednesday, 13:30-15:00 - RVH|II
Analytics in Retail and Digital Commerce I

Stream: Business Analytics, Artificial Intelligence and Forecasting
Parallel session
Chair: Thomas Setzer

1 - Potential Benefits of User Rankings for Predictions of Book millennials
Nicole Rauss, Klaus Ambrosi

In Germany, the publication of new books is traditionally announced in spring and in autumn. Booksellers have to decide which books they want to order in which quantities up to six month before release. To ease the decision process, publishers usually send catalogues comprising information about the new releases as well as advance reading copies (ARCs) for some selected books. In addition, some catalogues might contain information about planned marketing actions. Apart from this, the booksellers need a lot of experience to calculate the right order quantity. Whereas for popular authors the booksellers can use historical purchasing data to estimate the demand, it can be difficult to predict the success of new authors due to a lack of evidence. Consumers tend to read reviews before they decide on buying a certain book. Today, this process of opinion making is often shaped by the impact of social media and other web platforms. For example, reviews can be found on websites of online shops, blogs, and book communities, and this content is also frequently created by the consumers themselves. Sometimes, such reviews are published prior to the official book release. Given this trend, the objective of our study is to answer the following research questions: 1) Do ratings in book communities have any impact on the ranking of a certain book? 2) Is there a correlation between the rankings in book communities and the official bestseller lists? 3) Can online book reviews be used to predict the success or ranking of certain books that are not yet released? To address these research questions, an analysis of given data in web 2.0 platforms will be performed and different data mining techniques will be used to find patterns and correlations.
2 - Customer segmentation and market basking analysis for an electronics retailer using machine learning and optimisation methods

Hlynur Stefánsson, Júlíus Péter Gudjohnson, Sigurður Jónsson, Eyjólfur Aegirsson

In this contribution, we work with data from an electronics retailer and use machine learning and optimisation methods to gain actionable insights. We present a method for customer segmentation using self-organising maps (SOM). The SOM algorithm maps a high dimensional input space (customer features) onto a low dimensional output space (2D map) using unsupervised competitive learning. The results provide insights into customer behaviour and can be used to improve customer service and marketing strategies. Furthermore, the results from the customer segmentation are used as input for mining for products with high cross-selling potential within each customer segment. Those results are used by an optimisation model to determine the optimal product selection in promotions. Identifying and promoting products with high cross-selling potential for specific customer segments can aid in increasing the average basket size of the retailer resulting in increased revenues. Taking cross-selling effects into account is essential when it comes to replenishment decisions and category-management decisions, such as promotions, discontinuing or expanding certain categories within the retailer as it gives a deeper insight into the interaction between categories and how they affect sales.

3 - Efficiency Analysis of Migros Retail Stores in Turkey Using Data Envelopment Analysis

Birol Yüceoğlu, İslı Oztürk, Murat Celebi

Data envelopment analysis (DEA) is frequently used in order to assess the performance of decision making units. In this study, we use DEA to analyze the efficiency of stores belonging to Migros Turkey, a leading fast-moving consumer goods retailer in Turkey. We consider more than 1000 stores that are grouped under four formats with different size and product assortment and analyze each store format independently. After employing exploratory data analysis in order to determine outlying stores, we answer two questions related to store efficiency. First, we use output-oriented DEA in order to determine efficient stores and stores that need to perform better. The use of output-oriented DEA allows us to determine best practices for inefficient stores by setting new performance input targets for a given output level. In other words, we try to increase the performance of stores by keeping inputs as constant as changing inputs in the short run is not easy. Second, we use input-oriented DEA in order to determine optimal characteristics of future stores. The use of input-oriented DEA allows us to determine optimal store characteristics based on the performance of existing stores.

WC-15

Wednesday, 13:30-15:00 - RBMj III

Advances in Modelling and Simulation Methodologies

Stream: Simulation and Statistical Modelling
Parallel session
Chair: Zhengyu Wang

1 - Galerkin Method for Dynamic Nash Equilibrium Problem with Shared Constraints
Zhengyu Wang, Stefan Wolfgang Pickl

The dynamic Nash equilibrium problem with shared constraints involves a decision process with multiple players, where each player solves an optimal control problem with his own cost function and strategy set, both dependent on the rivals’ control variables. Such a problem appears frequently in realistic applications like in traffic assignment with side constraints, the numerical solution for this problem is challenging and has attracted growing attention in Operations Research community.

In this talk we introduce a variational inequality reformulation of this dynamic Nash equilibrium problem, which presents the dynamic and the equilibrium nature of the problem in a systematic way. This reformulation is advantageous since the variational inequality has been intensively studied and abundant theory is available. In addition, we propose a new numerical method by combining the exponential integrator and the discontinuous Galerkin approximation. Numerical experiment is performed for the traffic assignment problems, and the numerical results are reported for supporting our theoretical arguments and illustrating the good numerical performance of the proposed method.

2 - Hybrid Agent-Based Modeling (HABM) - A Formalism for Combining Agent-Based Modeling and Simulation, Discrete Event Simulation, and System Dynamics

Joachim Block

There is a growing interest within the operations research (OR) community in mixing different methods to form new kinds of optimization algorithms. Such hybrid algorithms offer a promising way for addressing real world problems that cannot be sufficiently solved by using single method approaches.

Very similar, some scholars argue that hybrid simulation could be a mean to support the decision making process for hard management problems. Hard problems are to a great extent dominated by intuition or judgement and hybrid simulation could contribute to more realistic models and, hence, result in better decisions. Despite considerable recent advances in coupling different modeling paradigms such as agent-based modeling and simulation, discrete event simulation (DES), and system dynamics (SD) research on hybrid modeling seems still to be in its infancy.

We present a modeling formalism intended to specify hybrid agent-based models (HABM) with elements from DES and SD. Basic idea is that agents not only exhibit discrete but also continuous behavior. Furthermore, the formalism has the capability to consider dynamic structures. Structural dynamics such as changing relations between agents as time passes by are an important property of agent-based models. The modeling formalism is founded on and extends the well established Discrete Event System Specification (DEV'S).

We have used the formalism to support the decision making process in a strategic workforce planning context. However, HABM can also be applied to other OR fields such as supply chain networks simulation or even for the specification of agent-based meta-heuristic.

3 - Regulating the degree of conservatism: An error flexible single step approach to multiple testing

Christina Bartenschlager, Jens Brunner

Multiple testing concepts for testing more than one null hypothesis based upon the same data set become more and more sophisticated and at the same time users become more and more deterred. For instance, when deciding on at least 55 multiple testing procedures the user at first has to decide on eight multiple α-error definitions, which guarantee different degrees of conservatism regarding the rejection of null hypotheses. This situation results in neglecting multiple testing in empirical research and thus an impairment of the reliability of research findings: α-errors can inflate significantly with the number of tested null hypotheses by employing a series of conventional tests. We present a new application-oriented multiple method that is able to outline different multiple α-error definitions at the same time by mixing the intuitive multiple Bonferroni correction and well-known conventional tests. Simulation studies show that this results in a significantly better performance than existing comparable procedures. Thus, our new method transforms the two-stage decision on multiple α-error definitions and multiple tests to a one-stage decision on the multiple α-error definition. In addition, our method is the first one that is able to control the False Discovery Rate, i.e. one multiple α-error definition, by a single step concept.

WC-16

Wednesday, 13:30-15:00 - RBMj I 102

Finance II

Stream: Finance
Parallel session
Chair: Michael H. Breitner

1 - A Generalization for the Duration concepts
Marius Rademacher
Duration concepts are standard methods for measuring interest rate risks of portfolios. Macaulay duration, effective duration and Key-Rate duration are mostly used according to different types of yield curves. In this lecture, a generalization of the duration concept is presented, by using multi-dimensional Taylor series development. It allows to measure the interest rate risk based on variable yield curves (variable forward rates). They even can be negative. The standard duration concepts turn out to be special cases within this approach. For actuarial purposes, it also allows to measure the mortality risk.

2 - Enhancing the wisdom of the crowd - evidence from social trading
Christopher Helm, Martin Rohleder

We propose a novel crowd aggregation approach, which considers the past returns and experience of crowd members, while maintaining the diversity of opinions provided by all members of the crowd. We test our "crowd ensemble" alongside alternative crowd approaches on a unique and comprehensive dataset of 12,144 social trading portfolios. These "wikifolios" publish all of their individual trading decisions on the platform wikifolio.com. The data covers over 2.5 million trades between 2012 and 2015. From such trades, we derive daily portfolio holdings and use the resulting portfolio weights as asset allocation signals, weighted based on the wikifolio's past return, which also serves as a proxy of traders’ experience and learning progression. Our results indicate that compared to a market cap weighted market portfolio, crowd aggregations provide superior risk-adjusted returns according to the Carhart (1997) model. However, a detailed risk factor loadings analysis additionally shows that alternative crowds suffer from behavioral biases. Young and inexperienced wikifolios are generally less diversified and more exposed to sudden returns. We hypothesize that newly created wikifolios try to stand out from their counterparts and provide a unique, recognizable profile to attract followers, similar to the phenomenon of "mutual fund incubation". Conversely, the crowd ensemble does not display any remarkable factor loadings on any risk factors except the market. Overall, our results provide valuable new insights into the behavior of individual investors. Moreover, the crowd ensemble is not restricted to stock portfolio decisions or finance in general but may be applied to many other non-mutually exclusive decisions between alternatives.

3 - Improving the recovery rate of unsecured debt in multistep workout processes
Johannes Kriebel, Kevin Yam

Forecasting recovery rates is usually mainly concerned with the prediction of a customer’s capacity to repay defaulted debt given a set of contract, demographic and macroeconomic information. In this paper, we suggest a model to determine workout strategies given the stylized fact that debtors react differently to weaker and stronger workout actions (e.g. mail contact, phone contact, legal proceedings). Debtors are ceteris paribus more likely to pay when faced with stronger workout actions but stronger workout actions tend to be more costly for the creditor. There is therefore a need to find optimal workout strategies for the creditor. We suggest a regression model in which the creditworthiness of a debtor is a linear combination of debtor characteristics. The reaction towards workout actions is incorporated by using skewed error terms that make payments more likely for strong workout measures and less likely for weak workout measures. We outline that newly created wikifolios try to stand out from their counterparts and provide a unique, recognizable profile to attract followers, similar to the phenomenon of "mutual fund incubation". Conversely, the crowd ensemble does not display any remarkable factor loadings on any risk factors except the market. Overall, our results provide valuable new insights into the behavior of individual investors. Moreover, the crowd ensemble is not restricted to stock portfolio decisions or finance in general but may be applied to many other non-mutually exclusive decisions between alternatives.}

1 - Duty Rostering for Physicians at a Department of Orthopedics and Trauma Surgery
Clemens Thienlen

Duty rostering for nurses and physicians is an important task within personnel planning in hospitals and has a large impact both on the efficiency operation of the hospital and on employee satisfaction. Creating duty rosters for physicians is particularly challenging due to complex constraints (resulting, e.g., from minimum rest times and physician preferences) that should be satisfied by a "good" roster. In larger departments, these constraints cannot be handled adequately when generating duty rosters manually. This motivates us to propose a mathematical optimization model in order to generate duty rosters for physicians that satisfy all arising constraints and at the same time allow an efficient operation of the department.

We present an integer programming model for the generation of duty rosters for physicians at a large department of orthopedics and trauma surgery that is used in practice since January 2016. Besides the specific constraints that need to be respected, we also model possible work schedules for trainees and estimate the optimal number of trainees in the system. The complexity of apprenticeships is rising in highly technological industries. As a consequence, traineeships are not only time-related but task-related. In an apprenticeship, trainees have to pass several departments of a company in a specific time. Predicting the exact number of procedures that a trainee can perform in these periods is always possible. Accordingly, a trainee might not be able to perform all of the needed procedures resulting in an extension of the apprenticeship. To alleviate this reliability problem, we introduce a trainee's profile that is used to model the behavior of individual trainees. On the one hand, they have to make efforts to get the best candidates for their programs. On the other hand, they need to stay cost-efficient concerning their personnel planning. A good quality, systematic and scope of trainee programs is a possible opportunity to respect both sides. A cyclic model is presented that is able to reduce the number of trainees for trainees individually for each trainee and also to estimate the optimal number of trainees in the system. In addition to that, the new solution gives an employment policy for the organization. Since the compact formulation is not able to find solutions fast, a Dantzig-Wolfe Decomposition is used to accelerate the solution process. A pattern generation approach that is able to construct multiple patterns out of one solution is exposed for cyclic problems. The termination of column generation can be accelerated significantly by this approach. The model is evaluated by a real world case of a resident program in a German hospital and tested in a computational study where different parameter settings. The results can be used to reduce costs and ensure service quality even in case of departmental change of the trainees.

2 - Robust Cyclic Apprenticeship Scheduling with an Application in Resident Scheduling
Sebastian Kraul, Jens Brunner

The complexity of apprenticeships is rising in highly technological industries. As a consequence, traineeships are not only time-related but task-related. In an apprenticeship, trainees have to pass several departments of a company in a specific time. Predicting the exact number of procedures that a trainee can perform in these periods is always possible. Accordingly, a trainee might not be able to perform all of the needed procedures resulting in an extension of the apprenticeship. To alleviate this reliability problem, we introduce a trainee's profile that is used to model the behavior of individual trainees. On the one hand, they have to make efforts to get the best candidates for their programs. On the other hand, they need to stay cost-efficient concerning their personnel planning. A good quality, systematic and scope of trainee programs is a possible opportunity to respect both sides. A cyclic model is presented that is able to reduce the number of trainees for trainees individually for each trainee and also to estimate the optimal number of trainees in the system. In addition to that, the new solution gives an employment policy for the organization. Since the compact formulation is not able to find solutions fast, a Dantzig-Wolfe Decomposition is used to accelerate the solution process. A pattern generation approach that is able to construct multiple patterns out of one solution is exposed for cyclic problems. The termination of column generation can be accelerated significantly by this approach. The model is evaluated by a real world case of a resident program in a German hospital and tested in a computational study where different parameter settings. The results can be used to reduce costs and ensure service quality even in case of departmental change of the trainees.

3 - A Column Generation Approach to Flexible Nurse Scheduling
Jan Schoenfelder, Markus Seizinger

We model a hospital’s scheduling decisions for (partially) cross-trained nurses under uncertain demand. While we approximate the true demand distribution by formulating a deterministic equivalent formulation, we are able to incorporate a refined set of possible demand realizations by employing a column generation approach. Based on data collected from three hospitals, we derive insights into the potential benefit that may or may not be gained from employing cross-trained nurses. Furthermore, we analyze the schedule improvements that result from incorporating possible nurse reassignments into the initial scheduling decisions.
1 - Runway Scheduling under Consideration of Winter Operations
Maximilian Pohl, Rainer Kolisch
We address the problem of scheduling incoming and departing aircraft on multiple runways under consideration of snow removal and runway de-icing during winter operations. Since this problem has not been addressed so far in the literature, we are presenting a mixed-integer program (MIP) with the objective of minimizing the weighted earliness and lateness of scheduled starting and landing times. We report about solving small to medium real-world instances from Franz Josef Strauß airport in Munich. Since larger instances cannot be solved to optimality, we will also be discussing heuristic approaches.

2 - Explicit modelling of multiple intervals in a constraint generation procedure for multiprocessor scheduling
Emil Karlsson, Elina Rönningen
Multiprocessor scheduling is a well studied NP-hard optimisation problem that is of interest in a variety of applications. The focus of this paper is explicit modelling of tasks with multiple intervals. This work extends a constraint generation procedure previously developed for avionics scheduling and we here address a relaxation of the problem that can be considered as a multiprocessor scheduling problem with dependencies and chains. A dependency restricts the time from one task instance to another and a chain prescribe that task instances execute in a specified order.

The explicit modelling of tasks with multiple intervals facilitates the introduction of valid inequalities to strengthen the model formulation used in the constraint generation procedure. We illustrate the computational effect of the formulation on instances that are relevant in an avionics context since these instances lend themselves to such a formulation.

3 - Scheduling jobs and maintenance activities subject to job-dependent machine deteriorations
Liliana Grigoriu, Dirk Briskorn
We consider machine scheduling that integrates machine deterioration caused by jobs by also scheduling maintenance activities. The maintenance state of the machine is represented by a maintenance level which drops by a certain, possibly job-dependent, amount while jobs are processed. A maintenance level of less than zero is associated with the machine’s breakdown and is therefore forbidden. Hence, maintenance activities that raise the maintenance level may become necessary and have to be scheduled additionally. We consider the objective to minimize the makespan throughout the paper. For the single machine case, we provide a linear-time approximation algorithm with worst-case a bound of $\frac{5}{4}$, and comment on how an FPTAS from previous literature can be employed to apply to our problem. Due to problem similarity, these results also apply to the minimum subset sum problem, and the $\frac{5}{4}$ linear-time approximation algorithm is an improvement over the $\frac{5}{4}$ quadratic-time approximation algorithm of Güntzer and Jungnickel. For the general problem with multiple machines, we provide approximability results, two fast heuristics, an approximation algorithm with an instance-dependent approximation factor, and a computational study evaluating the heuristics. For integers $k$ that are greater than 5 we present $(k+1)/k$ linear-time approximation algorithms for minimum subset sum (assuming that $k$ is constant) that were developed using the ideas that led to the $\frac{5}{4}$ approximation algorithm.

4 - Preemptive scheduling of jobs with a learning effect on two parallel machines
Marcin Zurowski
Scheduling problems with variable job processing times occur very often in practice. For example, the variable processing times of jobs may depend on the starting times or positions of the jobs in schedule. One of the more popular models of variable job processing times is the model of scheduling jobs with a learning effect. In this model, the variable processing time of each job is the product of the job basic processing time and the value of a non-increasing function of the job position in schedule. The range of applications of the model, however, is limited by the fact that one assumes that jobs are non-preemptable. In the presentation, we consider a problem of preemptive scheduling of jobs with a learning effect. In the problem, a set of independent and preemptable jobs has to be scheduled on two parallel identical machines. The optimality criterion is the maximum completion time. We show by examples that applying the definition of preemptability known in the classical scheduling theory leads to some anomalies. Based on analysis of these examples, we introduce a new definition of job preemptability. Finally, we prove some properties of our problem and propose an exact algorithm for finding an optimal schedule.

WC-20
Wednesday, 13:30-15:00 - RBM|4403
Stream: Supply Chain Management
Chair: Christopher Grob
1 - Optimal Randomized Ordering Policies for a Capacitated Two-Echelon Distribution Inventory System
Tahir Ahmadi
We propose a new formulation for controlling inventory in a two-echelon distribution system consisting of one warehouse and multiple non-identical retailers. In such a system, customer demand occurs at the retailers and propagates backward through the system. The warehouse and the retailers have a limited capacity for keeping inventory and if they are not able to fulfill the demand immediately, the demand will be lost. All the locations review their inventory periodically and replenish their inventory spontaneously based on a periodic randomized ordering (RO) policy. The RO policy determines order quantity of each location at each period by a fraction of safety stocks, when stages quote guaranteed service times. Safety stocks depend on the quoted service times between stages and the production cycle time (PCT) of each stage. Each stage can use overtime to increase production capacity and mitigate PCT variability. We formulate, analyze, and solve the problem of jointly optimizing overtime planning and safety stock placement with the objective of minimizing production and inventory costs while satisfying a target service level. Extensive numerical experiments show the efficiency of the proposed solution procedure and characterize the effect of various parameters on basic trade-offs between production and inventory costs.
2 - Window Fill Rate with Compound Arrival and Assembly Time
Michael Dreyfuss

Exchangeable-item repair systems are inventory systems in which customers receive operable items in exchange of the failed items they brought. The failed items are not discarded, but instead, they are repaired on site. We consider such a system in which failed item arrival follows a Compound Poisson process and in which assembly and disassembly times of the items is nonzero. For this system we develop exact formulas for the window fill rate, that is, the probability that customers receive service within a specific time window. This service measure is appropriate in situations that customers tolerate a certain delay and therefore the system does not incur reputations costs if it completes service within this time window.

3 - A solution procedure for joint optimization of reorder points in n-level distribution networks using (R,Q) order policies
Christopher Grob, Andreas Bley, Konrad Schade

We present an algorithm to minimize the investment in stock in an n-level inventory distribution network with stochastic demands and wait times using a (R,Q) policy. Our research is motivated by the inventory planning for a worldwide spare parts supply chain of a big automotive company. The algorithm is fast enough to be used in real world applications. It is, to our knowledge, the first one to determine reorder points for inventory distribution systems using complex wait time approximations. In a previous work, we determined optimal reorder points for a 2-level network, which cannot easily be extended to n-levels. The service constraints included in these models are nonlinear and can be evaluated only using a time-consuming binary search. Our work uses the wait time approximations by Kiesmüller et al. Service constraints only apply at local warehouses, i.e., the last level of the network where customer demand is fulfilled. To cope with these challenges, we reformulate the original non-linear constraints by piecewise linear functions by strictly overestimating the effect of a stocking decision at non-local warehouses on local-warehouses and we create constraints that trade-off stocking decision between all non-local warehouses. We iteratively solve the resulting integer program and refine the piecewise linear functions adaptively during the execution of the algorithm. In each iteration we are able to evaluate the quality of the solution and can terminate the algorithm when the optimality gap is as small as required.

WC-21
Wednesday, 13:30-15:00 - RBM4404
Optimization of Technical Systems
Stream: OR in Engineering
Parallel session
Chair: Lena Charlotte Altherr

1 - Energy efficient design of a decentralized fluid system by mixed integer nonlinear programming
Philipp Leise, Lena Charlotte Altherr, Peter Pelz

Energy efficiency of technical systems has become more and more important in recent times. Based on governmental energy efficiency regulations and environmental protection rules, the systematic design of technical systems is a key factor to improve the whole systems’ efficiency. Once the components’ interaction is taken into account, further potential for optimization opens up. An approach for the systematic design of technical systems was developed at the Chair of Fluid Systems at TU Darmstadt. With “Technical Operations Research” (TOR) it is possible to ensure a global optimal layout and operation strategy of technical systems. With this work, we show the practical usage of this approach for the systematic design of a decentralized water supply system for skyscrapers. At the beginning, a construction kit of multipurpose objects is provided and available for combination by designers. The AMS drag design is configured as a Mixed-Integer Nonlinear Program to support the human designer during the multiple layout decisions. To model all possible network options of the water supply system in skyscrapers, tree structured graphs are used. Binary variables are introduced to model the selection of different components at different levels in the building. Additional binary variables are introduced to model the operation strategy in the different load cases (turn pumps on or off). Since the characteristic curves of the pumps in the construction kit are nonlinear, this leads to a Mixed Integer Nonlinear Program (MINLP). We model the MINLP in the framework JuMP and solve it with SCIP. We show the best layout option and operation strategy found by our approach and compare the energy savings with a conventional system design.

2 - Product Family Design Optimization using Model Based Engineering Techniques
David Steinger, Tankred Mueller, Lena Charlotte Altherr, Peter Pelz

Highly competitive markets paired with great production volumes demand particularly cost efficient products. The usage of common parts and modules across product systems can potentially reduce production costs through economy of scale. Yet, increasing commonality may result in overdesign of the individual products. Thus, product families as a whole instead of individual products need to be optimized for minimal overall costs. Multi-domain virtual prototyping enables designers to evaluate cost and technical feasibility of different single product designs at reasonable cost. However, multidimensional parameter spaces combined with product families consisting of many products make the optimization of the whole product family a challenging task. Additionally, savings by platform commonality are hard to quantify and require detailed knowledge of the production process and the supply chain. Therefore, we present a multi-objective metamodeling-based optimization algorithm which enables designers to explore the trade-off between platform commonality and cost optimal design of the single products in an industrial setting. The method is demonstrated on a mechatronic drive system product family.

3 - How Do Structural Designs Affect the Economic Viability of Offshore Wind Turbines? An Interdisciplinary Simulation Approach
Clemens Huybler, Jan-Hendrik Piel, Raimund Rolles, Michael H. Breitner

Offshore wind energy is a seminal technology to achieve the goals set for the deployment of renewable energies. However, offshore wind energy projects are today not yet sufficiently competitive to be realized without financial support mechanisms. Consequently, the optimization of offshore wind turbine substructures with regard to costs and reliability is a promising approach to increase cost-efficiency and competitiveness. Interdisciplinary optimization concepts considering sophisticated engineering models and their complex economic effects are rare and, in general, deterministic. We address this research gap by combining an aero-elastic wind turbine model, being capable to estimate costs and stochastic lifetimes of substructure designs, with an economic viability model for Value-at-Risk analyses of investments in offshore wind energy projects. By means of our modelling approach, we investigate the impact of the three different substructure designs on the profitability and financial viability of a simulated offshore wind energy project. We differentiate the substructures with regard to diameters and wall thicknesses of legs and braces and create a classical, a conservative, and a risky design. For each substructure, our aero-elastic wind turbine model yields an own fatigue lifetime distribution and different total costs due to changing masses, welding and coating costs, which we then apply in our economic viability model. Our results indicate that the effect of the initial cost differences slightly exceeds the effect of the differences in the stochastic lifetime on the competitiveness of the simulated project.

WC-22
Wednesday, 13:30-15:00 - HFB1 A
MCDM 1: Complexity and Special Techniques
Stream: Decision Theory and Multiple Criteria Decision Making
Parallel session
Chair: Kathrin Klamroth
1 - The Multiobjective Shortest Path Problem is NP-hard, or is it? Fritz Bökler

To show that multiobjective optimization problems like the multiobjective shortest path or assignment problems are hard, we often use the theory of NP-hardness. In this talk we rigorously investigate the complexity status of some well-known multiobjective optimization problems and ask the question if these problems really are NP-hard. It turns out, that most of them do not seem to be and for one we prove that if it is NP-hard then this would imply P = NP under assumptions from the literature. We also reason why NP-hardness might not be well suited for investigating the complexity status of intractable multiobjective optimization problems.

2 - Optimization of Bio-Objective TSP
Thomas Stidsen, Kim Allan Andersen, Kim Allan Andersen

A large number of the real world planning problems which are today solved using Operations Research methods are actually multi-objective planning problems, but most of them are solved using single-objective methods. The reason for converting, i.e. simplifying, multi-objective problems to single-objective problems is that no standard multi-objective solvers exist and specialized algorithms need to be programmed from scratch. Over the last decades two different approaches to solve, to optimality, Multi-Objective Mixed Integer Programming (MOMIP) models has emerged: Criterion space approaches and decision space approaches. Criterion space approaches iteratively solves a number of single-objective MIP’s. Decision space approaches extend the classic Branch & Bound algorithm to handle more than one objective.

In this article we will present a hybrid approach, which both operate in decision space and in objective space. The classic Branch & Bound algorithm is extended to handle two objectives, i.e. specialized bounding and branching methods are utilized. Furthermore a criterion-space based parallelization is performed, enabling simple massive parallelization, since no communication between the processes is necessary. This Branch & Bound (Cut) approach can be used for a wide variety of bi-objective Mixed Integer Programming models. We test the approach on the biobjective extension of the classic traveling salesman problem, on the standard dataset, and determine for the full set of nondominated points for 100 city problems. The found exact Pareto fronts have a size between 1900 and 3300 points, i.e. tours.

3 - Multiobjective optimization for complex systems
Kathrin Klamroth, Stefan Ruzika, Margaret Wieck

We consider complex systems that are composed of two subsystems with single or multiple objectives. Their complexity is reflected, among others, in the fact that direct solution approaches are available only at the subproblem level and not at the level of the entire system. In practical applications, these subsystems model, for example, different parts or aspects of an overall system. Such subsystems often have interactions with each other and are usually not sequentially ordered or obviously decomposable. Thus, the individual solutions of subsystems do not generally induce a solution for the overall system. We discuss this subsystem and system feasibility and suggest different notions of optimality for complex systems with two interacting subsystems. Solution concepts are discussed in the light of recent developments in this field.

1 - Stable Clusterings and the Cones of Outer Normals
Felix Happach

We consider polytopes that arise in the cluster analysis of a finite set of data points. These polytopes encode all possible clusterings and their vertices correspond to clusterings that admit a power diagram, which is a polyhedral separation of the underlying space in which each cluster has its own cell. We study the edges of these polytopes and show that they encode cyclical transfers of elements between clusters. We use this characterization to obtain a relation between power diagrams and the volume of the cones of outer normals of the respective clustering. This allows us to derive a new stability criterion for clusterings, which can be used to measure the dependability of the clustering for decision-making. Further, the results explain why many popular clustering algorithms work so well in practice.

2 - Solving the Time-Dependent Shortest Path Problem on Airway Networks Using Super-Optimal Wind
Adam Schienle

We study the Horizontal Flight Trajectory Optimisation Problem (HFTOP), where one has to find a cost-minimal aircraft trajectory between to airports s, t on the Airway Network, a directed graph. We distinguish three cases: a static one where no wind is blowing, and two cases where we regard wind as a function of time. This allows us to model HFTOP as a Shortest Path Problem in the latter cases. Then we observe how the exit of any member state from the union affects the power distribution of the member states within the EU. From the impacts of a possible leaving we inspect one factor: how the power distribution changes in the Council of the European Union. Because the Treaty of Lisbon specified the decision-making to the number of member states and the population, an exit of a member state does not invoke the renegotiation of the voting weight system. Using the Shapley-Shubik power index, we calculated the power of the member states both with and without the member who might leave the union. Because the actual budget changes in case a member state leaves the union, we adjusted the new power indexes with the change in the budget caused by the leaving of the member state. We found a pattern connected to a change of the threshold of the required member states and the change in power distribution. An exit which causes a change to the member state threshold of the Council of the European Union benefits large, an exit which does not cause such a change benefits small member states.
In the time-dependent version, we study two different modelling approaches. Firstly, we compute the exact costs for the time on the arcs. In a second version, we use piecewise linear functions as the travel time. For both versions, we design problem-specific potential functions for the A* algorithm. As the exact costs are non-linear, we introduce the notion of Super-Optimal Wind to underestimate the travel time on the arcs, and show that Super-Optimal Wind yields a good underestimation in theory and an excellent approximation in practice. Moreover, we compare the runtimes of the time dependent versions of Dijkstra’s Algorithm, A* and Time-dependent Contraction Hierarchies (TCHs) in the PWL case, showing that A* outperforms Dijkstra’s Algorithm by a factor of 25 and TCHs by a factor of more than 16.

For the exact case, we compare Dijkstra’s Algorithm to A* and show that using Super-Optimal Wind to guide the search leads to an average speedup of 20.

3 - The two dimensional bin packing problem with side constraints
Markus Seizinger

We propose a new variant of Bin Packing Problem, where rectangular items of different types need to be placed on a two-dimensional surface. This new problem type is denoted as two-dimensional Bin Packing with side constraints. Each bin may consist of different two-dimensional layers, and items of different types may not overlap on different layers of the same bin. By different parameter settings, our model may be reduced to either a two- or three-dimensional Bin Packing Problem. We propose practical applications of this problem in production and logistics. We further introduce lower bounds, and heuristics for upper bounds. We can demonstrate for a variety of instance classes proposed in literature that the GAP between those bounds is rather low. Additionally, we introduce a Column-Generation based algorithm that is able to further improve the lower bounds and comes up with good solutions. For a total of 400 instances, extended from previous literature, the final relative gap was just 6.8%.

1 - Benefits and Limitations of Simplified Transient Gas Flow Formulations
Felix Hennings, Tom Streube

The mathematics of gas transportation networks have been much studied in recent years. However, the optimization of the time-dependent transient control of large real world networks is still out of reach for current state-of-the-art approaches. Due to this, we investigate further simplifications of the model constraints describing the gas network elements. We aim at significantly reducing the problem complexity while preserving a good approximation of the more complex element behavior.

2 - The Value of Diversified Infrastructure in the European Natural Gas Market Using Chance Constrained Programming
Philipp Hauser

The ongoing transformation of the energy system in Germany and Europe aims to reduce CO2-emissions. Against this background, the role of gas in the energy mix and the need of investment in gas infrastructure in the next decades is unclear. In gas markets, uncertainties occur in three different dimensions. Firstly on the demand side, where in the electricity sector gas power plants provide flexibility with lower emissions than lignite or coal power plants. However, gas power plants currently suffer from low capacity factors and thus the future level of gas demand in this sector is unclear. Secondly, uncertainties raise on the supply side, where decreasing Europe-an gas production in western Europe enhance the market position of non-European suppliers as Russia or Qatar and simultaneously increase the European dependence on supplies of these countries. Finally, uncertainties grow on the transmission side, where Russia tries to build new transmission routes to Europe e.g. Nord Stream II and Turkish Stream. These activities change supply structures in Europe and increase European dependence on transfer countries. According to these challenges, this paper will focus on uncertainties on the supply and transmission side. As the overall goal of energy policy is to ensure security of supply, the question of diversification in both, gas suppliers and transmission ways, gains in importance. Therefore, the objective is to calculate the value of diversified infrastructures using an extended version of the linear optimization model Gas market model (GAMAMOD). An application of the chance con-strained programming approach will be introduced in order to evaluate total system costs of different infrastructure scenarios by taking uncertainties of supply interruptions into account.

Automated Negotiations in Logistics (i)
Stream: Game Theory and Experimental Economics
Parallel session
Chair: Tobias Buerc

1 - Improving a Genetic Algorithm-based Mechanism for Allocating Requests in Transport Coalitions
Jonathan Jacob, Tobias Buerc

The allocation of transportation requests in coalitions of freight carriers is an area of growing interest. The main challenge in that field of research is to reconcile the conflicting goals of maximizing the coalition’s profits, restricting information shared between the carriers, and allocating surplus profits. We examine a number of improvements to an existing mechanism for solving the transportation request assignment problem (TRAP), where a pool of pickup-and-delivery requests with profits gets partitioned between the members of a transport coalition. In this mechanism, request allocations are encoded as arrays of integer numbers which are used as chromosomes of a genetic algorithm (GA). The members of the coalition place bids on each chromosome, the sum of which is used as the fitness function of the GA. This way, as opposed to most existing approaches, no direct information about the carriers’ valuations of single requests or routes is disclosed to the coalition. The surplus profit generated is distributed evenly between the carriers. The improvements to our mechanism for solving the TRAP we examine comprise the introduction of a geographical component into the set-up of the initial population of the GA, as well as the analysis of different selection, crossover, and mutation operators. We run tests of our mechanism with different parameter settings regarding these improvements and compare their results with each other and the results obtained through centralized planning.

2 - A combinatorial double auction for exchanging empty marine containers
Tobias Buerc

For many regions in the world, the volume of imported and exported goods is imbalanced. Consequently, in seaborne trade the supply and demand of empty containers is imbalanced, too. This creates the need for repositioning of empty containers. The costs of repositioning empty containers could be reduced if the involved ocean carriers would or could cooperate more intensively. However, in many situations sharing the necessary data among competing carriers is not an option due to privacy concerns. Therefore, in order to balance supply and demand of empty containers we propose an exchange mechanism based on a double auction. Market players may be all organisations which supply or demand empty containers, in particular (but not limited to) carriers. In the proposed auction, the bidders buy and sell the right to use a number of empty containers at a specific location on a certain day defined by their bids. A bidder may combine multiple individual bids into a bundle bid. Bundle bidding avoids the exposure problem. By means of bundle bidding, a bidder is able to construct a transport network which is more balanced with respect to supply and demand of empty containers. In order to support the auctioneer of such a double auction we propose and study a model for the winner determination problem of a multi-period empty container exchange mechanism with bundle bidding. The impact of different objective functions on the clearing of the auction is studied by means of computational experiments.
3 - Agent-driven versus mediator-driven contract proposal in automated negotiations
Gabriel Franz Guckenbiehl, Tobias Buer

Automated negotiation mechanisms (ANMs) are used to negotiate well-structured and complex contracts. Complex contracts are used, for example, to align suppliers in a supply chain. Negotiations among multiple agents easily get stuck in a local optimum because the agents block each others proposals. Many negotiation mechanism are mediator-driven, i.e., they assume a new contract proposal is generated by a neutral mediator. However, as the agents are not willing to disclose private information about their utility functions, the search process of the mediator is uninformed. Therefore, mediator-based ANMs usually use randomized contract proposal mechanisms. This preserves private information of the agents but may extend the negotiation process considerably.

A way to overcome this deficit may be to allow agents to propose their own contracts. As agents propose contracts, each new proposal benefits at least one agent. In contrast, in mediator-driven negotiations many contracts proposed by the (uninformed) mediator may not be improving at all. On the other hand, agent-driven negotiations may get stuck in local optima even faster and, therefore, result in inferior contracts. In these agent-driven negotiations the performance depends, among others, on the sequence in which the agents are allowed to propose new contracts. We study the impact of three different sequences (random, static, result-dependent) on the performance of four ANMs: greedy, greedy with compensation payments, simulated annealing, and simulated annealing with compensation payments. Based on computational results we provide insights on the performance of mediator-driven versus agent-driven automated negotiation mechanisms.

Wednesday, 15:30-16:15

■ WD-01
Wednesday, 15:30-16:15 - WGS\101
Cancelled: Semi-Plenary Panos M. Pardalos
Stream: Semi-Plenaries
Semi-plenary session
Chair: Stefan Wolfgang Pickl

■ WD-22
Wednesday, 15:30-16:15 - HFB\A
Presentation by the GOR Science Award Winner
Stream: Semi-Plenaries
Semi-plenary session
Chair: Karl Inderfurth

1 - Presentation by the GOR Science Award Winner
(Name: to be announced!)
Karl Inderfurth

The GOR Science Award is the most prestigious prize awarded by the German OR society. In this semi-plenary session, this year’s GOR Science Award winner will present an overview of his research. The winner will be announced at the conference opening plenary session.

■ WD-23
Wednesday, 15:30-16:15 - HFB\B
Semi-Plenary Dirk Christian Mattfeld
Stream: Semi-Plenaries
Semi-plenary session
Chair: Jan Fabian Ehmke

1 - Models and Optimization in Shared Mobility Systems
Dirk Christian Mattfeld

IT-based processes have fostered the rise of shared mobility business models in recent years. In order to play a major role in people’s future transportation, reliable shared mobility services have to be ensured. The availability of a shared vehicle at the point in time and location of spontaneously arising customer demand is recognized as requirement to replace individual vehicle ownership in the long term. Methodological support for shared mobility systems can draw on operations research models originally developed in the field of logistics. We give an overview on optimization models with regard to network design, transportation, inventory, routing, pricing and maintenance that have been adopted to operational support of shared mobility systems. For instance, the problem of relocating bikes over time in a station-based bike sharing system can be formulated as service network design problem. We show that next to the coverage of routing, the problem formulation incorporates inventory and transportation decisions. The fact that the number of bikes is kept constant over time is depicted by asset management constraints. A matheuristic is proposed to solve this problem to near optimality. Tailored techniques are to be developed in order to cope with these complex problems.
WD-24

Semi-Plenary Marco Lübbecke

Stream: Semi-Plenaries
Semiplenary session
Chair: Thorsten Koch

1 - Optimization meets Machine Learning
Marco Lübbecke

Optimization, as a way to make "best sense of data" is a common topic and core area in operations research (OR), in theory and applications. Machine learning, being rather on the predictive than on the prescriptive side of analytics, is not so well known in the OR community. Yet, machine learning techniques are indispensable for example in big data applications. We start with sketching some basic concepts in supervised learning and mathematical optimization (in particular integer programming). In machine learning, many optimization problems arise, and there are some suggestions in the literature to address them with techniques from OR. More importantly, we are interested in the reverse direction: where (and how) can machine learning help in improving methods for solving optimization problems and what is it that we can actually learn? We conclude with an alternative view on this presentation's title, namely opportunities where predictive meets prescriptive analytics.

WD-25

Semi-Plenary Martin Bichler

Stream: Semi-Plenaries
Semiplenary session
Chair: Andreas Fink

1 - Market Design: A Linear Programming Approach
Martin Bichler

Market design uses economic theory, mathematical optimization, experiments, and empirical analysis to design market rules and institutions. Fundamentally, it asks how scarce resources should be allocated and how the design of the rules and regulations of a market affects the functioning and outcomes of that market. Operations Research has long dealt with resource allocation problems, but typically from the point of view of a single decision maker. In contrast, Microeconomics focused on strategic interactions of multiple decision makers. While early contributions to auction theory model single-object auctions, much recent theory in the design of multi-object auctions draws on linear and integer linear programming combined with game-theoretical solution concepts and principles from mechanism design. This led to interesting developments in theory and practical market designs. The talk will first introduce a number of market design applications and show how discrete optimization is used for allocation and payment rules. These markets include industrial procurement, the sale of spectrum licenses, as well as cap-and-trade systems. In addition, we survey a number of theoretical developments and the role of integer and linear programming in recent models and market designs. Models of ascending multi-object auctions and approximation mechanisms will serve as examples. Finally, we will discuss limitations of existing models and research challenges. Some of these challenges arise from traditional assumptions about utility functions and social choice functions, which often do not hold in multi-object markets in the field. For example, financial constraints of bidders have long been ignored in theory, but they are almost always an issue in the field. Such deviations from standard assumptions lead to interesting theoretical questions, but also to very tangible problems in the design of markets.

Wednesday, 16:30-18:00

WE-01

Robust Combinatorial Optimization

Stream: Optimization under Uncertainty
Parallel session
Chair: Sven Krumke

1 - A Robust Approach to Single-Allocation Hub Location Problems with Uncertain Weights.
Jannis Kurtz

The idea of min-max-min robustness is to calculate different solutions of a linear combinatorial problem such that these solutions are worst-case optimal if we consider the respective best of the calculate solutions in each scenario. This idea can be modeled as a min-max-min problem and improves the classical min-max approach. We extend the idea of min-max-min robustness to quadratic combinatorial problems and apply it to single-allocation hub location problems with uncertain weights.

2 - Strategic and operational ressource planning for emergency doctors
Manuel Streicher, Sven Krumke, Eva Schmidt

The german emergency system is based on doctors being send out in certain specified cases, determined by a classification of different emergencies. This is in contrast to systems in other countries, where for instance paramedics handle almost all emergency cases. Emergency doctors are a costly resource and maximizing the coverage and minimizing the cost are two conflicting goals. Both, locating doctors and assigning them to cases need to be planned in a way that important constraints, such as a maximal response time can be guaranteed for a given quantile of the cases. In order to ensure a good performance of the whole system, good decisions have to be taken on a strategic as well as operational level. On a strategic level emergency doctors need to be assigned to facilities which possibly have to be planned. When locating the doctors, several different constraints have to be taken into account, mainly the sufficient covering of the regions. This leads to a location or coverage problem with uncertain demand, since the actual number of emergencies is not known in advance. We present various models and solution approaches on the basis of robust optimization. The operational level involves the assignment of emergency doctors to specific emergencies and the planning of tours for emergency doctors. The emergencies occur over time and become known in an online fashion. Thus, decisions have to be made on the basis of incomplete data. We discuss various online settings based on reoptimization and other classical online policies. We also provide an offline model and algorithm, which can be used for a posteriori quality control and on the fly monitoring of solution quality. We present various computational results on the basis of real world data.

3 - An Approximate Dynamic Programming Based Heuristic for the Stochastic Lot-Sizing Problem in Remanufacturing Systems
Sedat Belbag, Mustafa Cimen, Mehmet Soysal, Armagan Tarim

The recovery of used products has been receiving more attention due to the growing awareness on sustainable production. Remanufacturing is a widely accepted product reuse process in practice, by which, the used products are recovered or updated to as good as new condition. The products are returned to the original equipment manufacturers due to various reasons such as end-of-life, false failure and warranty. The returned products are remanufactured to satisfy customer demands for new products. This study addresses a lot-sizing problem subject to the assumptions of capacitated production and remanufacturing, stochastic demand and returned products, and infinite planning horizon. The aim is to maximize the expected long-term discounted profit by deciding the amount of new products to be produced. The addressed lot-sizing problem is modelled as a Markov Decision Process. Dynamic Programming approach allows to obtain optimal solutions for small-sized instances of the problem. However, as the problem size increases, computation and memory requirements render Dynamic Programming approach infeasible. This study proposes an Approximate Dynamic Programming approach for solving large instances of the problem.
1 - Multi-Commodity Two-Echelon Vehicle Routing Problem with Time Windows
Fardin Dashi Saridaraq, Nico Dellaert, Tom van Woensel, Teodor Gabriel Crainic

This paper introduces and studies the multi-commodity two-echelon capacitated vehicle routing problem with time windows. This problem considers non-substitutable demands in account by introducing commodities for the two-echelon capacitated vehicle routing problem where these commodities are transferred from depots to satellites (first echelon) and then transferred from satellites to the final customers (second echelon). We propose an arc-model based and a path-based model using the traditional modelling approaches. Moreover, exploiting the structure of the problem, we propose a combined arc-path-based model which defines arc-flow variables for the routing at the first echelon and path-flow variables for the routing at the second echelon. A branch-and-price algorithm is developed which works on the arc-path-based model. We test the performance of the proposed algorithm through a computational study on problem instances.

2 - Vehicle Scheduling vs. Vehicle Routing: Efficient network flow-based mathematical models and constraints in structure and practical requirements
Taieb Mellouli

Although vehicle routing and vehicle scheduling problems (VRP, VSP) seem to share a very common structure (chaining locations or trips into routes/rotations), state-of-the-art methods for practical constraints are based on mathematical programming for the second, but large instances for routing problems are still solved heuristically. A network with (time-)space nodes and explicit arc connections is acyclic only for VSP due to irreversible time progress. Connections can be represented implicitly by introducing connection (time)lines at stations, leading to more efficient models for VSP. In order to efficiently solve hard versions of VSP and rotation building (multi-ple types and depots for buses, cyclic maintenance requirements for trains), the author developed crucial techniques for aggregating dead-head trips and resource paths based on computing latest-first-matches between connection lines and introducing multiple resource-state dependent connection lines. For vehicle routing, flow models suffer of sub-tours and lot of symmetry. One way to break sub-tours is to couple commodity flows (loads, linehaul/delivery & backhaul/pickup) with vehicle routes’ flow. We introduce the notion of DP-turns and restrict their average number per tour by a parameter tau: tau=1 means that linehaul is always before backhaul (VRPB) and the larger is tau the more general is the VRP version towards VRPDP. Recognizing route parts with linehaul and backhaul loads allows for an efficient modeling of restricted mixing (RM). Results for up to 100 nodes using Gurobi show that restricted versions are solved more efficiently—better tour quality to break symmetry! A special LP fixing heuristic leading to nearly optimal solutions enables to solve larger models up to 200 nodes for VRPMDP.

1 - Near-Optimal Approximate Shortest Paths and Transshipment in Distributed and Streaming Models
Ruben Becker, Andreas Karrenbauer, Sebastian Künning, Christoph Lenzen

We present a method for solving the shortest transshipment problem—also known as uncapacitated minimum cost flow—up to a multiplicative error of 1 + epsilon in undirected graphs with polynomially bounded integer edge weights using a tailored gradient descent algorithm. Our gradient descent algorithm takes epsilon-3 polylog iterations, and in each iteration it needs to solve the transshipment problem...
up to a multiplicative error of polylog $n$, where $n$ is the number of nodes. In particular, this allows us to perform a single iteration by computing a solution on a sparse spanner of logarithmic stretch. Using a careful white-box analysis, we can further extend the method to finding approximate solutions for the single-source shortest paths (SSSP) problem. As a consequence, we improve prior work by obtaining better results in several distributed models of computation. This includes for the first time matching a well-known lower bound in the CONGEST model up to logarithmic factors for the SSSP problem.

2 - Phase unwrapping for SAR interferometry using undirected shortest transshipments
Andreas Karrenbauer

We combine methods from combinatorial and continuous optimization to solve large scale optimization problems for constructing digital elevation models. Synthetic Aperture Radar (SAR) interferometry is a remote sensing technique to acquire information of the landscape from aircraft or satellite by measuring phase differences in signals reflected from the surface. Since the phase differences are wrapped modulo $2\pi$, there is some ambiguity in reconstructing the elevations of the grid points on the surface and the smoothest among all possibilities is chosen as good hypothesis, i.e., the solution with the minimum total absolute height differences between neighbors in the grid. This can be modeled as an undirected shortest transshipment problem. We demonstrate how a gradient descent can be combined with a combinatorial dual ascent algorithm for directed min-cost flows to solve this problem efficiently.

3 - Two Results on Slime Mold Computations
Pavel Kolev, Ruben Becker, Vincenzo Bonifaci, Andreas Karrenbauer, Kurt Mehlhorn

We present two results on slime mold computations. The first one treats a biologically-grounded model, originally proposed by biologists analyzing the behavior of the slime mold Physarum polycephalum. This primitive organism was empirically shown by Nakagaki et al. to solve shortest path problems in wet-lab experiments (Nature’00). We show that the proposed simple mathematical model actually generalizes to a much wider class of problems, namely undirected linear programs with a non-negative cost vector. For our second result, we consider the discretization of a biologically-inspired model. This model is a directed variant of the biologically-grounded one and was never claimed to describe the behavior of a biological system. Straszak and Vishnoi showed that it can epsilon-approximately solve flow problems (SODA’16) and even general linear programs with positive cost vector (ITCS’16) within a finite number of steps. We give a refined convergence analysis that improves the dependence on epsilon from polynomial to logarithmic and simultaneously allows to choose a step size that is independent of epsilon. Furthermore, we show that the dynamics can be initialized with a more general set of (infeasible) starting points.

1 - Airport Capacity Extension, Fleet Planning, and Optimal Aircraft Scheduling in a Four-Level Market Model: On the Effects of Market Regulations
Martin Weibelzahl, Mathias Sirvent

Given the liberalization in the airline sector, private airlines invest in new aircraft on the basis of expected market developments and future profits. In contrast, regulated airports choose their runway capacity investments in anticipation of future fleet planning of airlines and corresponding passenger growth. While capacity extensions of airports and fleet planning of airlines are highly interconnected, traditional planning processes typically ignored such an interplay. Therefore, in this paper we present a four-level market model that directly accounts for interdependent long-run investments of airlines and airports within a market environment.

In particular, on the first level we assume airports that choose their runway capacity extensions together with their level of charges. Airlines anticipate the behavior of airlines that will (i) invest in their aircraft fleet on the second level, (ii) schedule their (existing and new) fleet on the third level, and (iii) sell their tickets on several markets on the fourth level. Obviously, all four levels are highly interconnected. For instance, the number of sold tickets on the fourth level depends on the aircraft that is scheduled on the considered connection on the third level, which in turn is influenced by investment decisions on the first and second level. On the opposite, optimal long-run investments depend on profits realized on the ticket market on the fourth level as well as on current policy regulations.

Given this complex interdependency, we reformulate the original four-level problem and solve the resulting single-level problem with a sub and master problem decomposition. Finally, we illustrate the results of our market model and quantitatively evaluate different market regulations in a first case study.

2 - The Flight Planning Problem with Variable Speed
Marco Bianco, Ralf Borndörfer, Nam Dung Hoang, Thomas Schlechta

In the Flight Planning Problem, which generalizes the Shortest Path Problem, the objective is to compute a minimum-cost flight trajectory between two airports. Given are, among other factors, the aircraft’s type and weight, the departure time, and a weather prognosis. The objective function is the sum of fuel costs, time costs, and overflight fees.

Traditionally, Flight Planning algorithms assume that aircraft fly either at a constant speed (with respect to the surrounding air mass) or at every iteration a formula that returns a “good” flight speed as a function of the ratio between fuel price and time costs, and the aircraft’s current weight and altitude.

In this talk, we present a novel Dynamic Programming algorithm for solving the Flight Planning Problem to optimality in the case of constant flight speed. We introduce a few variants of the algorithm which consider speed as a free variable, and present corresponding computational results.

3 - Lessons learned on Robust Efficiency of Airline Crew Schedules
Lucian Ionescu, Natalia Kliewer

In airline operations, resource schedules are under constant exposure to unforeseen disruptions. In the aftermath, schedule infeasibility and delays often necessitate expensive recovery actions. Consequently, real costs for an airline may be considerably higher than planned costs. Narrowing this gap is the main goal of the concept of robust efficiency: schedules are generated in a way that they are robust against delay occurrences while preferably maintain their efficiency in terms of planned costs. Schedule robustness can be achieved by increasing the degree of stability or flexibility. While stability targets at operating schedules “as planned” and thus demands relatively good delay predictions, an increasing degree of flexibility offers more possibilities to react to unanticipated delays.

In this setting, we discuss lessons learned from a recent research project on the incorporation of stability and flexibility into airline crew schedules in connection with delay prediction studies. The main focus is on mutual impacts between stability and flexibility.

WE-05
Wednesday, 16:30-18:00 - WGS 104a
Planning and Scheduling in Air Transportation
Stream: Traffic, Mobility and Passenger Transportation
Parallel session
Chair: Lucian Ionescu

1 - Airport Capacity Extension, Fleet Planning, and Optimal Aircraft Scheduling in a Four-Level Market Model: On the Effects of Market Regulations
Martin Weibelzahl, Mathias Sirvent

Given the liberalization in the airline sector, private airlines invest in new aircraft on the basis of expected market developments and future profits. In contrast, regulated airports choose their runway capacity investments in anticipation of future fleet planning of airlines and corresponding passenger growth. While capacity extensions of airports and fleet planning of airlines are highly interconnected, traditional planning processes typically ignored such an interplay. Therefore, in this paper we present a four-level market model that directly accounts for
The field of applications for Fullerenes ranges from medical use to photovoltaic installations: There is an intense research throughout many areas ongoing. As a fullerene can be represented by so called Fullere graphs their chemical properties might be related to graph-theoretical properties of the corresponding polyhedral graphs. The lecture will focus on the relationship between maximum cycle packings in fullerene graphs and independence sets of the corresponding dual graph. The results are used to implement an efficient algorithm to apply exact maximum cycle packings for small fullerenes.

2 - On Maximum Cycle Packings in Halin Graphs using Wheel Decomposition
Christin Otto
Let G=(V,E) be an undirected graph. The maximum cycle packing problem is to find a collection C=C_1, ... , C_s of edge-disjoint cycles C_i in G such that the cardinality s of the collection is maximum. In general, this problem is NP-hard. For the class of Halin graphs an algorithm is presented for computing C. The procedure is based on splits and a decomposition of Halin graphs into wheels. Since the components can be represented by a decomposition tree (similar to SPQR-trees) the approach can be considered as a generalization of decomposing graphs into blocks and blocks into 3-connected components.

3 - Spontaneous postman problems
Peter Recht
In this lecture we address "Spontaneous Postman Problems". In this type of routing problems the postman selects subsequent streets of his tour by a willy-nilly strategy. In such a way it differs from well known "classical" postman-problems, where the postman’s transversal of streets is performed according to some routing plan. This problem appears in real world tour planning, if the selection of subsequent traversals is done careless. Such a choice can be observed in the display of tours in a museum or tours in trade fair. The spontaneous character of such a choice leads to the basic question how to partition a street network into different districts in such a way, that one can guarantee, that each district is served if the postman is "spontaneous". The structural problems of the network that arise within this framework are closely related to the investigation of local traces and maximum edge-disjoint cycle packings in graphs.

WE-07
Wednesday, 16:30-18:00 - WGS|106
Foundations of Linear and Integer Programming (i)
Stream: Discrete and Integer Optimization
Parallel session
Chair: Stefan Welte

1 - Beyond TU-ness: A Strongly Polynomial Algorithm for Bimodular Integer Linear Programming
Stephan Artmann, Robert Weismantel, Rico Zenklusen
We present a strongly polynomial algorithm to solve integer programs given by inequality constraints, where the constraint matrix A, the right-hand side and the objective function vector are integral and A is of the following type: It has full column rank n and the determinants of all quadratic (n times n)-sub-matrices of A are bounded by 2 in absolute value.
We thus obtain an extension of the well-known result that integer programs with constraint matrices that are totally unimodular are solvable in strongly polynomial time.

2 - On the number of distinct rows of a matrix with bounded sub-determinant
Christoph Glänzer, Robert Weismantel, Rico Zenklusen
Let A be an integral matrix with m rows and n columns whose maximal submatrices have a determinant of at most delta in absolute value. Assume that A attains full column-rank and that all of its rows are distinct. What is the maximal number of rows such a matrix can have? We prove that for fixed delta, m is bounded by O(n^2). This is a generalization of the well-known result of Heller that totally unimodular matrices admit at most O(n^2) distinct rows. We also present extensions of our result to cases where delta is a function of n.

WE-08
Wednesday, 16:30-18:00 - WGS|107
Public Transportation Planning 2
Stream: Traffic, Mobility and Passenger Transportation
Parallel session
Chair: Christian Puchert

1 - Demand-Driven Line Planning with Selfish Routing
Malte Renken, Amin Ahmadi Digehsara, Ralf Bornsdörfer, Guvenc Sahin, Thomas Schlechte
Bus rapid transit systems in developing and newly industrialized countries are often operated at the limits of passenger capacity. In particular, demand during morning and afternoon peaks is hardly or even not covered with available line plans. In order to develop demand-driven line plans, we use two mathematical models in the form of integer programming problem formulations. While the actual demand data is specified with origin-destination pairs, the arc-based model considers a cone. We are looking for a nonzero solution of this system. The algorithm is based on a procedure for finding sufficiently short convex combinations of the rows of the coefficient matrix. Whenever such a combination is found, the algorithm performs a linear transformation of the space which depends on this convex combination. The running time of the algorithm is bounded by a polynomial in the number of variables and in the maximum binary size of an entry of the coefficient matrix, provided that the separation oracle is a polynomial algorithm.

2 - Traffic management heuristics for bidirectional line segments on double-track railway lines
Norman Weik, Stephan Ziegler, Nils Nielßen
In this paper traffic management strategies for disruption-caused inaccessibility of one track on double-track railway lines are analyzed. In practice, this type of failure gives rise to heavily loaded temporarily bidirectional line segments. Building on previous results for polling systems with k-limited service discipline and non-zero switchover times heuristic rules for optimally switching the orientation of the bidirectional segment are investigated. QoS-standards for the waiting time enforcing delay constraints for both orientations as well as asymmetric traffic load, e.g. resulting from rerouting of train services to other lines, are accounted for.
Nonpriority systems are analyzed based on approximate formulae for the mean waiting time of queues. The approximations make use of results for 1-limited and exhaustive service policy. In addition, we numerically analyze polling systems with two priority classes of trains. The inclusion of different train priorities exhibiting different QoS-standards with respect to waiting times provides a new perspective setting the problem apart from existing polling applications in transportation modeling, e.g. traffic intersections or automated vehicle operation.
The performance of the heuristic management strategies are assessed by comparing the class-specific waiting times to the optimal solution obtained by solving the train scheduling problem for the bidirectional line segment. In the optimization approach the problem is solved both globally and with a limited time horizon. The input parameters for the tests are based on real-world train operation data including driving times as well as headway times resulting from interlocking constraints.
3 - Detecting, Interpreting and Exploiting Structures in Integrated Public Transport Planning Problems
Christian Puchert, Marco Löbbbecke, Philine Schiewe, Anita Schöbel

In this talk, we investigate traffic planning problems in public transport such as line planning, timetabling, vehicle scheduling, and passenger routing. Instead of solving the planning steps sequentially, we consider them simultaneously as one single integrated planning problem.

Such an integrated problem has a structure which is also reflected by corresponding mixed integer programming (MIP) models, whose coefficient matrix then has a (bordered) block diagonal structure reflecting the single planning steps. Besides, the steps themselves may again decompose into such a structure - a line planning model, e.g., may itself in turn decompose into the corresponding lines.

Besides the "obvious" structure that reflects the planning steps, the model may also bear "hidden" structures which are not known to the modeler. We employ structure detection methods based on graph models to find such structures. Furthermore, we analyze the detected structures w.r.t. to the network topology, and investigate in how far a variation on the input data affects the MIP model as well as the decomposition.

Last, we apply a Dantzig-Wolfe decomposition and branch-and-price approach on the models and their structures. We give a computational comparison on the solver performance between different structures as well as to a standard branch-and-cut approach.

WE-09
Wednesday, 16:30-18:00 - WGS|108

Discrete Optimization by Semidefinite Methods (I)
Stream: Discrete and Integer Optimization
Parallel session
Chair: Angelika Wiegele

1 - A Modified Bundle Method for SDP with Exact Subgraph Constraints
Elisabeth Gaar, Malwina Duda, Franz Rendl

The stable set problem, the coloring problem and the max-cut problem are three different famous combinatorial optimization problems. All the problems are downward monotone, that is restricting the problem to a subgraph yields an instance of the same problem on a smaller graph. We use this fact and define so called exact subgraph constraints. For a certain subgraph the exact subgraph constraint ensures, that the submatrix of the calculation of the relaxation corresponding to the subgraph is in the convex hull of all stable set, max-cut or coloring matrices of the subgraph respectively. Therefore, in order to get an improved bound for the above problems, one can start with the original relaxation and include the exact subgraph constraints for many small - wisely chosen - subgraphs. We call a problem of such form P1. Solving P1 is very time-consuming with off-the-shelf solvers, hence it requires alternative solution methods. By building the Lagrangian dual of P1 with respect to the exact subgraph constraints, one gets an optimization problem P2, where the objective function can be split (with common linear variables) into a part which captures the SDP and a second linear part. To P2 a specialized version of the bundle method, namely the bundle method with easy sum components, can be applied in a very natural way. In the resulting iterative solution method, in each iteration one has to solve an SDP with few constraints (for the oracle) and a very nicely structured QP or alternatively a larger LP (for getting the new trial point). In the talk we will discuss different solution methods for this QP and see that our method significantly improves the running times to solve P1 to our desired accuracy.

2 - Solving Extended Single Row Facility Layout Problems Using a Spectral Bundle Method
Anja Fischer, Mirko Dahlbeck, Frank Fischer

In this talk we consider the Single Row Facility Layout Problems (SRFLP) and extensions of it. Given a set of one-dimensional departments with positive lengths and pairwise transport connections between them, the aim is to determine an order of the departments along a line such that the weighted sum of the distances between the departments is minimized. We present a semidefinite programming formulation for the SRFLP which can handle asymmetric transport weights. Furthermore, the input and output positions might be arbitrary placed along the departments and one might specify clearance conditions between the departments. A relaxation of this model is solved using a spectral bundle method which allows to obtain good lower bounds rather quickly even for large instances. We compare our results to further solution approaches from the literature.

WE-10
Wednesday, 16:30-18:00 - WGS|108a

Scheduling and Resource Management under Uncertainty
Stream: Discrete and Integer Optimization
Parallel session
Chair: Nicole Megow

1 - The Itinerant List Update Problem
Kevin Schewior, Neil Olver, Kirk Pruhs, René Sitters, Leen Stougie

We introduce the Itinerant List Update Problem (ILU), in which items from a linear list are sequentially requested. In response to a request, the pointer, initially positioned at the front of the list, has to be moved to the corresponding item. Hereby, at all times, the item at the pointer’s position may be swapped with an adjacent one. The goal is to minimize the total number of pointer moves and swaps. This problem is a relaxation of the classic List Update (LU) problem in which the pointer no longer has to return to a home location after each request. The motivation to introduce ILU arises from the application of track management in Domain Wall Memory. We first show an Omega(log n) lower bound on the competitive ratio for any randomized online algorithm for ILU. This shows that online ILU is harder than online LU, for which deterministic O(1)-competitive algorithms, like Move-To-Front, are known. We then show that ILU is essentially equivalent to a variation of the Minimum Linear Arrangement Problem (MLA), which we call the Dynamic Minimum Linear Arrangement (DMLA) problem. We next discuss algorithms for DMLA, including an offline polynomial-time O((log2 n) approximation.

2 - Submodular Secretary Problems: Cardinality, Matching, and Linear Constraints
Andreas Tönnis, Thomas Kesselheim

We study various generalizations of the secretary problem with submodular objective functions. Generally, a set of requests is revealed step-by-step to an algorithm in random order. For each request, one option has to be selected so as to maximize a monotone submodular function while ensuring feasibility. For our results, we assume that we are given an offline algorithm computing an alpha-approximation for the respective problem. This way, we separate computational limitations from the ones due to the online nature. When only focusing on the online aspect, we can assume alpha = 1.

In the submodular secretary problem, feasibility constraints are cardinality constraints, or equivalently, sets are feasible if and only if they are independent sets of a k-uniform matroid. That is, out of a randomly ordered stream of entities, one has to select a subset size k. For this problem, we present a 0.3 alpha-competitive algorithm for all k, which asymptotically reaches competitive ratio alpha k for large k.
Furthermore, we consider online submodular maximization with random order of arrival subject to other types of constraints. We give a constant competitive algorithm for the submodular secretary problem subject to a matching constraints, which also covers the case where sets of items are feasible if they are independent with respect to a transversal matroid. Additionally, we give an algorithm for linear packing constraints. In this case, we parameterize our result in the column sparsity and minimal capacity ratio in a constraint. Here our guarantee depends on whether those parameters are known to the algorithm in advance or not.

3 - Greedy Algorithms for Unrelated Machines Stochastic Scheduling
Marc Uetz, Varun Gupta, Benjamin Moseley, Quamin Xie

We derive the first performance guarantees for a combinatorial online algorithm that schedules stochastic, nonpreemptive jobs on unrelated machines to minimize the expectation of the total weighted completion time. Prior work on unrelated machine scheduling with stochastic jobs was restricted to the offline case, and required sophisticated linear or convex programming relaxations for the assignment of jobs to machines. Our algorithm is purely combinatorial, and therefore it also works for the online setting. As to the techniques applied, this paper shows how the dual fitting technique can be put to work for stochastic and nonpreemptive scheduling problems.

WE-11
Wednesday, 16:30-18:00 - WGS\(\frac{1}{2}\),005
Vehicle Scheduling

Stream: Logistics and Freight Transportation
Parallel session
Chair: Martin Poul

1 - Exploration of Flexibility Schemes for Time Window Management
Charlotte Köhler, Jan Fabian Ehmkne, Ann Campbell

In the competitive world of online retail, customers can choose from a selection of delivery time windows on retailer websites. When accepting customer requests, retailers can build tentative delivery routes and check if each customer can be accommodated feasibly with the remaining delivery capacity. Since demand is not known at the beginning of booking process, but becomes available incrementally over time, the acceptance of an order request can restrict the ability of accommodating future requests significantly.

In this presentation, we investigate different schemes for more flexible time window management. The general idea is to adapt time window offerings based on characteristics of the evolving route plan to enable more customers to be served. Extending customer acceptance mechanisms from the literature, we consider the remaining logistics capacity, the time of the request relative to the booking horizon, and the customer location in the decision of how many different time windows and what time window widths to offer to the customer. We investigate the impact of these ideas on the number of served customers given the demand structure of order data from an e-grocer in Berlin, Germany. We also develop and demonstrate different measures of customer service to further compare the performance of different adaptive schemes.

2 - A randomised three-stage algorithm for the multiple depot vehicle scheduling problem
Sarang Kutkarni, Mohan Krishnamoorthy, Andreas Ernst, Abhiram Ranade, Rahul Patil

The multiple depot vehicle scheduling problem (MDVSP) in the public transport industry is a well-known NP-hard problem. The MDVSP deals with the sequencing and assignment of a set of timetabled trips to buses, which are stationed at different depots. A sequence of the trips corresponds to a schedule for a bus to which the trips are assigned. A bus may need to travel empty from the end location of one trip to the start location of its next trip. Such bus trips are referred to as deadheading trips or repositioning trips. One of the objectives of the MDVSP is to minimize deadheading and hence, the total deadheading cost. The second MDVSP objective is to minimize the number of buses that are required for covering all the trips. We have developed a three-stage algorithm to solve the MDVSP. The first stage converts the MDVSP to a single depot vehicle scheduling problem using a suitable relaxation procedure. In the second stage, a feasible solution is obtained using the solution to the single depot problem from the first stage. The third stage involves an iterative procedure to improve the initial feasible solution. Each iteration involves randomly dividing the entire scheduling horizon into two partitions. Improvements to the solution, if any, can be obtained by determining the optimal connections that join the two partitions. An assignment formulation is solved to get the optimal connections. The best of these solutions obtained in the second and third stage is selected as the solution to the MDVSP. We tested the algorithm using benchmark instances. The solutions are compared with those that are obtained using standard solvers as well as existing heuristic-based solution approaches.

3 - A Branch-and-Price Algorithm for the Scheduling of Customer Visits in the Context of the Multi-Period Service Territory Design Problem
Martin Poul, Matthias Bender, Jörg Kalcsics, Stefan Nickel

Many companies employ field representatives to provide services at their customers’ sites on a regular basis. Consider, for instance, the delivery of goods to retailers or regular technical maintenance tasks. In these applications, the entire region under study is subdivided into service territories, with one field representative being responsible for all customers in a territory. At a tactical planning level, customer visits within each service territory must be scheduled over a given planning horizon. The goal is to determine a valid visit schedule for each customer that meets customer-specific requirements such as visiting rhythms. In addition, the schedule must achieve a balanced daily and weekly workload. Lastly, compactness is important, as field representatives need to travel to their customers, and thus visits on the same day should be geographically concentrated. In this talk we present a column generation formulation of the resulting scheduling problem and propose an exact branch-and-price algorithm. Our method incorporates specialized acceleration techniques, such as a fast pricing heuristic and a symmetry handling strategy. The latter aims to reduce the symmetry inherent to the model by fixing variables and thereby eliminating symmetric solutions from the search tree. We perform extensive experiments on test instances based on real-world data in order to evaluate the different algorithmic components, such as branching variable selection and symmetry handling. Compared to the commercial general purpose mixed integer programming solver Gurobi, our algorithm achieves a significant speedup and is able to solve instances with up to 55 customers and a planning horizon of 4 weeks to optimality in a reasonable running time.

WE-12
Wednesday, 16:30-18:00 - WGS\(\frac{1}{2}\),BIB
Hackathon: Gurobi-TomTom Mobility Maximization Mission Prize Award Session

Stream: Business Track
Parallel session
Chair: Heiko Schilling

1 - Gurobi-TomTom-Hackathon Prize Awards
Heiko Schilling

This session presents the ideas and implementations of the participants of the Gurobi-TomTom Hackathon "Mobility Maximization Mission" (GT3M). At the end of the session, the jury will announce the winners and hand over the prizes.

WE-13
Wednesday, 16:30-18:00 - RVH\(\frac{1}{2}\)
Forecasting Algorithms & Methodology

Stream: Business Analytics, Artificial Intelligence and Forecasting
Parallel session
Chair: Sven F. Crone
1 - Generalized Lasso for Weight Regularization in Forecast Combination

**Thomas Setzer, Sebastian Blanc**

This work considers the regularization of weightings in group forecasts. Empirical studies regularly reveal that a simple averaging (SA) over a group of forecasts outperforms the best individual forecast. It is also found that SA typically performs better out of sample than weights learned from past error observations. The latter finding is due to the instability of learned weights that are sensitive to randomness in limited training data. The weighting scheme most sensitive to training data is the least squares solution that determines so-called optimal weights (OW). Some work has been published that show that a linear combination of OW and SA, i.e., the proportional shrinkage of OW towards SA, can be profitably turned off the high bias of SA and the high sampling-based variance of OW and improve the accuracy achieved with either one of the individual weighting schemes. We propose the nonlinear shrinkage of OW towards SA by penalizing the absolute sum of weight deviations from equal weights using the Generalized Lasso. Based on cross-validation results in Monte-Carlo simulations we provide guidelines when Combination Lasso asymptotically outperforms OW, SA and linear shrinkage.

2 - Efficiency improvement by employing forecast correction in judgmental revisions

**Florian Knöll**

Accuracy of forecasts is essential for financial services within corporations. In business corporations, experts in distributed subsidiaries usually forecast judgmentally cash flows for corporate risk management. As of the importance of cash flow forecasts in corporate risk management, techniques for data-driven forecast correction are applied. Of ten the forecast correction techniques apply solely statistical methods based on historical data and the consideration of organizational effects is entirely missing.

In accounting the forecast accuracy depends on statistics like lead time, but also on important organizational conditions such as targets of return margin. The author argues that the disregard of organizational information in forecast correction techniques misses opportunities that are truly impacting forecast efficiency. Forecast efficiency provides a statistical method to measure the amount of structure within forecasts and corrected forecasts.

However, empirical results not only show that the incorporation of organizational information is crucial to determine forecasts with suspicious pattern that are unaligned with planned margin targets. They also show that correction techniques can utilize organizational effects to improve forecast efficiency. The reduction of inefficient pattern shows that organizational forecast correction is superior to basic statistical approaches.

### WE-14

**Analytics in Retail and Digital Commerce II**

**Parallel session**

Chair: Henning Nobmann

1 - The Modelling and Assessment of Online Customer Interaction, Customer Journeys and Churning

**Bernhard Luther, Nicola Winter**

We present a strategy to forecast and assess customer behaviour in the field of e-commerce. Starting point is the assignment of all actors in a market to an exhaustive set of potentially accessible users. Usually, only a small part of this set belongs to real customers in the context of commercial transactions. The user information generated by arbitrary online-interaction is much more voluminous than the customer data collected. Typical customer profiles - regular customers as well as change customers and churners - can be generalised to corresponding user profiles. However customer data is much better structured than the naturally granular, heterogeneous and often incomplete data of arbitrary users. These users cannot be connected in a simple way with standardised monetary indicators like the customer lifetime value (CLV). In consequence an effective exploitation of unstructured user data requires explorative and descriptive methods of correction and classification as well as statistical limitations arising from the heterogeneity of the data. As a clear focus the mean- and short-term user identification in the context of an effective classification is discussed. The main goal is to improve the representation and description of customer journeys together with an effect analysis of marketing activities. The traceable "journey" of all users hardly differs. Nevertheless, it might be the main base for decisions about general marketing campaigns and individual offers. Robust inferences on the base of many short-term user steps are an important goal. In this contribution, a case study of an online short break internet platform serves as an example.

2 - The relationship between behaviors in real life and buying behaviors on the electronic commerce site

**Kei Takahashi**

In this paper, we focus on the relationship between behaviors in real life and buying behaviors on the fashion EC site. The proprietor of the EC site desires that users in their sites enrich their lives through purchasing via their own sites. In Japan, people enriching their real lives are called "Riaju". These people tend to have some activities or parties, specifically firework display, sea bathing, and barbecue, Christmas, cherry-blossom viewing and Halloween parties. However, the proprietor of the EC site did not know which fashion items Riaju users tend to purchase on the EC site, or weather heavy users tend to have the same activities or parties. Then the proprietor of the EC site conducted a questionnaire survey for users including questions regarding to users' fashion perspectives and sense of their values. Using questionnaire result and point of sales with identifiers data, we construct a statistical model via Bayesian network and categorical factor analysis. As a result of the analysis, we found that Riaju people tend to purchase not clothes but fusion accessories, e.g. hats.

3 - Analyzing customer journeys in e-commerce

**Henning Nobmann, Thomas Winter**

We develop parametric models describing individual customer’s journeys from first contact to an eventual purchase or defection in order to analyse the impact of different marketing channels on the retention and defection probabilities at different stages of the sales funnel. Our data consists of the logged webtraffic of a European short break online platform as well as data on their use of different marketing channels. As individual users are not readily identified from the data, we employ a hierarchical classification algorithm based on an ensemble of technical identifiers of differing accuracy and longevity to arrive at a fuzzy matching of our data to a predefined user base, allowing us to trace individuals’ paths of interaction with the website through time. The goal is to evaluate and optimise the usage of different marketing channels throughout the sales funnel by estimating the conditional odds of retention/defection at different stages of the sales funnel with respect to the marketing tools targeting individual users. In addition, we aim to develop a clustering of users according to their search behaviour in order to be able to identify likely buyers or potential defectors that have a sufficiently high probability of retention if targeted with the appropriate channels early in their journey. Our data exemplifies various challenges in working with data on e-commerce: Identification of individual users depends on a multitude of cookies and individual IDs of varying quality, data formats are subject to continuous change, and the determinants of the often seemingly erratic behaviour of customers in the online market place are by no means obvious.

### WE-15

**Safety and Security**

**Parallel session**

Chair: Truong Son Pham

1 - Developing a Generalized Cyber Security Quantification Model

**Vandana Kadam, Rakesh Verma**

Cyber Security has gained a prime importance in today's dynamic computing world of networked-based, mobile-based, cloud based and IOT based environment. In such scenario, Generalized Cyber Security Model has become a need of an hour. In this research paper, a
2 - Big-Data Approaches for Categorization of Ships based on AIS-Data

Max Krueger

The Automatic Identification System (AIS) is a system of cooperative VHF-radio exchange of navigational and ships’ data for purposes of maritime safety, surveillance, and information. Since 2004, most of larger vessels are obligated to participate in AIS data exchange. Our contribution is based on a real-life data set, which contains collected AIS-data from 2014 and 2017 covering a few days to several weeks in different maritime areas, e.g., German Bight, English Channel, Vancouver Island, and others. After a brief descriptive statistical analysis of vessel types and properties in our geographical area of interest, we address the question, whether it is possible to categorize vessels based on AIS-data with respect to allegiance, behavior, and intention by means of Big-Data classification methods. As test case in our treatment, we try to categorize vessels on basis of their ships’, positional, and motion AIS-data. Type- and identity-related data, which are also provided by AIS are used not as classification input but for reference and evaluation of categorization results. For deductive reasoning and statistical evaluation, we use the open-source tool KNIME Analytics Platform (www.knime.org), which provides different classification approaches, e.g., Naive Bayes, clustering approaches, Neural Networks, and others. An evaluation and comparison of classification results in this maritime Big data context concludes our contribution.

3 - Modeling the Causes for Terrorism: An Innovative Framework Connecting Impactful Events with Terror Incidents

Truong Son Pham, Gonzalo Barbeito, Martin Zisfikovits, Stefan Wolfgang Pickl

Terrorism has become an increasingly relevant issue accounting for significant social, economic and political impact. Due to powerful media coverage on the subject, a lot of information is now publicly available, although normally found in an unstructured form. This research aims to better understand the connection between a collection of impactful events, such as external or internal conflicts and military operations, with terror events and its motivations. To this end, a framework for performing predictive analytics was devised using distinguished OR-techniques, starting with an online news scraper, coupled with machine learning and natural language processing techniques, capable of clustering keywords into the main topics found in the news. The results of these adaptive algorithms, in the form of structured data, were later fed to a modeling technique capable of finding, to a certain degree, the reference and evaluation of categorization results. For deductive reasoning, in the form of structured data, were later fed to a modeling technique capable of finding, to a certain degree, the reference and evaluation of categorization results. The approach presented in this work adopts a perspective that, to the best of our knowledge, has not been previously seen in specialized literature. Furthermore, this methodology constitutes the groundwork for open source intelligence, capable of being applied on various similar domains, aiding in prediction of political and economic crises.

 WE-16

Wednesday, 16:30-18:00 - RBM|1102

Finance III

Stream: Finance

Parallel session

Chair: Michael H. Breitner

1 - Fast methods for the index tracking problem

Dag Haugland

In the index tracking problem, the goal is to select a restricted number of shares included in a stock market index, such that the portfolio resembles the index as closely as possible. Various definitions of closeness to the index have been proposed in the operations research literature. In the current work, the difference between the portfolio and the index, referred to as the tracking error, is measured by a quadratic function with the covariance matrix of the index returns as coefficient matrix. Recently, it was proved that despite this simplicity, the index tracking problem is strongly NP-hard. It was also demonstrated that the best-known approximation algorithms achieve a constant-factor approximation ratio, and the running time of one iteration of the best-exchange-by-one improvement heuristic is of the same order. In the current work, construction and improvement methods with more favourable running times are developed. We demonstrate, in particular, how the running times can be reduced by one order of magnitude, with only modest increase in the tracking error. The merit of the new heuristics is justified through computational experiments applied to real-life stock market indices.

 WE-17

Wednesday, 16:30-18:00 - RBM|2204

Strategic Planning in Health Care

Stream: Health Care Management

Parallel session

Chair: Brigitte Werners

1 - Simulation-based Evaluation of Locations for Ambulances and Emergency Doctors

Pia Mareike Steenweg, Lara Wiesche, Brigitte Werners

In medical emergencies, patients require fast assistance. Therefore, ambulances and - in life-threatening cases - emergency doctors shall reach the emergency location within a given time frame. In Germany, they both travel separately and meet at the location, this is called Rendezvous-system. Thus far, tactical location and allocation planning models for emergency medical services focus on ambulances only. Our existing location model for ambulances determines sophisticated results based on data-driven empirically required coverage. The model incorporates temporal and spatial variations of emergency demand as well as variation of intraday travel times according to empirical studies. This contribution extends recent research by considering emergency doctors. Furthermore, we take into account increasing demand for services due to demographic change. Therefore, comprehensive
simulation studies investigate the optimal location of additional ambulances and the influence of extended availability of emergency doctors. The analysis of real-world data from a German city and takes dynamics and uncertainty into account. By performing What-if analyses respecting relevant criteria e.g. the coverage degree, the decision makers get improved insights on different options to allocate additional resources.

2 - A Location Problem for Emergency Healthcare Facilities
Z. Pelin Bayindir, Cem iyigün, Melike İşbilir

In this study, we consider the problem of locating emergency healthcare facilities in urban areas. Upon emergency occurrence, patients are directed to any one of the emergency centers with a likelihood that depends on the travel time. Moreover, the survival, that represents the severity of the consequences of the emergency situation, is also probabilistic and is a function of the travel time. A mathematical model is constructed under the objective of maximizing expected number of survivors while determining the location of predetermined number of facilities. Characteristics of this model under certain situations, such as when a concave or convex survival function is used, or when the facility is located on a line or a network, are investigated. After presenting the analytical findings, we propose a Genetic Algorithm based solution approach to solve the model for locating healthcare facilities on a network. Lastly, we present its performance and findings through an extensive numerical study.

3 - Long-term personnel scheduling - A case study
Lena Wolbeck, Natalia Kliewer

Within 24/7 services like care facilities, the scheduling process and the resulting duty roster have a huge influence on the satisfaction of shift workers. To preserve and ideally raise the employee commitment, their needs have to be considered when creating a roster. There are many well-performing solution methods for varying kinds of personnel rostering problems, but these approaches mainly concentrate on a single planning period and marginally take the long-term perspective into account. Therefore, we look at a recurrent scheduling problem and simultaneously at the previous run. Furthermore, we incorporate accumulated key figures from all previous periods in our case study. Considering these aspects results in constraints beyond common constraints like working time regulations due to laws or labor agreements and, thus, raises the model’s complexity. In addition, a variety of individual regulations are taken into account. Examples of individual constraints are the working time resp. days off, the number of consecutive working days or requests for resp. against working on specific days or shifts. These limitations are personalized per employee and change every planning period. The aim of our study is to develop a solution approach for a generic personnel rostering problem considering the long-term aspect, in particular the passing from one planning period to the next. To examine the impact in practice, we test our methods in cooperation with a care facility for disabled people. This case study enables us to enhance the optimization model with respect to actual requirements and receive real-world data. Based on real-world data, a set of artificial data is generated to increase sample size and validate the findings.

WE-18
Wednesday, 16:30-18:00 - RBM|2215
Models and Methods for Resource-Constrained Project Scheduling
Stream: Project Management and Scheduling
Parallel session
Chair: Norbert Trautmann

1 - A branch-and-bound procedure for the resource-constrained project scheduling problem with partially renewable resources and time windows
Kai Watermeyer, Jürgen Zimmermann

The resource-constrained project scheduling problem with partially renewable resources which is denoted as RCPSP/Pi has received relatively less attention by the research community to this day. For the RCPSP/Pi the capacity of each resource is given for an arbitrary subset of time periods of the planning horizon whereby each activity with a demand for this resource only consumes if its activity is executed during these periods. The partially renewable resources make it for instance possible to model problems in the area of complex labor regulations. Until now just a few solution procedures for the minimization of the project duration have been developed including only one exact solution method based on a branch-and-bound procedure for a general problem. Our work focuses on the development of a branch-and-bound procedure for a generalization of the RCPSP/Pi which takes also minimal and maximal time lags between pairs of activities into consideration. The new enumeration scheme for the branch-and-bound procedure make use of the fact that the consumption of a resource by an activity is dependent on its start time. In each search node the earliest time-feasible schedule is determined by a modified label correcting algorithm where each activity is restricted to certain time points. If the calculated schedule is not resource-feasible the resource conflict is resolved by excluding further start time points of activities so that the given resource conflict cannot occur in following search nodes. To improve the performance of the branch-and-bound procedure we develop an efficient destructive lower bound based on the relaxation of schedule dependent start time windows.

2 - Markovian PERT networks: A new CTMC and benchmark results
Stefan Creemers

Markovian PERT networks were first studied by Kulkarni and Adlakha (1986), who use a continuous-time Markov chain (CTMC) to determine the exact distribution of the completion time of a project where activities have exponentially-distributed durations. All existing work on Markovian PERT networks adopts the CTMC of Kulkarni and Adlakha (1986) to develop scheduling procedures. We define a new CTMC that drastically reduces memory requirements when compared to the CTMC of Kulkarni and Adlakha (1986). Our CTMC can be used to develop scheduling procedures for a wide variety of problems that allow activities to be preempted. If preemption is not allowed, these scheduling procedures can be used to obtain lower bounds. In addition, we also propose a new and efficient approach to structure the state space of the CTMC. These improvements allow us to easily outperform the current state-of-the-art in optimal resource-constrained project scheduling procedures, and to solve instances of the PSPLIB J90 and J120 data sets.

3 - CTMDP-Based Exact Method for Stochastic RCPSP with Uncertain Activity Durations and Rework
Xiaoming Wang, Roel Leus, Stefan Creemers, Qingxin Chen, Ning Mao

Many practical projects incorporate random rework, which leads to a stochastic project network structure. Until now, however, there have been only few works in the literature that have looked into this particular aspect of project planning and scheduling. In this paper, we consider a resource-constrained project scheduling problem (RCPSP) with exponentially distributed activity durations and two types of random rework. A mathematical model is proposed based on a continuous-time Markov decision process (CTMDP) with the objective to minimize the expected project makespan. In order to cope with the curse of dimensionality that comes into play upon solving large-scale instances, we examine a decomposition method that improves the memory management. In addition, we also analyze the effect of random rework on the expected project makespan and decisions, as well as the optimal rework strategy. Finally, a computational experiment with randomly generated project instances as well as with instances from the well-known PSPLIB is set up to validate the effectiveness of the proposed model and procedures.

4 - An novel mixed-integer linear programming formulation for the resource-constrained project scheduling problem
Norbert Trautmann, Tom Rihm

The resource-constrained project scheduling problem consists in determining start times for a set of precedence-interrelated project activities that require time and scarce resource capacities during execution such that the total project duration is minimized. Besides a large variety of problem-specific solution approaches, various mixed-integer linear programming (MIP) formulations have been proposed in the literature. We present a novel MIP formulation which is based on assignment and sequencing variables. In an experimental performance analysis, it has turned out that the novel formulation outperforms two state-of-the-art models in particular when the resource capacities are very scarce.
1 - Pricing, Lead-time Quotation, Inventory Control and Capacity Setting in a Make-to-order System

Ata Jalili Marand

How do the inventory control related costs and uncertainty affect the performance of a manufacturing system quoting a promised delivery time to its time- and price-sensitive customers? We consider this question for a make-to-order system modeled as an M/M/1 queue with an attached inventory. We assume that satisfying each customer’s demand requires a unit of a single inventory item. Inventories of the required item, therefore, need to be kept in the system. The inventory is continuously reviewed and at appropriate time epochs purchase orders are placed to replenish the inventory. We deal with this problem under two assumptions: zero and exponentially distributed inventory replenishment lead times. The objective is to maximize the system’s long-run average profit by integrating pricing, lead-time quotation, capacity setting and inventory control decisions subject to a service reliability level and inventory control related constraints. We provide the following results. First, we identify a necessary and sufficient condition, in terms of all problem parameters, for the existence of a unique interior solution in the zero replenishment lead time case and characterize the optimal solution. Second, based on the parametric fractional programming, we propose a solution method to solve the problem to the optimality under the assumption of exponentially distributed replenishment lead time. We provide a necessary condition, in terms of all problem parameters, for the existence of an interior solution in this case. Third, we conduct a sensitivity analysis to compare the performance of the system under different circumstances. Our analysis suggests that ignoring the inventory related costs and uncertainty in the decision-making process may lead to complete profit loss.

2 - Disruptive Innovation, Market Entry and Production Flexibility in Oligopoly

Benoit Chevalier-Roignant

We model a Cournot oligopoly whereby several innovative firms invest in technology development acquiring the option to enter a new market under stochastic demand. Invested firms have production flexibility to adjust output while market entry gives rise to a coordination problem among rivals. We characterize Markov Perfect Equilibria and derive the option value to invest in general oligopoly. This value is not convex increasing in demand but exhibits “competitive waves” due to rival entry. We further analyze firm asymmetry in technology development and commercialization with economies of scale and examine how firm heterogeneity and market conditions impact on industry structure configuration. A firm with a headstart in technology development or with an advantage in commercialization involving economies of scale will invest when demand is low, while firms with neither advantage may enter only if demand is sufficiently large to accommodate more firms.

3 - Managing an Integrated Production and Inventory System Selling to a Dual Market: Long-Term and Walk-In

Mohsen Elhafsi, Essia Hamouda Elhafsi

We consider a manufacturer selling a product through two markets: long-term and walk-in. Walk-in demand materializes according to an independent Poisson process while long-term demand materializes according to a K-stage Erlang distribution. Additionally, demand for the product fluctuates due to varying state of the world conditions evolving according to a finite-state Markov chain. Units are produced ahead of demand, with exponentially distributed times. Sales revenue is collected upon fulfillment of demand. If orders cannot be fulfilled immediately, they are either backordered, in the case of the long-term market, or lost, in the case of the walk-in market. The objective of the manufacturer is to coordinate pricing, production scheduling and inventory allocation, in order to maximize the average expected profit. Due to the different characteristics of the two markets, the long-term market is quoted a single price while the walk-in market is dynamically priced. We compute the problem as a Markov decision process and characterize the structure of the optimal policy. We show that the optimal policy, in addition to specifying the optimal walk-in market sales price, is characterized by two state-dependent thresholds: one specifies how to allocate inventory among the two markets and the second specifies how to schedule production. We also study the special cases of static and state of the world dependent walk-in market pricing strategies as well as the case of a spot market where the price is exogenously set. Finally, we conduct numerical experiments to show how the optimal policy is affected by system parameters change.

4 - Disruptive Innovation, Market Entry and Production Flexibility in Oligopoly

Mohsen Elhafsi

Ata Jalili Marand

Benoit Chevalier-Roignant

1 - A Multi-Period Heuristic for Balancing Effort and Plan Quality in Tactical Supply Chain Planning

Annika Vernbro, Boris Anberg, Stefan Nickel

In Hierarchical Supply Chain Planning tactical planning is typically executed based on rolling horizons. While optimization models for tactical planning usually address the buckets of a planning horizon simultaneously, common heuristics can be found which plan buckets individually. If in practice planning personnel skilled in applying advanced methods is scarce, traceable heuristics may however be the planning method of choice. To allow integrated consideration of the buckets in a horizon, we extend a capacity constrained single-period heuristic to the multi-period-case. Incorporation of key aspects of plan quality is the first guiding design principle, in particular the incorporation of profit maximization as strategic objective, preparation of subsequent planning steps and contained variation in product-resource allocation as a typical operations-specific requirement. The second main principle is consideration of method tractability and intricacy requirements which may be encountered frequently in planning practice. In cooperation with BASF SE this multi-period heuristic has been benchmarked with regard to plan quality against MIP-based planning procedures for Supply Network Planning based on real world data typical for the chemical industry. We give examples how the extent and the nature of the complexities in the supply chain can drastically influence the ability of the multi-period heuristic to appropriately prepare and coordinate subsequent planning steps, in particular scheduling and procurement planning.

2 - Sequential vs. Integrated Solution Approaches for the Combined Manpower Teaming and Routing Problem

Yulia Anoshkina, Frank Meisel

In the context of workforce routing and scheduling there are many applications in which workers must perform geographically dispersed tasks, each of which may require a combination of skills or qualifications. In many such applications, a group of workers is required for performing a task in order to provide all needed qualifications. Examples are found in maintenance operations, the construction sector, health care operations, or consultancies. In this study, we analyze the combined problem of composing worker groups (teams) and routing these teams, under various goals expressing service-, fairness-, and cost-objectives. We develop mathematical optimization models for an integrated solution and a sequential solution of the teaming- and routing-subproblems. The resulting problem shares similarities with the VRP but it also differs in relevant aspects that result from the teaming decision and the qualification requirements. Computational experiments are conducted for identifying the tradeoff of better solution quality and computational effort that comes along with combining the two problems into a single monolithic optimization model. We also analyze the impact of the structure of teams on the different objectives and the efficiency of the provided services.

3 - Managing schedule instability in automotive supply networks: insights from an industry case

Tim Gruchmann

Within automotive supply chains schedule instability leads to inefficiencies at production processes of 1st tier suppliers and bears the risk of supply disruptions. Due to the market power of the OEM, 1st tier suppliers are not always able to influence the scheduling behavior of their customers. Consequently, they need to find an efficient way to protect their production against short-term demand variations. The placement of safety stocks, when designed effectively, is generally seen as a
probate instrument to reach a higher service level. Taking into consider-
ation the scheduling behavior of the customer, safety stocks can be
dimensioned more precisely. This paper presents an approach to setup
safety stocks calculated on the OEM’s forecast reliability. Moreover,
this approach is applied to an industry case. By applying the approach
to company data, relevant schedule instability related insights are ob-
tained.

**WE-21**

**Wednesday, 16:30-18:00 - RBM;4404**

**Flight Systems**

**Stream: OR in Engineering**

**Parallel session**

**Chair: Michael Hartisch**

1. **An NLP Model for Free-flight Trajectory Planning**
   
   Liana Amaya Moreno, Armin Fügenschuh, Anton Kaier, Sven Schlobach

   Free-flight emerged as a dynamic alternative to the traditional network
   approach of Flight Trajectory Planning. Free-flight trajectories are not
   aligned to an Air Travel Network (ATN), instead, the full 4D space
   (3D+time) is used for the computation of fuel-efficient trajectories that
   minimize the travel costs. From a computational point of view, the
   challenge is to find trajectories, composed of adjacent segments con-
necting two points (on the earth’s surface), that avoid head-winds and
benefit from tail-winds. The wind field usually differs in various flight
levels (altitudes), therefore the speed of the aircraft and a flight al-
titude must be assigned to the segments composing the trajectory so
the fuel consumption during the flight time is minimized. Moreover,
a time constraint is always enforced in order not to incur extra costs
due to early or late arrival. This problem is computationally difficult,
therefore it is solved in practice, in two subsequent stages: a horizon-
tal phase, in which the segments of a 2D trajectory are computed, and
then a vertical phase, in which different altitudes are assigned to the
segments. We propose a nonlinear programming model for the com-
putation of Free-flight trajectories. This model requires continuous for-
mulations of the problem’s input data such as the fuel consumption and
the weather data, hence approximation techniques are required. We in-
tegrate the formulation of these approximations into our NLP model
using AMPL as modelling language along with the solvers SNOPT,
KNITRO and MINOS. We present numerical results on test instances
using real-world data provided by our project partner Lufthansa Sys-
tems AG and compare the resulting trajectories in terms of the fuel
consumption and the trajectories themselves, and the computation times.

2. **Quantified Programming applied to Airplane Scheduling**
   
   Michael Hartisch, Simon Gnad

   Quantified Mixed Integer Programs (QMIps) are Mixed Integer Pro-
grams (MIPs) with variables being either existentially or universally
quantified. They are closely linked to two-person zero-sum games and
can be used to model problems under uncertainty. We investigate the
matching of airplanes to a finite set of time windows with a maximum
number of assigned planes per window. Planes usually have a given
time span in which they are expected to arrive at the destination airport.
Those time spans may alter due to unforeseen events. The optimiza-
tion goal is to find a good initial matching such that in the worst case
of disturbed arrival times the costs of replanning are minimized. For
each plane universally quantified variables are introduced to model the
possible alterations of their arrival time. It is extremely important to
model the possible disturbances thoroughly: Allowing extreme distur-
bances may result in an unpractical initial plan, whereas considering
only marginal changes will result in an non-robust plan regarding re-
alistic deviations. We present a QMIP model providing the intended
optimization goal and present modeling techniques to restrict the uni-
versal variables. Further, we show that solving QMIPs using a special-
ized solver can be beneficial compared to building the deterministic
equivalent program and solving the resulting MIP.

3. **Co-allocation of communication messages in an in-
tegrated modular avionic system**

   **Elina Rönnberg**

   Electronics in an aircraft is called avionics and nowadays the major-
ity of the avionics industry uses an integrated architecture called Inte-
grated Modular Avionics (IMA) where applications share hardware re-
sources on a common avionic platform. In such architectures it is vital
to prevent faults from propagating between different aircraft functions
and one component used to ensure this is pre-runtime scheduling of
the tasks and the communication in the system.

In the IMA-system considered in this paper the nodes communicate
over a switched Ethernet where communication messages are assigned
to and sent in discrete time slots in which the full bandwidth is avail-
able. To send a communication message also involves the execution of
a set of tasks, both on a module in a sending node and on a module in a
receiving node. The execution requirement (duration) of such tasks
constitutes of a fixed part for sending a message and a message specific
part for the content of the message. To co-allocate messages in a slot
means that these messages are treated as a single message and that the
tasks involved share the fixed part of the execution requirements. For
this reason, co-allocation of messages induces capacity savings at the
involved modules.

This paper extends a previous model for pre-runtime scheduling of
an IMA-system to facilitate the co-allocation of communication mes-
sages. The model is integrated in a constraint generation procedure
used for solving large-scale instances of practical relevance and we
show some preliminary computational results related to co-allocation
of messages.

**WE-22**

**Wednesday, 16:30-18:00 - HFB;A**

**MCDM 2: Multi-Criteria Optimization and
Uncertainty**

**Stream: Decision Theory and Multiple Criteria Decision
Making**

**Parallel session**

**Chair: Stefan Ruzika**

1. **Risk aversion of veto functions in multi-attribute utility
theory based preference models**

   **Andrej Bregar**

   Multi-attribute utility theory has been recently extended with the con-
cept of veto function, which has been adopted from the outranking
approach, and models full or partial non-compensation of unsatisfactory
preferences. In this research, forms and properties of the veto func-
tion are studied, particularly with respect to risk aversion. Outcomes
of risk averse, risk seeking and risk neutral veto functions are analysed
and compared for additive and multiplicative aggregation models, and
with regard to the decision-making problematics of choice, ranking
and sorting. Risk aversion of veto functions is also correlated with risk
aversion of utility functions, which are aggregated in the same multi-
attribute model and exhibit common complementary preference struc-
tures of the decision-maker. The aims of the study are to assess the
influence of risk aversion on the decision, to identify possible anomali-
ies in preference structures and outcomes, to determine the suitability
of different risk aversion formats and intensities for various problem
settings, and to derive key characteristics. The study is based on a sim-
ulation experiment. The experimental model considers several evalua-
tion factors, such as validity of results, robustness, ability to efficiently
discriminate alternatives, richness of output data, extremeness of re-
sults, consistency and relevance of judgements, and psychophysical
applicability.

2. **Scalarizations for multi-objective combinatorial
problems with cardinality-constrained uncertainty**

   **Lisa Thom, Marie Schmidt, Anita Schöbel**

   Two of the main difficulties in applying optimization techniques to
real-world problems are that several (conflicting) objectives may ex-
ist and that parameters may not be known exactly in advance. Multi-
objective robust optimization tackles these difficulties by combing
concepts and methods of two fields: In multi-objective optimization
several objectives are optimized simultaneously by choosing solutions
that cannot be improved in one objective without worsening it in an-
other objective. To find such solutions one often uses scalarization
methods, where the vector-valued objective function is replaced with
A scalar function. Robust optimization hedges against (all) possible parameter values, e.g., by assuming the worst case for each solution (min-max robustness). When solving robust optimization problems the definition of robust solution and the considered uncertainty set play an important role. In the popular concept of cardinality-constrained uncertainty only a bounded number of parameters differs from their minimal value. In this talk, we introduce an extension of cardinality-constrained uncertainty to multi-objective optimization. Further, we present two scalarization methods for multi-objective min-max robust problems, the min-max-min and min-max-max scalarization. We then apply these scalarization methods to multi-objective combinatorial optimization problems with cardinality-constrained uncertainty. We develop MILP-formulations for the resulting problems and investigate their complexity for particular combinatorial problems.

3 - A General Approximation Algorithm Applied to Biobjective Mixed Integer Programming Problems

Stefan Ruzika, Xavier Gandibleux, Pascal Haddad, Flavien Lucas

There exist several approaches for approximating general biobjective minimization problems (see e.g. the work of Papadimitriou and Yannakakis or the work of Gäfvert et al.). The output of these algorithms is a set of feasible solutions which constitutes a $(alpha, beta)\$-approximation of the efficient set, i.e., for every efficient solution there exists an approximating solution which dominates this efficient solution up to a factor of $S_M alpha$ in the first objective and up to factor of $S_M beta$ in the second. The specific values of $S_M alpha$ and $S_M beta$ depend on the algorithm used. In this talk, we will present the theory of a new approximation algorithm. This algorithm relies on iteratively solving weighted-sum scalarization problems for a certain set of weights. We prove correctness, the approximation quality and a bound on the runtime of the algorithm. Moreover, we report on some ongoing work which is concerned with studying how this algorithm (which is mainly motivated by theoretical considerations) can be applied to a difficult class of problems, that is biobjective mixed integer programming problems.

The players' stubbornness is the scaling factor used to counterbalance the two contributions to the players' payoff. We derive tight upper and lower bounds on the efficiency of Nash equilibria as functions of the players' stubbornness. Differently from the previous setting, where the social influences are assumed to be static, we also present simple opinion formation games with dynamic social influences, where opinion formation and social relationships co-evolve in a cross-influencing manner. We show that these games always admit an ordinal potential, and so, pure Nash equilibria, and we design a polynomial time algorithm for computing the set of all pure Nash equilibria and the set of all social optima of a given game. Also in this case we present bounds on the efficiency of Nash equilibria as functions of the players' stubbornness.

3 - Opinion Formation with Aggregation and Negative Influence

Martin Hoefer

We study continuous opinion formation games with aggregation aspects. In many domains, expressed opinions of people are not only affected by local interaction and personal beliefs, but also by influences that stem from global properties of the opinions present in the society. To capture the interplay of such global and local effects, we propose a model of opinion formation games with aggregation, where we concentrate on the average public opinion as a natural way to represent a global trend in the society. While the average alone does not have good strategic properties as an aggregation rule, we show that with a limited influence of the average public opinion, the good properties of opinion formation models are preserved.

More formally, we show that a unique equilibrium exists in average-oriented opinion formation games. Simultaneous best-response dynamics converge to within distance $\eps$ of equilibrium in $O(2^{ln(n/\eps)})$ rounds, even in a model with outdated information on the average public opinion. For the price of anarchy we show a small bound of $9/8+o(1)$, almost matching the tight bound for games without aggregation. Moreover, we prove some of the results in the context of a general class of opinion formation games with negative influences, and we extend our results to cases where expressed opinions must come from a restricted domain.

WE-23
Wednesday, 16:30-18:00 - HFB B

Opinion Formation (I)

Stream: Game Theory and Experimental Economics
Parallel session
Chair: Martin Hoefer

1 - Opinion Formation Games in Social Networks
Diodato Ferraioli

In a discrete preference game, each agent is equipped with an internal belief and declares her preference from a discrete set of alternatives. The payoff of an agent depends on whether the declared preference agrees with the belief of the agent and on the coordination with the preferences declared by the neighbors of the agent in the underlying social network. These games have been used to model the formation of opinions and the adoption of innovations in social networks.

In this talk, we survey recent results about the Price of Anarchy and on the Price of Stability of discrete preference games and the rate of convergence of (noisy) best-response to equilibria. Finally, we use these games to highlight the extent at which social and time pressure can alter the choices taken on a social network.

The talk is based on joint work with Vincenzo Auletta, Ioannis Caragiannis, Clemente Galdi, Paul W. Goldberg, Giuseppe Persiano, and Carmine Ventre.

2 - Opinion Formation in a Metric Space and Dynamic Social Influences
Angelo Fanelli

We consider opinion formation games in which the strategy set of the players is endowed with a distance function which determines a notion of "similarity" among strategies. A player's payoff is determined by two components: the distance from her chosen strategy to her preferred strategy (inmate belief) and the weighted average of the distances from her chosen strategy to the strategies chosen by her network neighbors, where the weights denote the strength of the neighbors' influence.

WE-24
Wednesday, 16:30-18:00 - HFB C

Multiobjective Linear Programming and Global Optimization

Stream: Control Theory and Continuous Optimization
Parallel session
Chair: Andreas Löhne

1 - Algorithm for solving bilevel optimization problems being polyhedral on the lower level
Alexandra Rittmann

This talk presents an algorithm for solving bilevel optimization problems (BLP) being polyhedral on the lower level. Bilevel optimization problems are mathematical optimization problems, where a part of the constraints of the lower level problem are determined by the solutions of a second optimization problem, the lower level problem. In general this leads to non-convex constraints on the upper level.

Fulop [1993] has shown, that linear bilevel optimization problems can be solved by optimizing the upper level objective function over the set of Pareto-optimal extremal points of a corresponding multiple objective linear program (MOLP). By picking up this idea we propose an algorithm which is an extensions of Benson's outer approximation algorithm for solving linear vector optimization problems to compute the feasible set of (BLP). Furthermore the algorithm uses branch and cut techniques to construct hyperplanes which are added to the inequality representation of the feasible set of (MOLP) in order to avoid the calculation of all feasible points of (BLP).
2 - Bensolve tools - polyhedral calculus with Mat-lab/Octave
Andreas Löhne, Benjamin Weißing, Daniel Ciripoi

We present a tool box to treat the following problem classes with Mat-lab and Octave: 1. Calculus of convex polyhedra and polyhedral con-

vex functions. 2. Multiobjective linear programming. 3. Global opti-
mization.

Among other operations, one can compute the Minkowski sum, in-

tersection and the convex hull of the union of two convex polyhedra; moreover, the polar, an H-representation and a V-representation of a

convex polyhedron. The tool box also covers subset testing. Given two polyhedral convex functions, we provide commands to compute, for instance, their infimal convolution, pointwise maximum or lower convex envelope. Also, one can compute the conjugate of a polyhedral convex function. The global optimization part covers problem classes like minimization of a quasi-concave convex function under linear con-

strains, minimizing the difference of two polyhedral convex functions

and others.

The toolbox is based on the vector linear programming solver Ben-
solve and a recent result saying that polyhedral projection is equivalent to multiobjective linear programming.

3 - Decomposition-based Inner- and Outer-Refinement Algorithms for Global Optimization without Branching
Ivo Nowak

Traditional deterministic global optimization methods are often based

on a branch-and-bound tree, which may grow rapidly, preventing the

method to find a good solution. Motivated by column generation

methods for solving transport scheduling problems with over 100 mil-

lion variables, we present a new deterministic global optimization

approach, called Decomposition-based Inner- and Outer-Refinement

(DIOR), which is not based on branch-and-bound.

DIOR can be applied to general modular and/or sparse optimization

models. It is based on a block-separable reformulation of the model

into sub-models, which can be solved in parallel. In the first phase, the

algorithm generates inner- and outer-approximations using column
generation. In the second phase, it refines a nonconvex outer approxi-

mation based on a convex-concave reformulation of sub-problems. Lo-
cal solutions are computed by a decomposition-based alternating direc-
tion method. We present preliminary numerical results with Decogo, a

new DIOR-based MINLP solver implemented in Python and Pyomo.

WE-26
Wednesday, 16:30-18:00 - HFB Senat

Managerial Economics
Stream: Game Theory and Experimental Economics
Parallel session
Chair: Rainer Kleber

1 - Inspection strategies and risk self-assessment - an extension of the classical inspection game
Jan Trockel, Benjamin Florian Siggelkow

In this paper we set forth the conditions governing the probability of
the reduction of intensive auditor’s control and discuss how this de-
crease proves beneficial for the organization assigning the audit. We
also show that the unique roles of risk management and internal au-
dit decrease the level of risk in the organization. Firstly, the classical
inspection game is adapted to an approach of internal auditing with
one auditee and one internal auditor. Secondly, the number of auditees
is increased to two auditees. Thirdly, we extend the classical inspec-
tion game by risk self-assessment of the auditees, that we define as the
risk management game. It can be shown that the control probability in
the three-person approach is lower than in the classical inspection
game. In the auditee-auditee-auditor approach, the auditees’ probabil-
ity of correct behavior increases as well and thus leads to better risk
management for the organization.

2 - Audit Strategies in the Presence of Evasion Capabilities: a Mechanism Design Approach
Francis de Vericourt

In this work, we provide managerial insights on how to uncover an ad-
verse issue that may occur in organizations with the capability to evade
detection. To that end, we formalize the problem of designing efficient
auditing and remediation strategies as a dynamic mechanism design
problem. In this set-up, a principal seeks to uncover and remedy an is-

sue that occurs to an agent at a random point in time, and which harms
the principal if not addressed promptly. This occurrence is the agent’s
private information. Further, the agent can exert effort to render the
principal’s audit ineffective at discovering the issue. We fully charac-
terize, in closed form, the corresponding optimal policy, which can be
implemented as a dynamic remediation cost-sharing mechanism with
cyclic audits. We show that the strength of the agent’s evasion capability changes the nature of the audit policy. When the effort cost is high (i.e., the evasion capability is weak), the principal runs the audit according to a pre-determined schedule. However, when the effort cost is low (i.e., the evasion capability is strong), the audit schedule becomes random. Further, as the effort cost increases and the evasion capability becomes more limited, the principal audits the agent more frequently, which overall results in higher audit costs.

3 - On the Robustness of the Consumer Homogeneity Assumption with Respect to the Discount Factor for Remanufactured Products
Rainer Kleber, Marc Reimann, Gilvan C. Souza, Weihua Zhang

The strategic closed-loop supply chains (CLSCs) literature makes the assumption that a consumer’s willingness-to-pay (wtp) for a remanufactured product is a fraction of his/her wtp for the corresponding new product, and this fraction, called discount factor, is assumed to be constant among consumers. Recent empirical research challenges this assumption, by showing that there is considerable variability in discount factors among consumers. This paper considers a complex model in the CLSC literature: strategic remanufacturing under quality choice, and compares its solution under constant discount factors with the solution that assumes a probability distribution for the discount factors (which is analytically intractable and must be obtained numerically). We consider quality choice and remanufacturing for both monopoly and competitive cases. Overall, we find remarkable consistency between the results of the constant and variable discount factor models. Thus, we make a convincing argument that the constant discount factor assumption is robust and can be used due to its tractability.
Thursday, 9:00-10:30

**TA-01**

*Thursday, 9:00-10:30 - WGS101*

**Risk Aversion in Stochastic Programming**

Stream: Optimization under Uncertainty

Parallel session

Chair: Matthias Claus

1 - Risk averse scheduling with scenarios

*Mikita Hradovich, Adam Kasperski, Pawel Zielsinski*

We are given a set of jobs which must be executed on some machines. For each job a set of parameters, such as a processing time, a due date or a weight can be specified. In the classic deterministic case the values of these parameters are known precisely and we seek a schedule which minimizes a given cost function. In practical applications, the exact values of the parameters are rarely known in advance. We can model this uncertainty by introducing a scenario set, containing a set of possible parameter realizations. One popular method of defining scenario set is the discrete uncertainty representation, under which a finite set of scenarios is given, and the parameters are defined as uncertain random variables with known probability distribution. In order to compute a solution the popular risk criteria, such as the value at risk and the conditional value at risk, can be used. These criteria allow us to establish a link between the very conservative maximum criterion, typically used in robust optimization, and the expectation, commonly used in the stochastic approach. Using them we can take a degree of risk aversion of decision maker into account. In this paper we consider various scheduling models with a specified scenario set and the risk criteria for choosing a solution. We show some new negative and positive complexity results for them.

2 - On stability of stochastic bilevel programs with risk aversion

*Matthias Claus*

Two-stage stochastic programs and bilevel problems under stochastic uncertainty bear significant conceptual similarities. However, the step from the first to the latter mirrors the step from optimal values to optimal solutions and entails a loss of desirable analytical properties. The talk focuses on mean risk formulations of stochastic bilevel programs where the lower level problem is quadratic. Based on a growth condition, weak continuity of the objective function with respect to perturbations of the underlying measure is derived. Implications regarding stability for a comprehensive class of risk averse models are pointed out.

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**TA-02**

*Thursday, 9:00-10:30 - WGS102*

**Nonlinear Programming Solvers and Specialized Interfaces**

Stream: Software Applications and Modelling Systems

Parallel session

Chair: Renke Kuhlmann

1 - WORHP Zen: A Parametric Sensitivity Analysis for the Nonlinear Programming Solver WORHP

*Renke Kuhlmann, Sören Geffken, Christof Böskens*

Nonlinear optimization problems that arise in real-world applications usually depend on parameter data. Parametric sensitivity analysis is concerned with the effects on the optimal solution caused by parameter changes. The calculated sensitivities are of high interest because they improve the understanding of the optimal solution and allow the formulation of real-time capable update algorithms. We present a sensitivity analysis module for the nonlinear programming solver WORHP that is capable of the following: (i) Efficient calculation of parametric sensitivities using an existing factorization; (ii) efficient sparse storage of these derivatives, and (iii) real-time updates to calculate an approximated solution of a perturbed optimization problem. Finally, an application of WORHP Zen in the context of parameter identification is presented. Besides the fitting of the parameters, a somehow contrary goal is to minimize the curvature of the resulting parameter maps. Here, the parametric perturbation is the weight for the curvature component of the objective function. Choosing a suitable weight can be a difficult task for the user. The computed sensitivity fields greatly increase the understanding of the effects of this perturbation to the resulting model.

2 - Efficient Computation of Pareto Frontiers with the Multi-Objective Interface of WORHP

*Arne Berger, Sören Geffken, Christof Böskens*

In order to solve non-linear problems which consist of multiple objectives, one usually solves scalarized subproblems. One method is the Pascoaletti-Seralini scalarization. The solutions of these subproblems represent samples of the so called Pareto-Front. Challenges are for example the minimization of computational effort and the generation of an evenly distributed set of samples. Parametric sensitivity analysis can be used to tackle both of these problems. It can be used for: (i) Calculating good initial guesses based on the solution of scalarized problems which are "near by". (ii) Implementation of an adaptive variation of hyper-parameters in order to improve the distribution of sample points on the Pareto-Front. This talk will present how the information gained by parametric sensitivity analysis is exploited within the multi-objective interface of the NLP solver WORHP. Numerical results will be demonstrated using an example from parameter identification.

3 - On the performance of NLP solvers within global MINLP solvers

*Benjamin Müller, Renke Kuhlmann, Stefan Vigerske*

Solving mixed-integer nonlinear programs (MINLPs) to global optimality efficiently requires fast solvers for continuous sub-problems. These appear in, e.g., primal heuristics, convex relaxations, and bound tightening methods. Two of the best performing algorithms for these sub-problems are Sequential Quadratic Programming (SQP) and Interior Point Methods.

In this talk we present the impact of different SQP and Interior Point implementations on important MINLP solver components that solve a sequence of similar NLPs. We use the constraint integer programming framework SCIP for our computational studies on instances of the minlpbenchmark instance library.

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**TA-03**

*Thursday, 9:00-10:30 - WGS103*

**Vehicle Routing - Column Generation**

Stream: Logistics and Freight Transportation

Parallel session

Chair: Stefan Imich

1 - Branch-and-Price-and-Cut for the Periodic Vehicle Routing Problem with Different Schedule Structures

*Ann-Kathrin Rothenbächer*

This paper deals with the periodic vehicle routing problem with time windows (PVRPTW). A set of customers requires one or several visits during a planning horizon of several periods. Given schedules per customer determine the offered visit period combinations. In previous work, each customer usually was assumed to require a specific visit frequency and to offer all corresponding schedules with regular inter-vals between the visits. In this paper, we permit all kinds of schedule structures and the choice of a higher service frequency. We present an exact branch-and-price-and-cut algorithm for the classical PVRPTW and its variant with more flexible schedules. The pricing problem is based on two new networks and solved with a labeling algorithm, which uses several known acceleration techniques as the NG relaxation and dynamic half-way points within bidirectional labeling. For the case of periodic schedules, we apply some ideas to effectively deal with the symmetry. Computational tests on benchmark instances for the PVRPTW show the effectiveness of our algorithm. Furthermore, extensive comparisons analyze the different schedule structures.
2 - Bidirectional Labeling in Column-Generation Algorithms for Pickup and Delivery Problems
Timo Guschwind, Stefan Irnich, Ann-Kathrin Rothenbächer, Christian Tilk

For the exact solution of many types of vehicle routing problems, column-generation based algorithms have become predominant. The column-generation subproblems are then variants of the shortest-path problem with resource constraints which can be solved well with dynamic programming algorithms. For vehicle routing problems with a pickup-and-delivery structure, the strongest known dominance between two labels requires the delivery triangle inequality (DTI) for reduced costs to hold. When the direction of labeling is altered from forward labeling to backward labeling, the DTI requirement becomes the pickup triangle inequality (PTI). DTI and PTI cannot be guaranteed at the same time. The consequence seemed to be that bidirectional labeling, one of the most successful acceleration techniques developed over the last years, cannot be effectively applied to pickup and delivery problems. In this paper, we show that bidirectional labeling with the strongest dominance rules in forward as well as backward direction is possible and computationally beneficial. A full-fledged branch-and-price-and-cut algorithm is tested on the pickup and delivery problem with time windows.

3 - Nested column generation for a rich vehicle routing problem
Christian Tilk, Stefan Irnich

In this talk, we consider an extension of the vehicle routing problem with time windows in which additionally minimum and maximum delivery quantities for each customer are given and a customer-dependent profit is paid for each demand unit delivered. Additionally, synchronization between some pairs of customers is required. We call the problem vehicle routing problem with time windows, soft demand and customer synchronization (VRPTWSDC). We solve the problem with a branch-and-price algorithm. The corresponding subproblem is an elementary shortest path problem with resource constraints (ESPPRC) in which a tradeoff between cost and time as well as a tradeoff between load and time exists. For the exact solution of many ESPPRC variants, dynamic programming based labeling algorithms are predominant. When using a labeling algorithm to solve the subproblem of the VRPTWSDC, the handling of the tradeoffs necessitates the usage of two interdependent tradeoff curves resulting in a weak dominance criterion such that the algorithm is almost a pure enumeration. Therefore, we solve also the subproblem with branch-and-price. The arising sub-subproblem asks for negative reduced-cost paths that are feasible with respect to time windows, minimum delivery quantities and precedences arising from the synchronization constraints. The sub-master problem then determines the visiting time and the delivery quantity for each customer. This results in a multi-layer branch-and-price algorithm. Therein, some data generated in the upper layers can be useful in the lower layers and vice versa. We analyze different variants of the algorithm to enable, e.g., the exchange of columns between the different layers.

2 - The Free Route Flight Planning Problem on Airway Networks
Adam Schienle, Marco Blanco, Ralf Borndörfer, Nam Dung Hoang

The Flight Planning Problem (FPF) deals with finding a minimum cost flight trajectory subject to initial conditions such as departure and destination airport, fuel cost and weather conditions. Traditionally, an aircraft’s horizontal route is restricted to the Airway Network, a directed graph. Time dependent weather conditions allow us to model the FPF as a Time-Dependent Shortest Path Problem. Since the Airway Network is prevalent almost everywhere on earth, this structure renders combinatorial shortest path algorithms, such as Dijkstra's algorithm and algorithms derived from it, a natural choice for solving FPF. It is interesting to give the users of the Airway Network more freedom in planning their routes, together with easing congestion in parts of the network, giving rise to an increasing number of Free Route areas. Essentially, these are regions where there is no network defined at all, or where it is allowed to travel directly between any two points of the network, thus corresponding to cliques in the directed graph. This leads to the Free Route Flight Planning Problem, whose altered network structure impacts the performance of combinatorial shortest path algorithms. In the talk, we shall discuss different algorithmic approaches to solve the Free Route Flight Planning Problem.

3 - Cost Minimal Aircraft Trajectories on Airway Networks
Pedro Maristany de las Casas, Marco Blanco, Ralf Borndörfer, Nam Dung Hoang

Given the departure and destination airports, the Flight Planning Problem (FPF) seeks to find cost minimal flight trajectories for commercial aircraft along the Airway Network (A.N.), which is modeled as a dagraph.

In a static setting of the FPF, where time dependent components are neglected, the two main cost components for such a trajectory are fuel and overflight costs (OFC). While fuel costs can be defined as costs on the arcs of the A.N., there are many airspaces, such as European ones, where OFCs do not depend on the chosen route within the airspace, but instead are linearly dependent on the great-circle distance between entry and exit nodes for this airspace.

In this talk we will discuss the Shortest Path Problem with Crossing Costs (SPPCC), a generalization of the known Shortest Path Problem (SPP), which translates the described properties into a combinatorial problem. Crossing Costs are the general term used to refer to overflight costs.

The talk will begin with a brief analysis of the complexity of the SP-PCC. The polynomial case described above can be solved using an algorithm called Two Layer Dijkstra (2LD), which yields a non-satisfactory runtime in practice.

Thus, during the talk, we will mainly focus on the analysis of different methods that can be used to distribute the exact OFCs over the arcs of the corresponding region. Finding good such methods allows us to reduce SPPCC instances to SPP instances, thus being able to approximate a solution to the original problem extremely fast. This reduction does not only perform well concerning the runtime of the algorithm (x708 faster in average than using the 2LD), but also concerning the quality of the approximated solutions: they differ by 0.09% from the optimal ones.
1 - Robust Recoverable Matchings on a Budget  
Moritz Mühlenhajler, Viktor Binnewald

We investigate the complexity of making matchings in a graph robust against the deletion of edges. The robustification happens either before fixing a particular matching or afterwards. In both settings there are budget restrictions for deleting edges and repairing a matching. In the former setting, the task has recently been proved to be NP-hard. We show that for a suitable restriction of the input graphs the problem becomes tractable. To the best of our knowledge, the second setting has not been considered before and we present a number of complexity results. They indicate that making existing infrastructure robust is as hard as designing robust infrastructure.

2 - A New Integer Linear Programming Model for the Vertex Coloring Problem  
Adalat Jabrayilov

The vertex coloring problem asks for the minimum number of colors that can be assigned to the vertices of a given graph such that for all vertices v the color of v is different from the color of any of its neighbors. The problem is NP-hard. Here, we introduce a new integer linear programming formulation which is based on partial orderings. It has the advantage that it is as simple to work with as with the “classical assignment formulation”, since it can be fed directly into a standard integer linear programming solver. We evaluate our new model using Gurobi and show that our new simple approach is a good alternative to the best state-of-the-art approaches for the vertex coloring problem. We also compared our formulation with other simple formulations like the “classical assignment formulation” and “representative formulation” on a large set of benchmark graphs as well as randomly generated graphs. The evaluation shows that our new model dominates both formulations for sparse graphs, while the representative formulation is best for dense graphs.

3 - Mixed-Integer Programming Models for Multiprocessor Scheduling with Communication Delays  
Sven Mallach

We revise existing and introduce new mixed-integer programming models for the Multiprocessor Scheduling Problem with Communication Delays and the objective to minimize the makespan. Especially, we reveal that the feasible region of almost all existing formulations contains redundant solutions and formulate new constraints in order to exclude these. As a result and by exploiting further structural properties, the models are improved in their strength and, at the same time, in terms of their size and modeling complexity. This inevitably leads to new more compact formulations which are then experimentally compared with each other and with further formulations from the literature.

The Travelling Salesman Problem (TSP) is a combinatorial optimization problem to which the optimal solution cannot be found in a reasonable short time for large instances. In this paper we are going to describe a new heuristic, which, according to our research, has not been discussed in scientific literature yet. Our heuristic starts with an infeasible solution of a TSP that includes subtours. Such an infeasible solution is exact and can be found through integer programming. If then tries to merge these subtours fast and cost-efficiently, so that the increase in cost in every merging step is as small as possible. The basic idea is to generate a problem-based metric to get information on the approximated distances between the subtours. As a result, we are able to estimate which subtours should be merged. In a second step, we will upgrade the basic idea to improve the subtour-selection. Finally, we will improve the subtour joining by developing different ideas for minimal cost increase during the merging process.

We will present our findings in the form of a benchmark-study, which compares 3-Opt with our heuristic as well as the different selection methods within our heuristic, applying the well-known data-set USA13509.

3 - Cost-Dependent Clustering: A General Multiscale Approach to Optimal Transport  
Jörn Schrieber, Anita Schöbel, Dominic Schuhmacher

Optimal transport is a classical problem with a variety of modern applications. The Wasserstein or earth mover’s distance obtained from it is a useful tool in computer science, engineering and statistics. However, large optimal transport problems are still computationally challenging. The recent past has seen the advent of a variety of multiscale methods to tackle large discrete optimal transport problems, where solutions to coarser versions of the problem are used to initialize the finer problem. While many different algorithms have been proposed to be used with a multiscale scheme, the scaled instances themselves are mostly generated as simple coarsenings of the original instances. Cost-dependent clustering is a new approach to construct small-scale approximations of discrete optimal transport instances by coupling points with regard to similar cost vectors. Using the solution to the clustered problem, we derive upper and lower bounds on the optimal value of the original instance. The clustering approach is independent of the structure of the underlying space and can be applied to general cost functions.

Computational Mixed-Integer Programming 1

Stream: Discrete and Integer Optimization  
Parallel session

Chair: Ambros Gleixner

1 - Exploring the Numerics of Branch-and-Cut for Mixed Integer Linear Optimization  
Matthias Miltenberger, Ted Ralphs, Daniel Steffy

We investigate how the numerical properties of the LP relaxations evolve throughout the solution procedure in a solver employing the branch-and-cut algorithm. The long-term goal of this work is to determine whether the effect on the numerical conditioning of the LP relaxations resulting from the branching and cutting operations can be effectively predicted and whether such predictions can be used to make better algorithmic choices. In a first step towards this goal, we discuss here the numerical behavior of an existing solver in order to determine whether our intuitive understanding of this behavior is correct.

2 - Measuring the Impact of Branching Rules for MIP  
Gerald Gamrath, Christoph Schubert

Branching rules are an integral component of the branch-and-bound algorithm typically used to solve mixed integer programs and subject to intense research. Different approaches for branching are typically compared based on the solving time as well as the size of the branch-and-bound tree needed to prove optimality. The latter, however, has some flaws when it comes to sophisticated branching rules that do not
only try to take a good branching decision, but have additional side-effects. We propose a new measure for the quality of a branching rule that distinguishes tree size reductions obtained by better branching decisions from those obtained by such side-effects. It is evaluated for common branching rules providing new insights in the importance of strong branching.

3 - Compiling MIPLIB 2017: the 6th Mixed-Integer Programming Library
Ambros Gleixner

Since its first release in 1992, MIPLIB has become a standard test set used to compare the performance of mixed-integer linear optimization software and to evaluate the computational performance of newly developed algorithms and solution techniques. It has been a crucial driver for the impressive progress we have seen over the last decades. In this talk we will give an overview of the activities to compile the sixth edition of MIPLIB and present the current status. This work is only possible due to the concerted efforts of many researchers and developers from academic and commercial MIP solver software.

Data-driven Transportation Analysis

Stream: Traffic, Mobility and Passenger Transportation
Parallel session
Chair: Alexander Immer

1 - Analyzing Temporal Mobility Patterns of Senior and Disabled Passengers in a Multimodal Setting
Büşra Sevinç, Uğur Eliyiyi, Selma Gürler

Providing a comfortable public transportation service to its senior and disabled citizens is one of the vital topics for a metropolitan city in order to reach higher liveability rankings. Izmir, the third largest city of Turkey, needs to improve also in that aspect all through its vast multimodal transit network. In view of that, we consider a temporal ridership analysis of senior and disabled passengers, who regularly use a specific intermodal transfer center in Izmir. The active transport modes evaluated for that center are bus, metro and ferry systems. The location-specific boarding data includes immediate connections’ info, namely for both previous and subsequent transfer trips if present. The boarding times are analyzed synchronously with scheduled departure or arrival times of the buses, trains or ferries for getting more robust results. The boarding fees of the disabled and senior passengers are waived totally or partially with respect to age intervals. Therefore, time-stamped ridership statistics might reflect the mobility preferences of those passengers regarding factors such as vehicle types, peak-hour utilization, traffic congestion and accessibility issues. The individual trip patterns of passengers are examined over a four-week period. Apart from the individual trips of a day for a passenger, her trips in consecutive days are also evaluated for drawing preferred route info, namely for both previous and subsequent transfer trips if present.

2 - Joint Travel Mode Detection and Segmentation using Recurrent Neural Networks
Alexander Immer, Florian Stock, Patrick Wagner

Transportation survey data is highly useful for planning and optimising infrastructure or understanding human mobility behaviour. Smartphones allow the collection of location and sensory data with few or no interaction of study participants. To make use of such data, especially when available in high volume, it is necessary to detect transportation modes and changepoints in between these automatically. We propose a mode detection and journey segmentation algorithm based on a recurrent neural network with gated recurrent unit (GRU). Previously proposed methods have either neglected the temporal characteristic of such data by classifying time frames individually or used methods that are restricted to a fixed order of temporal dependencies. In real-world studies, we collected more than 2000 hours of labelled travel data hundreds of different users with various devices. We are therefore able to train and evaluate our models on one of the largest and most general data sets of such kind. We investigate if treating the data as sequences, i.e. structured objects, leads to superior performance compared to other recently successful approaches.

3 - Enhancing option bundling for automotive manufacturers by reducing demand variability
Rada Constantin Popa, Martin Grunow

Premium automotive manufacturers strive to maintain a competitive advantage by offering their customers a wide array of customization possibilities by means of options. The heterogeneity of customer preferences that results from the freedom of choice leads to difficulties in accurately forecasting the demand for options. Automotive manufacturers use the forecasts to plan production and to derive the component demands that are communicated to the suppliers. The uncertainty regarding the accuracy of these requirements and the pressure to cope with component demands changed on a short notice can severely strain the relationship of the automotive manufacturers with the suppliers. Our work presents a branch and price approach that enhances the design of bundles by minimizing the variability of the demand of the options alongside the maximization of the revenues. We highlight the advantages of simultaneously considering both perspectives compared to traditional option bundling approaches that focus only on improving revenues or profits. We also analyze the impact of input parameters, such as the willingness to pay of customers for individual options or the discounts offered for the combination of bundles, on the bundling decisions designed by our approach, as well as the resulting revenues and options demand variability.

Location Problems

Stream: Discrete and Integer Optimization
Parallel session
Chair: Andreas Klose

1 - Cut generation algorithm for the competitive facility location problem
Andrey Melnikov, Vladimir Beresnev

The paper considers a Stackelberg game where two players sequentially open their facilities with egoistic aims to maximize own profits calculated as income from service customers minus cost of open facilities. Both the set of potential facility locations and the set of customers are assumed to be finite and known for the players. It is assumed that each customer has preferences represented with a linear order on the set of potential facilities and utilizes a single facility to satisfy his or her demand. In the model, a player can service a customer only with a facility which is more preferable for the customer than any another player’s facility. The problem can be written in terms of bilevel mixed-integer linear programming. A cut generation scheme suggested in the present paper obtains an optimal solution of the model by solving a series of common MIPs derived from the initial bilevel program with an inner goal function excluded (so-called high-point problem). An obtained single-level program is iteratively supplemented with inequalities approximating a feasible region of the bilevel program. The inequalities are taken from an exponential family of valid cuts based on properties of optimal solutions of the inner problem. The idea behind these inequalities is to formulate a sufficient condition of a subset of facilities to contain a facility which is open in optimal Follower’s solution. By adding the mentioned inequalities coupled with constraints forcing Follower’s variables to take their optimal values for a given value of Leader’s variables, the solutions of obtained MIPs converge to the optimal solution of the initial bilevel program. Numerical experiments show that a number of added cuts and, consequently, a number of solved MIPs is relatively small.

2 - Crane selection and location on construction sites
Michael Dienstknecht, Dirk Briskom

Cranes are a key element on construction sites and are among the most expensive construction equipment. Thus, crane selection and location are an important factor with respect to a construction project’s profitability. In this research, a set of pairs of supply and demand areas - modelled as polygons - on a polygonal construction site has to be covered by tower cranes. For covering these pairs, there are different types of tower cranes available, each with specific attributes such as rental cost and working radius. The goal is to find a minimum-cost
3 - A branch-and-bound algorithm for the capacitated facility location problem with convex production costs

Andreas Klose

We consider the capacitated facility location problem (CFLP) with differentiable convex production cost functions. The problem arises in numerous real-world applications including queues in call-centres, transportation, or graph coloring problems as examples. Here the variables assigning requests for exchange to a common pool. These requests are then combined to a set of bundles by a central authority and offered back to all participating carriers. After a bidding phase, the central authority allocates requests to carriers according to their preferences. Gained profits are divided among participating carriers. Such auction-based exchange mechanisms can be performed without any information sharing of carriers’ sensitive data. In this study we investigate how shared information in a combinatorial transportation auction improves the total collaboration profit. We develop different concepts, where carriers share aggregated information on their existing customers with (i) the auctioneer and/or (ii) other carriers. Through a computational study we assess the effectiveness of the proposed concepts.

1 - Forming near-optimal regions from bids of less-than-truckload logistics providers on country subdivisions in reverse auctions

Jan-Philipp Eisenbach, Felix Zesch

Shippers usually contract logistics service providers (LSP) for less-than-truckload (LTL) shipments by giving all transports originating in one region and going to one or more destinations to one single LSP. The assignment of LSPs to regions is usually done in reverse auctions. In the current process, the country needs to be divided into such regions before LSPs can bid on them. In Germany, these regions are often based on arbitrary grouping of administrative divisions such as areas with the same two-digit zip codes. There is no accepted methodology for this decision process. We propose a methodology for dividing a country into regions based on bids from different LSPs on single administrative divisions. Each LSP can reduce costs if the sources of its LTL-shipsments are close to each other. Our approach is to have each LSP bid on several single administrative divisions, leaving us to combine them to regions respecting the LSPs’ general requirements. This creates a geometric set cover problem with additional constraints: a) the regions must not overlap b) they must respect some real-world capacity constraints c) they must respect the bids of each LSP. Our solution proposes to integrate these modifications into the geometric set cover problem and to build an approximation algorithm finding near-optimal cuts through the entire country. After presenting the current and new bidding processes, the new dynamic region cutting methodology with the algorithm developed is compared to the existing static approach with an industry dataset. In addition, we discuss whether an LSP can exploit the new bidding process through untruthful bids. The cost effect of relaxing several constraints is explored, providing managerial insight on the newly designed bidding process.

2 - The benefit of information sharing in horizontal carrier collaborations

Margareta Gansterer, Richard Hartl, Martin Savelsbergh

In horizontal collaborations, carriers form coalitions in order to perform parts of their logistics operations jointly. By exchanging transportation requests among each other, they can operate more efficiently and in a more sustainable way. This exchange of requests can be organized through combinatorial auctions, where collaborators submit requests for exchange to a common pool. These requests are then combined to a set of bundles by a central authority and offered back to all participating carriers. After a bidding phase, the central authority allocates requests to carriers according to their preferences. Gained profits are shared among participating carriers. Such auction-based exchange mechanisms can be performed without any information sharing of carriers’ sensitive data. In this study we investigate how shared information in a combinatorial transportation auction improves the total collaboration profit. We develop different concepts, where carriers share aggregated information on their existing customers with (i) the auctioneer and/or (ii) other carriers. Through a computational study we assess the effectiveness of the proposed concepts.

10 - Feature Engineering, Segmentation and Optimization

Stream: Business Analytics, Artificial Intelligence and
Forecasting
Parallel session
Chair: Evren Guney

1 - A First Derivative Potts Model for Denoising and Segmentation Using MILP
Ruoqing Shen, Gerhard Reinelt, Stéphane Canu

Unsupervised image segmentation and denoising are two fundamental tasks in image processing. Usually, graph-based models such as graph cuts or multicuts are used for globally optimum segmentations and variational models like total variation are employed for denoising. Our approach addresses both problems at the same time. An image can be seen as a function $y: \mathbb{R} \rightarrow \mathbb{R}$ giving the intensity of pixels located on a finite 2-dimensional grid $P$. The segmentation problem is tackled by fitting a piecewise constant function $f: P \rightarrow \mathbb{R}$ to $y$ minimizing

$$\sum_{p \in P} \|f(p) - y(p)\|^2 + \text{L}_0 \text{ regularization term}$$

with the L_0 norm. The model approximates the values of pixels in a segment by a constant plane and incorporates multicuts constraints to enforce the connectedness of segments. As a by-product the image is denoised.

Our approach could also be interpreted as a piecewise constant fitting in 2D. To the best of our knowledge, it is the first globally mathematical programming model for simultaneously segmentation and denoising. Numerical experiments on real-world image are carried out against multicuts and variational models.

2 - Long-Term Forecasting: Cross-Impact-Analysis vs. time-sliced Bayesian Networks
Hans-Joachim Lenz, Thomas Schwarz

The design and production of the automotive industry or the oil exploration and production industry have business cycles of eight, fifteen or up to 60 years. The scenario technique (ST) is a methodology for allowing such long lead times. It enables making assumptions and statements about the future system state with subject, time and region well defined. A 'What-if'-Analysis allows generating various future world states of interest. ST is a triple $(G, I, E)$ with $G = (V, K, P)$ as the model graph, $V$ (finite) set of variables (knots) with finite Range($v$), where $v$ is element of $V$. $K$ is the set of linked pairs of variables, $v$ and $w$ are elements of $V$. $P$ represents a set of measures of uncertainty on $V$. $I$ is a set of restrictions over $P$, strongly dependent upon the approach selected, cf. Reibnitz [1991], Pearl [1986], Laruitzen und Spiegelhalter.

Cross-Impact-Analysis (CIA) and dynamic Bayesian Networks (DBN) differ in model and inference, Müller and Lenz [2013]. CIA is a static approach, leads necessarily to too many loops, and considers only bivariate dependencies of attributes. DBN is based on multi-casual influence with interactions but without feedback. While CIA changes uncertainty factors into probabilities in a purely heuristic way, DBN uses decomposition of $P$ under the Markovian (1st order) assumption, while being restricted to DAGs.

We demonstrate long-term forecasting of the oil price using the DBN scenario technique.

Ref.: Müller und Lenz [2013], Business Intelligence, Springer, Heidelberg

3 - Efficient Election Campaign Optimization Using Integer Programming
Evren Guney

Election Campaign Optimization Problem (ECOP) is one of the critical issues in many countries ruled by democracy. During the election campaigns, political parties spend a lot of effort to introduce themselves and invest their resources to convince voters. Given that each political party already has a loyal base community, what becomes important is persuading the so-called swing voters - the voters who do not have a clear decision about their choice. ECOP can be described as finding the best way to allocate a political party’s resources among different election locations in order to maximize the seats or member of parliament (MPs) won. The level of effort of advertising on earning votes or winning elections has been studied extensively in the sense of determining the best advertising strategy or determining the marketing mix. However, most of the studies focus on determining the magnitude and significance of the effect of spending through various regression analysis methods. In this study our objective is to determine the election regions to market heavily so that the party wins extra MPs in those regions. For this purpose, first one has to determine the amount of swing votes for each election region and the minimum amount of votes needed to pass the opponent to win extra seat(s). We carry out our analysis on one of the most popular election rules: D’Hondt rule and derive mathematical formulae to exactly determine the threshold values. Next, we develop mathematical formulations to represent two different versions of the election campaign optimization problem. Last, we perform detailed computational analysis on the Turkish Parliamentary elections to test our methodology, which is generic and can be applied to many different election methods.

Customer-Oriented Pricing Mechanisms
Stream: Pricing and Revenue Management
Parallel session
Chair: Claudius Steinhardt

1 - Threshold Problems in Ascending Combinatorial Auctions
Bart Vangerven, Dries Goossens, Fris Spieksma

Combinatorial auctions are auctions that sell multiple items simultaneously and allow bidders to bid on packages of items. Allowing bidders to create custom packages potentially increases economic efficiency and seller revenues. Indeed, when package bids are allowed, the exposure problem is avoided. However, economic efficiency is still hampered by the presence of the so-called threshold problem, which is the phenomenon that multiple “small” bidders (i.e. bidders on sets with small cardinality) may not be capable of jointly outbidding a ”large” bidder, although the valuation of the bidders would allow the small bidders to do so. This effect is partly attributed to the fact that the small bidders are unaware of each other’s presence, and therefore experience no incentive to keep bidding in an ascending combinatorial auction. We study bidding behavior in ascending combinatorial auctions with threshold problems, using different levels of feedback. We do this in an experimental setting using human bidders. We vary feedback from very basic information about provisionally winning bids and their prices, to more advanced concepts as winning and deadness levels, and even so-called coalitional feedback, aimed at helping bidders to overcome potential threshold problems. Hence, the main question we address is the following: “Does additional feedback help bidders overcome threshold problems in ascending combinatorial auctions?” We test this in different auction environments, varying the number of items and bidders as well as the severity of the threshold problem, investigating the effects on economic efficiency, auction revenues, auction duration, etc.

2 - Pricing with Informative Delay Announcements
Secil Savasanelir, Sirma Karakaya, Yasemin Serin

We study the pricing problem of a service provider who makes delay announcements to inform the customers about anticipated delays. Besides making price quotes to arriving customers, the provider decides on the amount of delay information to be revealed to the customers. Price and announcement decisions affect the behavior of the customers who are delay- and price-sensitive, which in turn affects the profitability of the firm. We model the system as a stochastic discrete-time Markovian queue, and model the pricing problems through Markov decision process. We compare several delay information and pricing schemes and through analytical results and numerical study identify the conditions that make specific delay information or pricing schemes more preferable. We also analyze the impact of the information asymmetry on the preference of the provider. We consider pricing schemes with varying levels of flexibility, and our findings show that even if the information asymmetry favors the service provider, the delay information scheme might severely curtail the benefit of the pricing flexibility. Furthermore, results show that traffic intensity, customer-sensitivity and precision of the price quotes have a significant impact on selecting the delay information scheme.
Agent-based modelling and simulation has seen a huge increase in interest within operations research in the last decade as a promising approach to model and study the behavior of individuals in complex situations. While agent-based modeling is easily applicable to and has been used in very different application fields, the challenge remains how to analyse and understand the complex simulation output: Agent-based models usually are very complex so that models of reduced complexity are needed, not only to see the wood for the trees but also to allow the application of advanced analytic methods. We show how to construct so-called Markov state models that approximate the original Markov process by a Markov chain on a small finite state space and represent well the longest time scales of the original model. More specifically, a Markov state model is defined as a Markov chain whose state space consists of sets of population states near which the sample paths of the original Markov process reside for a long time and whose transition rates between these macrostates are given by the aggregate statistics of jumps between those sets of population states. An advantage of this approach in the context of complex models with large state spaces is that the macrostates as well as transition probabilities can be estimated on the basis of simulated short-term trajectory data.

An agent-based simulation for analyzing supply chain strategies in the apparel industry

In the past, the aim of minimizing manufacturing costs has dominated the design of supply chains for many companies from the (European) apparel industry, which came along with long-distance shipping from Far East and relatively lengthy production cycles. Today, short throughput times have become another, in some market segments even more important, factor for gaining competitive advantage as flexibility in production allows for adjusting to the rapidly changing fashion trends in these segments. Choosing the ‘right’ supply chain strategy is well analyzed in literature. However, in an attempt to reduce complexity when modeling the underlying market, recent research limits itself to some selected aspects (e.g., strategic buyers, one period, one product, and one retailer). An agent-based simulation, in contrast, can account for several competing retailers with different supply chain strategies as well as variations of individual consumer preferences over time as a result of word-of-mouth communication and social influence. In our talk, we introduce such a simulation approach. It has been parameterized by means of a conjoint study that provides consumers’ preferences for clothes and brands, as well as information on their communication and buying behavior. The possible application of the ABS is illustrated for several supply chain strategies (i.e., fast fashion versus traditional). With increasing consumer awareness and environmental concern, companies face the challenge of reducing their environmental footprint. In this contribution, the authors present an approach to model carbon emissions in the context of supply chain management. The simulation approach is based on a system of agent-based models that represent various actors in the supply chain, such as suppliers, manufacturers, retailers, and consumers. The model takes into account different factors influencing carbon emissions, such as transportation modes, production processes, and consumer behavior. The simulation results highlight the potential of different strategies to reduce carbon footprints, providing valuable insights for decision-makers in the apparel industry.

A Methodological Framework for Validating Agent-Based Simulation Models to Support Decision Making

We present a flexible framework to model, calibrate, and validate the interactions of heterogeneous decision makers in an agent-based model. In our approach, derived from Partially Observable Stochastic Games, each agent has an individualized information set and model, from which they derive decisions. Agents measure the performance of previous decisions according to one or more metrics. The outcome of their decisions emerges from the combination of all individual models. Agents repeatedly decide and act over multiple turns, continuously updating their information set via observed changes in the environment. The approach is illustrated for several supply chain scenarios, such as production planning and inventory management, where the decision focus is on balancing costs and lead times. The framework allows for the systematic validation and calibration of agent-based models, providing a clear separation of model specification and validation processes. This ensures that the model accurately represents the real-world system. In conclusion, the methodological framework presented in this work serves as a valuable tool for researchers and practitioners in the field of supply chain management, enabling the development of more reliable and trustworthy simulation models.
costs in the Lotsizing and Scheduling Problem towards classical planning approaches is analysed and appropriate frame conditions are investigated within a structured parameter analysis.

**TA-17**

**Thursday, 9:00-10:30 - RBM|2204**

**Surgery Planning**

*Stream: Health Care Management*

*Parallel session*

*Chair: Katja Schimmelpfeng*

1. **How starting times influence performance of the operating theater**
   *Lisa Koppka*

   Decision makers in hospitals aim to allocate given capacities best possible to support staff’s, patient’s and management’s interests. This applies in particular to the operating theater, since a large part of revenue and costs emerges here. The allocation of total capacity to different operating rooms determines the respective operating hours - the periods of time in which regular surgeries are to be assigned. Most common in reality is that all operating rooms start simultaneously in the morning. Considering the tendency to flexible shift models for doctors and nurses in order to support work-life balance, starting work later becomes more attractive. In cooperation with one of the biggest heart centers in Germany, we examine the influence of adjusted starting times for operating rooms, while the operating room capacity remains the same. Performance criteria considered are especially overtime, rescheduling of patients and utilization on behalf of staff, patients and management. Results indicate that starting times can strongly influence performance.

2. **Surgery scheduling with consideration of ICU utilization leveling**
   *Steffen Heider, Sebastian Hof, Jan Schoenfelder, Thomas Koperna, Jens Brunner*

   Cost pressure forces many hospitals around the world to improve their efficiency. As two of the main cost drivers, the operating theater and the ICU have a prioritized role when it comes to analyzing and optimizing the processes in a hospital. The bed occupancy at the ICU is directly connected to the weekday and sequence of surgeries performed in the OR as well as the type of surgery, since the probability of an ICU transfer and the length of stay vary drastically by surgery type. We present a mixed integer quadratic program (MIQP) to minimize the variability of ICU bed demand in a given week by rearranging elective surgeries in the OR. Based on 2 years of available data from our partner the Klinikum Augsburg, we analyze the existing scheduling and compare it with multiple scenarios of our model.

3. **A hybrid simulation-optimization approach for mobile GP operation planning**
   *Christina Büsing, Martin Comis*

   Demographic change lead to a severe shortage of general practitioners in many rural areas of Germany. As a counter-measure, the statutory health insurance pursues the setup of mobile medical units. Mobile medical units allow for an efficient medical coverage of sparsely populated, spacious areas. Unfortunately, flexibility comes at the price of a highly complex operation planning process. In order to solve the resulting operation planning problem, we developed an optimization approach that combines a facility location, routing and scheduling problem. Succeeding this optimization stage, we evaluate our obtained solutions by an agent based simulation tool to predict the resulting coverage of medical treatment based on multiple performance indicators. These predictions are then fed back into our optimization model and the simulation-optimization cycle starts over. We applied this hybrid simulation-optimization approach to a rural area in the German Eifel. In this talk, we present the obtained results.

**TA-18**

**Thursday, 9:00-10:30 - RBM|2215**

**Scheduling in Shops**

*Stream: Project Management and Scheduling*

*Parallel session*

*Chair: Julia Lange*

1. **Partially Concurrent Open Shop Scheduling with Resource Constraints**
   *Hagai Ilani, Elad Shufan, Tal Grinshpoun*

   Partially Concurrent Open Shop Scheduling (PCOSS) is a relaxation of the well-known Open Shop Scheduling (OSS), where some of the operations that refer to the same job may be processed concurrently. Here we extend the study of the PCOSS model by considering the addition of renewable resources. The purpose of this study is generalization of results from OSS model with resource constraints to the PCOSS model. In particular, we deal with the case of preemption PCOSS, where a few polynomial algorithms are known for its OSS counterpart. We investigate the structure of the conflict graph of a PCOSS instance and focus on the efficiency of solving the problem to optimality. The model has a natural application of assigning technicians to vehicles in a garage where besides the technicians (machines) and vehicles (jobs) there are additional resources, such as vehicle lifts.

2. **A dynamic programming approach for the no-wait job shop problem**
   *Ansis Ozolins*

   We consider the no-wait job shop scheduling problem with no-wait constraints (NWJS). The objective is to minimize a makespan. The majority of research is focused on developing the heuristics. However, only a few exact algorithms are known in the literature. We propose a new exact algorithm, which is based on the dynamic programming (DP). The main elements of the DP algorithm for solving the NWJS are introduced: a graph associated with the problem, the state space, a dominance rule, the Bellman equation, a bounding procedure to reduce the state space of the DP algorithm. As an extension of our algorithm, we also present a heuristic variant of the algorithm. Extensive computational results show that our algorithm is able to solve moderate benchmark instances to optimality in a reasonable time limit. In addition, it is shown that the heuristic DP can obtain good quality upper bounds for large-size benchmark instances.

3. **Neighborhood structures for the blocking job-shop scheduling problem**
   *Julia Lange, Frank Werner*

   By including a real-world aspect in the classical job-shop scheduling problem, the consideration of blocking constraints refers to the absence of buffers in a production or logistics system. In case that the succeeding machine is not idle, a job will block the machine until its processing can be continued. Following customer satisfaction as one of the main goals in many industries, a schedule (i.e., the starting times of the jobs on the machines), which minimizes the total tardiness of all jobs, is to be determined. A job-shop scheduling problem with a total tardiness objective is NP-hard even without blocking constraints and mathematical programming results give evidence to the necessity of heuristic methods to obtain near-optimal solutions even for small instances. One of the main components of most heuristic approaches is the neighborhood structure. Here, the integration of blocking constraints causes significant difficulties, since a permutation of operations does not always define a feasible schedule and it is not clear whether and how a partial solution obtained by a slight change in the schedule can always be completed to a feasible neighbor. For the blocking job-shop problem, a neighborhood, which applies adjacent pairwise interchanges together with a technique to repair and complete partial solutions, is presented. The mechanism is implemented in a simulated annealing metaheuristic and tested on train-scheduling-inspired problems as well as benchmark instances.
1 - Clustering the auto-part manufacturing companies based on the product value criteria (case study)
Houshang Taghibzadeh, Mostafa Ziyaee Hajipiri
Department of Management, Tabriz Branch, Islamic Azad University, Tabriz, Iran

Success factors and obstacles in an industrial cluster is directly and indirectly influenced by and a follower of the concept of value and its related concepts. Considering this reasoning, the researchers in the present study identified and evaluated the barriers to adding the value of products in the industrial cluster of auto parts manufacturing located in the North West of Iran using the exploratory factor analysis. The statistic population was 220 companies. The results of exploratory factor analysis identified the obstacles to the value creation of the products in the form of six major categories. Also, studies on the value of factors used at the companies indicates that 73 companies had products in the category of poor value, 105 companies had products in the category of average value and the products of 42 companies had high value. Furthermore, the cluster analysis of the means clustered the aforementioned companies in 5 categories of value in which the first category as the largest category of product output was mainly average. A general conclusion of the status of the companies in terms of value indicates that attention to removing barriers to the value making in the study population is still in its infancy, and with regard to the predictions made about the status of the companies, more changes in the companies towards removing the barriers to value creating and producing high value products can be expected in the future.

2 - Agility indices to selecting contractors in outsourcing projects (case study)
Seyyedreza Rahnamay Touhidi, Mostafa Ziyaee Hajipiri

Abstract. In this study we try to identify the criteria for selection of contractors with regard to the agility criteria in the processes of implementation and delivery of outsourced projects or those which are outsourcing in the National Iranian Gas Company. To do this, first of all we used of concepts related to agility paradigm, preparation, planning and execution of the projects as the primary literature of the research. To collect data, comments of officers, directors and experts related to the inspection and control of the company’s outsourced projects are used. Questionnaire validity was investigated by content validity approach and its reliability before the end questionnaire distribution and Cronbach’s Alpha index was obtained at 0.819 that show its good reliability. The final results of Exploratory Factor Analysis (EFA) method has classified the study indices in the form of 5 factors. The factors’ titles were selected with respect to the factor loads of indices. One of the research main achievements is the model of agile contractors for the maintenance- construction projects and gas delivery for Iran national gas company.

2 - A Distribution Planning Method for the Regional Logistics Center Considering Carbon Emissions
Jun-Der Leu, Jin-Jen Liu, Yi-Wei Huang, Larry Jung-Hsing Lee, Andre Krischke

One major function of a regional logistics center is to provide an effective distribution service utilizing the limited transportation capacity to fulfill the demands of local marketing channels. In it, the cargo distribution needs transportation vehicles, while the vehicles lead to carbon emission. Considering many green regulations, these carbon emissions are counted in the carbon footprint of the related products. According to the MOBILES Vehicle Emissions Model, traveling distance and speed is significant influence factors to the carbon emissions of transportation. Normally the logistics planning are defined by mathematical planning or discrete mathematics models, on which algorithms or heuristics are developed to optimize the distribution logistics. However, most of these models are static ones, which follow the assumptions of stable traffic and fixed traveling speed on the network so that a significant error might happened when they applied to the green logistics directly. Further, in reality, the traffic situations are not stable all the time, when facing traffic jams, vehicles move in a low speed, and the carbon emissions increase. Again, these models do not consider the issue of oil consumption and carbon emission caused by the dynamic traveling speed.

In this research, the cargo flows modeling approach is applied to analyze the logistics planning scenario of single or of single logistics center to many demand deposits in the market region, wherein both of distribution logistics as well as carbon emission will be well considered. The planning algorithms were developed, and the computer simulation method was applied to validate the solution quality in terms of different transportation network scale and traffic heavy level.

3 - A Mixed-Integer Programming Model for Green Location and Transportation in a Closed-Loop Supply Chain
Turan Paksoy, Ahmet Çalık, Abdullah Yıldızbaş, Alexander Kumpf

Nowadays, due to the increasing of the importance of climate change and global warming, numerous legislations and regulations reducing the environmental impact of supply chains have been published in the world. Therefore, Green Supply Chain Management (GSCM) has emerged as an important paradigm for the companies. In this paper, we investigate the environmental considerations through a new Closed-Loop Supply Chain (CLSC) model. We deal with green or sustainable location and transportation issues to decide on the optimal locations of plants, collection centers and refurbishing centers for new products and used products in order to minimize the total supply chain cost and carbon-dioxide emission regarding the technology level (low, medium, high) of potential plants. Herein, low technology level refers to lower fixed facility costs but higher carbon-dioxide emission levels at plants. Contrarily, high technology refers to higher fixed facility costs but lower environmental costs at plants. By the means of green transportation, the proposed model makes a trade-off between transportation cost and carbon-dioxide emission cost. We consider that all the transportation in the network is outsourced from a logistics firm where three different types of vehicles are used for transportation. Load ranges that can be transported with each of these vehicle types are pre-determined. Transportation costs can be reduced by choosing large-sized trucks but chains into lean and agile segments by using product specific criteria. The challenges for companies then are threefold: 1) determining the segmentation criteria, 2) transforming the segmentation strategy into operational activities, and 3) quantifying the impact of applying such a segmented strategy on total cost. Compared with the first issue, much less research effort has been made for the second and third issues. However, current studies still provide a conceptual framework for integrating segmented strategies into supply chain design: tactically, by determining the level of centralisation, and operationally, via any methods to shorten lead times and to optimise inventory levels. In this paper, we address the second and third issues by proposing an approach to jointly optimise the network configuration and segmentation based on segmentation criteria (e.g. volume and variability of demand). We include safety stock placement as one of the key decisions to assess the impact of uncertainty in different supply pull design. Particularly, we adopt the guaranteed service model to optimise safety stock while considering risk pooling effects. In addition, we consider other tactical aspects such as the consolidation effect in transportation. We show how a supply chain can be segmented into different network structures when risk pooling and consolidation effects are considered and evaluate the benefits through numerical analyses.

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Abstract. In this study we try to identify the criteria for selection of contractors with regard to the agility criteria in the processes of implementation and delivery of outsourced projects or those which are outsourcing in the National Iranian Gas Company. To do this, first of all we used of concepts related to agility paradigm, preparation, planning and execution of the projects as the primary literature of the research. To collect data, comments of officers, directors and experts related to the inspection and control of the company’s outsourced projects are used. Questionnaire validity was investigated by content validity approach and its reliability before the end questionnaire distribution and Cronbach’s Alpha index was obtained at 0.819 that show its good reliability. The final results of Exploratory Factor Analysis (EFA) method has classified the study indices in the form of 5 factors. The factors’ titles were selected with respect to the factor loads of indices. One of the research main achievements is the model of agile contractors for the maintenance- construction projects and gas delivery for Iran national gas company.
it causes to negative environmental effects when it compares to small-sized trucks. To handle these kinds of conflicts, we propose a mixed-integer linear programming (MILP) model. A numerical example is implemented and analyzed in order to demonstrate the efficiency of the developed model.

4 - A tri-objective multi-period model to redesign a food bank supply chain network

*Teresa Melo, Carlos Lúcio Martins, Margarida Vaz Pato*

Motivated by the increasing global interest in reducing food waste, we address the problem of redesigning a multi-echelon supply chain network for the collection of donated food products and their distribution to non-profit organizations that provide food assistance to the needy population. For the social organization managing the network, important strategic decisions comprise opening new food bank warehouses and selecting their storage and transport capacities from a set of discrete sizes over a multi-period planning horizon. Facility decisions also affect existing food banks that may be closed or have their capacity expanded. Logistics decisions involve the number of organizations to be supplied, their allocation to operating food banks, and the flow of multiple food products throughout the network. Decisions must be made taking into account that food donations are insufficient and a limit on the available food products is available. We propose a novel mixed-integer linear programming (MILP) model that accounts for sustainability by integrating economic, environmental, and social objectives. To this end, three objective functions are defined: (i) minimization of the cost of operating the food bank network, (ii) minimization of the environmental impacts of food waste and CO₂ emissions, and (iii) maximization of the social benefits generated for organizations supported by food banks. A computational study is conducted to investigate the trade-offs achieved by considering the three conflicting objective functions. Using a general-purpose solver, lexicographic optimal solutions are identified for instances capturing various characteristics of the network coordinated by the Portuguese Federation of Food Banks.

**TA-21**

*Thursday, 9:00-10:30 - RBM|4404*

**Miscellaneous**

*Stream: OR in Engineering*

*Parallel session*

*Chair: Zuzana Nedelkova*

1 - Scheduling a manufacturing process with several rail-bound and identical machines in the project EWiMa

*Markus Schreiber*

In the project EWiMa, efficient procedures for the manufacturing of wing covers are developed. One major objective is the manufacturing of such a component on GroFi'. GroFi is a technology demonstrator for an innovative manufacturing plant that is specialized on the production of large-scale lightweight components. It is developed by the DLR in Stade (Germany). A special feature of the plant is the possibility to split steps of the production process between several identical production-units. The units are mobile on a rail network. It is expected that the production process is drastically shortened by synchronizing those steps. Among other available. We propose a novel mixed-integer linear programming (MILP) model that accounts for sustainability by integrating economic, environmental, and social objectives. To this end, three objective functions are defined: (i) minimization of the cost of operating the food bank network, (ii) minimization of the environmental impacts of food waste and CO₂ emissions, and (iii) maximization of the social benefits generated for organizations supported by food banks. A computational study is conducted to investigate the trade-offs achieved by considering the three conflicting objective functions. Using a general-purpose solver, lexicographic optimal solutions are identified for instances capturing various characteristics of the network coordinated by the Portuguese Federation of Food Banks.

2 - Development of Optimal Transit Routes in Afghanistan

*Fawad Zazai*

Afghanistan is a landlocked country at the intersection between South and Central Asia. Three-quarters of the country consists of inaccessible mountainous regions. It is the intention of the Afghan government to turn the country into a so-called “logistical crossroad” - transit country by air, land and sea routes (rivers and sea routes in the ocean as part of a longer route) in Central Asia between the neighboring countries China, Iran, Tajikistan, Uzbekistan, Turkmenistan and Pakistan.

The aim of this study is to develop optimal transit routes in Afghanistan by mathematical optimization methods. The focus will be set on the optimal development of infrastructure in Afghanistan, which extends later to the South and Central Asian region. In the present initial research phase we focus on the shortest path problem between two cities. The path from one city to an other city may across mountains and canyons. The shortest path problem deals with the issue, how to find an optimal route between two nodes or points (start and end point)? An optimal route may be optimal a) with respect to the length of the route, b) regarding the construction cost of the route, or c) with respect to the height variation of the route. To solve the shortest path problem we use the Dijkstra’s algorithm.

3 - A splitting algorithm for simulation-based optimization problems with categorical variables

*Zuzana Nedelkova*

In the design of complex products some product components can only be chosen from a finite set of options. Each option then corresponds to a multidimensional point representing the specification of the chosen component. We present a splitting algorithm that explores the resulting discrete search space and is suitable for optimization problems with simulation-based objective functions. The splitting rule is based on the representation of a convex relaxation of the search space in terms of a minimum spanning tree and adopts ideas from multilevel coordinate search. The objective function is underestimated on its domain by a convex quadratic function. Our main motivation is the aim to find—for a vehicle and environment specification—a configuration of the tires such that the energy losses caused by them are minimized. Numerical tests on a set of optimization problems are presented to compare the performance of the algorithm developed with that of other existing algorithms.

**TA-22**

*Thursday, 9:00-10:30 - HFB|A*

**MCDM 3: Real-World Applications**

*Stream: Decision Theory and Multiple Criteria Decision Making*

*Parallel session*

*Chair: H.a. Eiselt*

1 - Sustainable tourism destination selection under the effect of digital economy

*Erdem Aksakal*

In today’s world, tourism become an enormous and widespread industry. The tourism can be defined as the activities of people for travelling or staying outside of the usual place for recreation, leisure, family or business purposes for a limited time. It is found all over the world and impacts social, economic, and environmental part of our lives. As being a part of our lives, it needs to be sustainable. According to the World Tourism Organization (WTO) sustainable tourism defined as “Tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities”. Sustainable tourism usually aims to have minimal negative impacts such as to minimize harm, and to have maximum positive impacts such as to optimize economic benefits. Nowadays with the growing population and mobilization, digital economy begins to affect every aspect of our lives. For tourism business, the Internet (as being a part of digital technology) plays an important role as offering potential to make information and booking facilities to large numbers of tourists. The aim of this study is to provide a fuzzy decision making model for sustainable tourism destination selection under the effect of digital economy. To select the appropriate destination, the criteria were selected from the “Making Tourism More Sustainable: A Guide for Policy Makers” according to the effect of digital economy. The decision process consists of six criteria as Economic Viability, Local Prosperity, Employment Quality, Social Equity, Local Control, Cultural Richness. The regions and the countries identified from World Tourism Organisation’s data. Fuzzy TOPSIS method used to find the appropriate destination selection.
2 - Multiobjective Spatial Optimization: The Canadian Coast Guard
H.a. Eiselt, Amin Akbari, Ronald Pelot

This presentation examines a problem of the Canadian Coast Guard. The mission of the Coast Guard (Atlantic) is to provide assistance to vessels or persons aboard that are in distress. This piece focuses on the search & rescue mission of the Coast Guard. The two most important criteria include the average time that it takes to reach a vessel in distress, and the number of vessel incidents that can be reached within a reasonable time limit. Given that demand throughout the year is not constant but peaks during the summer season (in excess of 50% of the distress calls occur in July and August), there is a potential for congestion and the resulting inability of the Coast Guard to answer distress calls within an acceptable amount of time. In order to avoid formulating the model as a probabilistic model with all its computational difficulties, we use backup coverage as a third important concern. We model the problem of locating different types of rescue vessels along the coastline of the Maritime Provinces as an integer programming problem with three objectives, each dealing with one of the major concerns. The problem is solved given the available vessels and on the basis of incidents reported in the past. The solution is compared to the arrangement that is presently used by the Coast Guard.

I will present new results regarding the use of linear item prices in combinatorial auctions. Prices for items form a solution to an altered dual of the winner-determination problem, are core-selecting, and constitute a combinatorial competitive equilibrium.

1 - Robust optimization methods for circle coverings of a square
Mihály Csaba Markót

In the talk we are dealing with coverings of a square with uniform circles of minimal radius, with uncertainties in the actual placement of the circles. We assume that each circle centre is located in given regions of uniform shape and size. (Hence, we skip the question of how the regions are generated; they may come, e.g., as confidence regions of a probability model of the problem.) This is an example model of, e.g., deploying sensors so that there are uncertainties in the realization of the process. Possible sources of the uncertainty include scenarios when the deployment has to be made remotely (e.g., from the air) into a potentially dangerous place, deployments into a location with unknown terrain, or deployments influenced by the weather.

Our goal is to produce coverings that are optimal in terms of a minimal radius, and are also robust in the following sense: wherever the circles are actually placed within the given uncertainty regions, the result is still guaranteed to be a covering. We investigate three special uncertainty regions: first we prove that for uniform circular uncertainty regions the optimal robust covering can be created from the exact optimal circle covering without uncertainties, provided that the exact covering configuration is feasible for the robust scenario. We also investigate uncertainty regions given by line segments and general convex polygons. For these latter settings we design a bi-level optimization method that combines a complete and rigorous global search using interval arithmetic, and a derivative free black-box search. We show the efficiency of our proposed method on some examples.

2 - Computing the splitting preconditioner for interior point method using an incomplete factorization approach
Marta Velazco, Aurelio Oliveira

The search directions in the interior-point method for linear programming are computed through the solution of one or more linear systems. The solution of such linear systems is the most expensive step of these methods. The performance of the implementations using an iterative solution depends upon the choice of an appropriate preconditioner. In particular, for interior point methods, the linear system becomes highly ill-conditioned as an optimal solution is approached. The splitting preconditioner is very effective when applied together with the conjugate gradient method, in the final iterations, for the linear systems arising from interior point methods. These preconditioners rely on an LU factorization of an a priori unknown linearly independent subset of the linear problem constraint matrix columns. However, that preconditioner is expensive to compute since a non-singular matrix must be built from such set of linearly independent columns. In this work, a new version of the splitting preconditioner is presented dropping the need to obtain a non-singular matrix. The controlled Cholesky factorization is used to compute the preconditioner from the normal equations matrix from a given set of not necessarily independent columns. Such an approach is practicable since the controlled Cholesky factorization may be computed by adding suitable diagonal perturbations with a polynomial shift strategy. Numerical experiments show that the new approach improves previous performance results for both robustness and time on some large-scale linear programming problems.
1 - Strategic generation investment using a stochastic rolling-horizon MPEC approach and adaptive risk management

Thomas Kallabis, Steven Gabriel

Investments in power generation assets are multi-year projects with high costs and multi-decade lifetimes. Since market circumstances can significantly change over time, investments into such assets are risky and require structured decision-support systems. Investment decisions and dispatch in electricity spot markets are connected, thus requiring anticipation of expected market outcomes. This strategic situation can be described as a bilevel optimization model. At the upper level, an investor decides on investments while anticipating the market re- sults. At the lower level, a market operator maximizes revenue given consumer demand and installed generation assets as well as producer price bids.

In this paper, we reformulate this problem into a mathematical program with equilibrium constraints (MPEC). We extend this model to include a dynamic rolling-horizon optimization. This structure splits the investment process into multiple stages, allowing the modification of the conditions in between. This is a realistic representation of actors making their decision under imperfect information. Furthermore, we model an endogenous learning algorithm that allows updating risk-aversion parameters. These two extensions allow us to investigate the success of learning algorithms in strategic investment decisions. Lastly, the rolling-horizon formulation also has computational advantages over a perfect foresight and we provide supporting numerical results to this point.

2 - A stochastic energy system model to investigate efficient markets for security of supply in Europe - and challenges when applying the model to high performance computing

Frieder Borggreve, Manuel Wetzal

This paper develops a stochastic multi-stage decomposition approach to model balancing markets and markets for security of supply in electricity systems. It provides insights from a simplified model and proposes an application to high performance computing in order to scale the model to represent the full European electricity system.

The European winter package presented in December 2016 provided a series of regulations and directives for a new energy market design. The market design however fails short to provide a market based approach to security of supply. In this paper we provide the concept for a stochastic energy system model incorporating day-ahead, intraday and real-time markets on the one hand and the emergency measures currently triggered by the TSOs on the other hand. We propose different market designs and outline how they can be modelled.

Based on a simplified energy system model we outline the concept of the model and compare the proposed market designs. In order to scale such a model to the European electricity system and model different levels of system adequacy sufficiently an application to high performance computing (HPC) is proposed. The last part of the paper discusses how the model can be applied to HPC. Based on the simplified electricity model different implementations and algorithms are tested to efficiently use distributed calculations. We outline the next steps necessary to scale and implement the model to HPC.

3 - Biomass Supply Planning for Combined Heat and Power Plants using Stochastic Programming

Daniela Guericke, Ignacio Blanco, Juan Miguel Morales, Henrik Madsen

During the last years, the consumption of biomass to produce power and heat has increased due to the new carbon neutral policies. Nowadays, many district heating systems operate their combined heat and power (CHP) plants using different types of biomass instead of fossil fuel, especially to produce heat. Since the biomass transport from the supplier to the consumption sites can be long and the contracts are negotiated months in advance, the negotiation process involves many uncertainties from the energy producer’s side. The demand for biomass is uncertain at the time of negotiation, and heat demand and electricity prices vary drastically during the planning period. Furthermore, the optimal operation of combined heat and power plants has to consider the existing synergies between the power and heating systems while always fulfilling the heat demand of the system.

We propose a solution method using stochastic programming to support the biomass supply planning for combined heat and power plants. Our two-phase approach combines mid-term decisions about biomass supply contracts with the short-term decisions regarding the optimal market participation of the producer to ensure profitability and feasibility. The risk of major deficits in biomass supply is reduced by including appropriate risk measures to the models. We present numerical results and an economic analysis based on a realistic test case.
Nonlinear problems under uncertainty

Stream: Optimization under Uncertainty
Parallel session
Chair: Raimund Kovacevic

1 - Optimal control and the Value of Information for a Stochastic Epidemiological SIS-Model
Raimund Kovacevic

This paper presents a stochastic SIS-model of epidemic disease, where the recovery rate can be influenced by a decision maker. The problem of minimization of the expected aggregated economic losses due to infection and due to medication is considered. The resulting stochastic optimal control problem is investigated on two alternative assumptions about the information pattern. If a complete and exact measurement is always available, then the optimal control is sought in a state-feedback form for which the Hamilton-Jacobi-Bellman (H-J-B) equation is employed. If no state measurement is available at all, then the optimal control is sought in an open-loop form. Given at least an estimated initial probability density for the number of infected, the open loop problem can be reformulated as an optimal control problem for the associated Kolmogorov forward equation (describing the evolution of the probability density of the state). Optimality conditions are derived in both cases, which requires involvement of non-standard arguments due to the degeneracy of the involved H-J-B and Kolmogorov parabolic equations. The effect of the observations on the optimal performance is investigated theoretically and numerically.

2 - Convex Approach with Subgradient Method to Robust Service System Design
Jaroslav Janacek, Marek Kvet

A robust design of a service system operating on a real transporta-
tion network has to be resistant to randomly appearing failures in the network. To achieve the resistance, a finite set of failure scenarios is generated to cover the most fatal combinations of the failures. Then, the system is designed to minimize the maximal detrimental impact of the individual scenarios. In the case of an emergency system design, a given number of facilities is to be deployed over a set of possible loca-
tions so that the sum of weighted time distances from users’ locations to the nearest service center is minimal. The considered randomly oc-
curring failures affect the time distances from the users’ locations to the nearest facility locations. As the emergency system design can be modelled as a weighted p-median problem, the failures influence only the coefficients of the objective function. This way, each scenario corresponds to a particular objective function, and thus searching for the robust emergency system design consists of minimizing the max-
imum of the particular objective functions. While a simple weighted p-median problem is easily solvable, the robust system design is hard to be solved from the two reasons. The first one consists in the size of the resulting model of the problem. The second one originates in usage of min-max constraints, which link up the individual scenario objective functions with their upper bound representing the objective function of the robust problem. The min-max link-up constraints represent an undesirable burden in any integer programming problem due to bad convergence of the branch-and-bound method. In this paper, we focus on handling big size of the original model by scenario dominance analysis to reduce the set of scenarios and to accelerate associated solution methods.

Implementation of Acceleration Strategies from Mathematics and Computational Sciences for Optimizing Energy System Models

Stream: Software Applications and Modelling Systems
Parallel session
Chair: Felix Cebula

1 - Getting linear optimising energy system models ready for High Performance Computing
Manuel Wetzel, Karl-Kien Cao, Frederik Fiand, Hans Christian Gils

State-of-the-art energy system models include a comprehensive repre-
sentation of energy sectors and their associated technologies in high spatial and temporal resolution. This complexity is increased further by technologies linking the system along temporal, spatial and sec-
toral dimensions such as electrical energy storage units, transmission grids or combined heat and power plants. One of the downsides of the increasing detail in linear optimising energy system models is the neces-
sary time to solve the model. The BEAM-ME project addresses the need for efficient solution strategies for complex energy system mod-
els. The project brings together researchers from the fields of energy systems analysis, mathematics, operations research, and informatics and aims at developing technical and conceptual strategies for every step of the solution process. This includes changes to the formula-
tion of the energy system model, improving the solvers and utilising the resources of high performance computing. This talk provides an overview of the challenges in adapting the formulation of the energy system model REMix to utilise a solver based on a parallel interior point method. The solver exploits the underlying block structure of the model while maintaining the ability to find the global optimal solution. The block structure has to be communicated to the solver by annotating the energy system model. First insights of current results are discussed and an outlook on future steps is given.

2 - Optimizing large-scale linear energy problems with block diagonal structure by using parallel interior-
point methods
Daniel Reiheld, Ambros Gleixner, Thorsten Koch

In the wake of the Fukushima nuclear accident in 2011, the German government initiated a policy (named “Energiewende”) to shift energy systems towards sustainable, renewable technologies. Since this transi-
tion comes with a massive decentralization and a concomitant increase in the size of realistic energy models, the project BEAM-ME has been launched to develop methods for solving currently intractable energy optimization problems. These models are encoded as large-scale lin-
ear programs (LPs) that exhibit a block-diagonal structure with both linking constraints and linking variables. In this talk, initial results of adapting the parallel interior point solver PIPS-IPM for these energy LPs are presented. In particular, the underlying mathematically ap-
proach will be presented and the practical implications of implementing supercomputers to implement this approach are discussed, both with respect to solution time and to solvability.
3 - High Performance Computing with GAMS
Frederik Fiand, Michael Bussieck

BEAM-ME is a project funded by the German Federal Ministry for Economic Affairs and Energy and addresses the need for new and improved solution approaches for energy system models of vast size. The project unites various partners with complementary expertise from the fields of algorithms, computing and application development. The main focus is on large-scale linear programs (LPs) arising from energy system models. Such models have a block structure that is not well exploited by state-of-the-art LP solvers. Without considering this structure the models become quickly computationally intractable. Within the BEAM-ME project, new solution algorithms that exploit the block structure and utilize the power of High Performance Computers (HPC) are developed and will be made available to energy system modelers. Automatic detection of the block structure in models has its limits and hence the user needs to provide block structure information via some model annotation. GAMS for some time has facilities to annotate a model. We discuss some extensions to the GAMS language which forms the interface between the energy system modeler and the newly developed algorithms.

We provide an overview on the large variety of challenges we are facing within this project, present current solution approaches and provide first results.

4 - High Performance Computing for Energy System Modelling
Thomas Breuer, Dmitry Khabi

The common approach to solve linear program (LP) arising from an energy system model (ESM) is based on the shared memory paradigm. However, the apparent simplicity of the non-uniform memory access architecture (NUMA) limits the scalability of the underlying hardware components, such as the memory and compute units. On the other hand, increasing of the resolution in spatial and temporal data of ESM requires more and more computational resources. High Performance Computing (HPC) provides a technical solution to overcome these limitations. Use of HPC demands changes to the existing ESM solving framework. This talk presents the latest results obtained in the BEAM-ME project. We discuss the central questions that came up during integration of the parallel optimization solver PIPS in the framework of GAMS language, which is widely used in the field of ESM. Based on a block structured (stochastic) linear problem, the results regarding the scalability and efficiency of the HPC solution were obtained on two Petaflops supercomputers: Hazel Hen, a Cray XC40-system, at High Performance Computing Center Stuttgart (HLRS) and JURECA, a fat tree EDR-InfiniBand cluster, at Jülich Supercomputing Centre (JSC).

TB-03
Thursday, 11:00-12:30 - WGS 103

Sustainable Logistics

Stream: Logistics and Freight Transportation

Parallel session

Chair: Moritz Behrend

1 - Multi-objective supplier portfolio configuration under supply risk and sustainability considerations: an a posteriori decision support methodology
Florian Kellner, Berndhard Lienland, Sebastian Utz

This research presents a novel, state-of-the-art methodology for solving the multi-criteria supplier portfolio selection problem under risk and sustainability considerations. Our approach combines multi-objective optimization with the analytic network process to meet the requirements for supplier portfolio configuration with sustainability considerations. To integrate the aspect ‘risk’ into the supplier selection problem, we developed a multi-objective optimization model based on the investment portfolio theory introduced by Markowitz. Our model is a non-standard portfolio selection problem with four objectives: to minimize the purchasing costs, to select the supplier portfolio with the best logistics service, to minimize the supply risk, and to order as much as possible from those suppliers with outstanding sustainability performance. We solve the optimization model, which has three linear and one quadratic objective function, with an algorithm which analytically computes a set of efficient solutions and provides graphical decision support by a visualization of the complete and exactly-computed Pareto front (a posteriori approach). The possibility of computing all Pareto optimal supplier portfolios is beneficial for decision makers as they can compare all optimal solutions at once, identify the trade-offs between the criteria, and study how the different aspects of supplier portfolio configuration may be balanced to finally choose the composition that satisfies the purchasing company’s strategy at best. The approach has been applied to a real-world supplier portfolio configuration case to demonstrate its applicability and to analyze how the considerations of sustainability requirements may affect the traditional supplier selection and purchasing goals.

TB-04
Thursday, 11:00-12:30 - WGS 104

Algorithms for NP-hard Problems

Stream: Graphs and Networks

Parallel session

Chair: Ernst Althaus
1 - Arboreal bipartite matchings
Stefan Canzar, Luka Borozan, Khaled Elbassioni, Sören Laue, Domagoj Matijevic

In this work we study a constrained variant of the bipartite matching problem. The constraints are imposed by two trees that connect the vertices in the two parts of the graph. Two matched vertices in one tree must be in the same ancestry relationship as the two vertices they are matched to in the second tree. We show that the problem of finding such an arboreal matching of minimum cost is NP-hard. We propose an ILP formulation that allows to compute a metric distance based on arboreal matchings between phylogenetic trees in reasonable time. We further develop cutting planes that can be separated in polynomial time to solve larger instances occurring in computational biology.

2 - Resolving Conflicts for Lower-Bounded Clustering
Henning Fernau, Katrin Casel

For most clustering problems, the quality of a solution is usually assessed with respect to a given pairwise distance on the input objects. Approximate solutions for such tasks often rely on this distance to be a metric. But what happens if this property does not hold? Especially for computing a clustering such that each cluster has a minimum cardinality k>2 (as required for anonymisation or balanced facility location problems) this becomes problematic. For example, with the objective to minimise the maximum radius of all clusters, there exists no polynomial-time constant factor approximation if the triangle inequality is violated while there exists a 2-approximation for metric distances. We try to resolve or at least soften this effect of non-metric distances by devising particular strategies to deal with violations of the triangle inequality (conflicts). With the use of parameterised algorithms, we find that if the number of such conflicts is not too large, constant factor approximations can still be computed efficiently.

3 - Solving SAT-Instances with Small Treewidth within the Apache Spark Framework
Ernst Althaus, Vitali Diel, Andreas Hildebrandt

We implemented a SAT-solver based on a tree decomposition within the Apache Spark framework. Due to some preprocessing that reduces the width of the tree decomposition, we were able to solve some instances not solved by any of the solvers participating in the last SAT-competition. This indicates that our approach can be superior in some situations.

TB-05
Thursday, 11:00-12:30 - WGS 104a
Time-Discretized Formulations for Scheduling Problems (i)
Stream: Discrete and Integer Optimization
Parallel session
Chair: Andreas Bärmann

1 - Lower Bounds for the Resource-Constrained Project Scheduling Problem from a Time Bucket Relaxation
Alexander Tesch

The Resource-Constrained Project Scheduling Problem (RCPSP) is a fundamental problem in scheduling theory and also one of the most challenging to solve in practice. It is well known that time-indexed integer programming formulations for the RCPSP can be solved quite efficiently. However, those models suffer from the large amount of variables and constraints when the time horizon becomes large. Recently, a time bucket relaxation has been presented for the RCPSP (Raidl et al. 2016). In that model, the time horizon is partitioned into a fixed number of generically chosen time intervals while a related time-indexed integer program is solved on this set of time intervals. In our talk, we present several new valid inequalities for the time bucket formulation. The improved relaxation is then solved in a destructive fashion to generate strong lower bounds for the RCPSP. Furthermore, we compare several strategies on how the time partitioning should be performed in order to get quick infeasibility certificates. Our computations are tested on instances of the PSPLIB.

TB-06
Thursday, 11:00-12:30 - WGS 105
Social Networks
Stream: Graphs and Networks
Parallel session
Chair: Marinos Gottschau

1 - Individualism and collectivism in social dynamics: contact process with stochastic opinion fluctuations in complex networks
Liudmila Rozanova, Alexander Temerev

We consider dynamics of a complex system modeling the behavior of a large heterogeneous population. Starting from compartmentalized voter model with two separate time scales for “fast” and “slow” interactions, we augment it with introducing a separate stochastic process, responsible for independent opinion formation. This simple modification leads to emergence of rich variety of behavioral modes (herd- ing behavior/opinion leadership, information cascades, consensus oscillations, opinion polarization etc.), with distinct phase separations in configuration space (i.e. forming a well-defined phase diagram.) Most importantly, introducing spontaneous formation of independent opinion allows for interaction modes where opinion distribution fluctuates indefinitely, instead of always converging to one of possible opinions. Describing and identifying these phases has immediate applications in behavioral analysis of financial markets, opinion dissemination and other complex social modeling problems.

In a railway network, incidents may cause traffic to deviate from the planned operations making impossible to operate the schedule as it was planned. In such a case, the operator needs to adjust the schedule in order to get back to the original schedules. Because a train operator may have the policy of economically compensating passengers who they incur in delays, it is important to have a way of deciding whether to speed up trains in order to absorb delays or to compensate passengers. In this paper a mathematical model which decides on the speed profile while considering passenger use is presented. The model decides on the optimal sequence of operating regimes and the switching points between them for a range of different circumstances and train types all while considering delays, passenger compensation policies, track specific constraints and train conflicts. The objective of this paper is to minimize both energy consumed and incurred compensation to passengers. Computational tests on realistic problem instances of the Spanish rail operator RENFE are reported.

In this talk, we present a generalization of project scheduling with precedence constraints for which it is still possible to give a totally unimodular description. We present five different formulations for the problem as an integer program, which we group into three classes. The first class contains intuitive formulations, where the constraints directly represent compatible choices. The second class contains improved formulations which describe the convex hull of all integer feasible points. The last class contains a dual flow formulation, whose advantage is its sparsity. We test our formulations on a peak load minimization problem with our project partner Deutsche Bahn AG. In the problem, a given timetable draft shall be adapted via small changes in the departure times of the trains to smooth the power consumption profile. Project scheduling with precedence constraints appears as substructure here. The computational results show that the dual flow formulation outperforms all other formulations and in general is two orders of magnitude faster than the intuitive descriptions.
2 - Bootstrap Percolation on Degenerate Graphs
Marinus Gottschau

We consider r-neighbor bootstrap percolation on finite graphs, a process which corresponds to the Ising Modell at zero temperature and which can be used to model rumor spreading in (social) networks. The process has been introduced by Chalupa, Leath and Reich in 1979 and has gotten much attention since then. Many different properties of the process and the behavior on a variety of graph classes have been analyzed, some of which we address briefly.

The process itself is defined as follows: Given a graph and an initially infected set of vertices, subsequently, an uninfected vertex becomes infected if it is adjacent to at least r infected vertices. We are mainly interested in the size of the infected set at the end of the process and shall present a result that bounds the size of the infected set at the end of the process from above for degenerate graphs. Recall that a graph is said to be d-degenerate if every subgraph contains a vertex of degree at most d. We prove that our given bound is sharp in the sense that there exist graphs and initially infected sets of vertices which get arbitrarily close to the given bound. Also, our results have some more implications, e.g. give raise to bounds on the size of percolating sets.

1 - Transforming Mobility – Navigation Technology Past, Present, and Future
Felix G. König, Heiko Schilling

Navigation technology is a key building block for mobility. As mobility evolves through technological advances like the connected car, electric vehicles, and autonomous driving, new navigation challenges arise.

Automotive navigation has crucially relied on algorithm engineering from day one. Crowd-sourced floating car data and big data processing have paved the way to extremely accurate historic speed profiles and up-to-the-minute real-time traffic information. Advanced routing algorithms make use of this abundance of data to outsmart traffic and reduce congestion, contributing to more efficient mobility for all.

Today, electric vehicles create new navigation challenges like optimizing routes for consumption and charging stops, or accurately estimating vehicle range based on advanced consumption models. Connected cars becoming the norm have opened up opportunities for more and richer navigation services, like incremental over-the-air map updates, on-street parking assistance, and an increasing level of personalization and contextual awareness in navigation.

Going forward, navigation is a key innovation area on the path towards automated driving. The fusion of sensor-based sub-lane-level positioning and real-time high-definition maps enable the automated vehicle to function safely in its immediate surroundings, but also see beyond its physical sensors. Autonomous driving will also pave the way towards mobility as a service, which will trigger a new wave of algorithmic challenges on the path to next-generation navigation.

2 - Precisely Detect “Object” Locations Using Crowdsourcing and Machine Learning
Sören Sonnenburg

Crowdsourcing, i.e., user provided input, is a highly scalable and effective way of involving a userbase to solve out-of-reach tasks. The ubiquity of devices utilizing the Global Navigation Satellite System enables a new kind of user provided input: The reporting of the presence or absence of “objects” at a certain location. Among the numerous examples or such “objects” are coffee shops, but in particular objects relevant to the field of traffic, like speed limit enforcement devices, traffic jams, and road closures to name but a few. Based on such user inputs, the exact localization of the object is hindered by:

a) low resolution of the geo coordinates provided by the device / user
b) inaccurate reports (user selecting wrong location, or reporting when no longer in the vicinity) c) adversely reported false locations.

Based on the statistics of a set of such rather noisy user reports in the (not necessarily close) vicinity of the object, a prediction method is presented that accurately and robustly estimates the object’s location. In this talk we illustrate how this machine learning based method can be used to detect speed limit camera locations as an example.

3 - Autonomos – Autonomous Driving Technology from Berlin
Tinosch Ganjineh

Interest in the subject of autonomous vehicles has vastly increased in recent years and nowadays it is a much discussed topic. Almost all automobile manufacturers are working on solutions of their own. Autonomos is one of the pioneers of self-driving cars, having started in 2007 and, since 2010, carrying out autonomous test drives in city traffic in Berlin.

This talk gives an overview of the technology supporting the sense-plan-act paradigm for autonomous vehicles: Visualization and real-time analysis of a variety of sensor data, calculation of traffic-related decisions by the vehicle itself, and the integration of relevant safety measures.
1 - Solving MIQCP Topology Optimization Problems by Successive Nonconvex Approximation
Gregoire Njauchon njanzoua, Ivo Nowak

The Topology Optimization (TO) problem is a basic engineering problem of distributing a limited amount of material in a design space. The finite element formulation of TO is a large scale nonconvex Mixed Integer Quadratically Constrained Quadratic Program (MIQCP) with millions of variables. Traditional methods for MIQCP are branch-and-bound methods, and cannot solve realistic TO problems. Commercial TO solvers can only compute local solutions, which depend strongly on the starting point.

In this talk we present a new decomposition-based global optimization method for TO, which is based on DIOIR (Decomposition-based Inner- and Outer-Refinement), a new algorithm for solving MIQCPs and MINLPs by successively refining a nonconvex approximation. We implemented the IDOIR algorithm in the open-source MINLP-solver Decogo, a new decomposition-based MINLP-solver. Numerical results will be presented.

2 - Hypervolume Maximizing Representation for the Bi-objective Knapsack Problem: The Rectangular Knapsack Problem
Britta Schulze, Carlos M. Fonseca, Luis Paquete, Stefan Ruzika, Michael Stiglmayr, David Willems

The cardinality constrained rectangular knapsack problem is a variant of the quadratic knapsack problem. It consists of a quadratic objective function, where the coefficient matrix is the product of two vectors, and a cardinality constraint, i.e., the number of selected items is bounded. In the literature, there are rather few results about the approximation of quadratic knapsack problems. Since the problem is strongly (NP)-hard, a fully polynomial approximation scheme (FPTAS) cannot be expected unless (P=NP). Furthermore, it is unknown whether there exists an approximation with a constant approximation ratio. However, the cardinality constrained rectangular knapsack problem is a special variant for that we present an approximation algorithm that has a polynomial running time with respect to the number of items and guarantees an approximation ratio of (4.5). We show structural properties of this problem and prove upper and lower bounds on the optimal objective function value. These bounds are used to formulate the approximation algorithm. We also formulate an improved approximation algorithm and present computational results.

The cardinality constrained rectangular knapsack problem is related to the cardinality constrained bi-objective knapsack problem. We show that the first problem can be used to find a representative solution of the second problem that is optimal for the hypervolume indicator, which is a quality measure for a representation based on the volume of the objective space that is covered by the representative points. Further ideas concerning this concept and possible extensions are discussed.

3 - Feasible Roundings for Granular Optimization
Oliver Stein

We introduce a new technique to generate good feasible points of mixed-integer nonlinear optimization problems which are granular in a certain sense. Finding a feasible point is known to be NP hard even for mixed-integer linear problems, and many constructive heuristics have been developed. We show, on the other hand, that efficiently solving certain purely continuous optimization problems and rounding their optimal points leads to feasible points of the original mixed-integer problem, as long as the original problem is granular. For the objective function values of the generated feasible points we present computable a-priori and a-posteriori bounds on the deviation from the optimal value, as well as efficiently computable certificates for the granularity of a given problem.

Computational examples for several problems from the MIPLIB libraries illustrate that our method is able to outperform standard software. A post processing step to our approach, using integer line search, further improves the results.

1 - A Stabilized Branch-and-Price Algorithm for Vector Packing Problems
Karin Hettler, Timo Gschwind, Stefan Imrich

This paper considers packing and cutting problems in which a packing pattern is constrained independently in two or more dimensions. Examples are restrictions with respect to weight, length, and value. We present branch-and-price algorithms to solve these vector packing problems (VPPs) exactly. The underlying column-generation procedure uses an extended master program that is stabilized by (deep) dual-optimal inequalities. While some inequalities are added to the master program right from the beginning (static version), violated dual-optimal inequalities from exponentially sized families of inequalities are added dynamically. The column-generation subproblem is a multi-dimensional knapsack problem, either binary, bounded, or unbounded depending on the specific packing or cutting problem that is addressed. Its fast resolution is decisive for the overall performance of the branch-and-price algorithm. In order to provide a generic but still efficient solution approach for the subproblem, we formulate it as a shortest path problem with resource constraints (SPPRC), yielding the following advantages: (i) Violated dual-optimal inequalities can be identified as a by-product of the SPRC labeling approach and thus be added dynamically; (ii) branching decisions can be implemented into the subproblem without deteriorating its resolution process; and (iii) larger instances of higher-dimensional VPPs can be tackled for the first time.

Computational results show that our branch-and-price algorithms are capable of solving VPP benchmark instances effectively.

2 - On the Gap of the Skiving Stock Problem
John Martinovic, Guntram Scheithauer

The (one-dimensional) skiving stock problem (or SSP for short) represents a combinatorial optimization task being of high relevance whenever an efficient and sustainable use of limited resources is intended. In the classical formulation, given (small) items shall be combined to obtain as many larger objects (specified by some minimum length to be reached at least) as possible. Hence, the SSP can be considered as a natural counterpart of the extensively studied 1D cutting stock problem. However, despite sharing a common structure (e.g. with respect to the input data), both problems are not dual formulations in the sense of mathematical optimization. Therefore, the SSP represents an independent challenge in the field of cutting and packing. As many other problems in combinatorial optimization, the SSP is known to be NP-hard. Due to this observation, (approximate) solution approaches based on LP relaxations and/or appropriate heuristics are of great scientific interest. Among others, their performance mainly depends on the tightness of the considered relaxation, i.e., on the absolute difference (called gap) between the optimal values of the LP relaxation and the ILP problem. While numerical computations suggest that there is always a very small gap, a theoretical verification of this observation is very difficult, in general. After a short introduction to the skiving stock problem, this presentation gives an overview on different approaches and results concerning the gap. Besides considering the general case of arbitrary instances, we mainly focus on the so-called divisible case. Thereby, special emphasis is placed on the development of new and improved lower and upper bounds for the (maximal) gap.

3 - Column Generation for the Soft-Clustered Vehicle-Routing Problem
Stefan Imrich, Timo Hintsch

The clustered vehicle-routing problem (CluVRP) is a variant of the classical capacitated vehicle-routing problem in which the customers are partitioned into clusters. It is assumed that each cluster must have been served in total before the next cluster can be served. This presentation considers the CluVRP with soft-cluster constraints (CluVRPSC). Customers of the same cluster must still be part of the same route, but no longer need to be served contiguously. We present an exact branch-and-price-and-cut algorithm, compare different solution methods for the subproblem, and discuss branching strategies and the addition of cutting planes. The subproblem is solved as an elementary shortest path problem with resource constraints by labeling algorithms.
We highlight similarities and differences to pricing for pickup-and-delivery problems. The labeling is supplemented by heuristic strategies for partial pricing. To the best of our knowledge, this branch-and-price-and-cut algorithm is the first exact approach for the CluVRPSC.

4 - A branch-and-price algorithm for the SPP
Isabel Friedow

We consider the 2D rectangular strip packing problem (SPP). Given a set of rectangles, the objective of the SPP is to place these rectangles within a strip of given width and unrestricted height in such a way that the strip height needed becomes minimal. A relaxation of this problem is the 1D horizontal bar relaxation (HBR), in which a rectangle is represented by a unit-height item-type with a demand corresponding to the rectangle height. The items are packed into 1D bins and the aim of the HBR is to meet the order demand of all types while minimizing the number of bins used. A solution of the HBR only represents a solution of the SPP if all items of the same type are placed in consecutive bins. In addition to this vertical contiguity condition, also the constant location of item-types has to be ensured, which means, all items representing one rectangle need to have the same x-position in each bin. We investigate a branch-and-price algorithm in which sequences of bins are generated which fulfill the constant location property. To obtain a next bin for a sequence, called successor, we solve the HBR with an additional constraint that ensures the usage of successors with an appropriate usage frequency. This linear problem is solved by column generation and the slave problem related to a successor is modified in such a way that both desired properties, the contiguity and the constant location property, are ensured. We test our approach for different sets of test instances and compare the results with those of other exact methods proposed in literature.

**NB-11**

**Thursday, 11:00-12:30 - WGS|005**

**Vehicle Routing - Heuristics I**

Stream: Logistics and Freight Transportation  
Parallel session  
Chair: Katharina Glock

1 - The Time Dependent Vehicle Routing Problem: A Simulation Based Dynamic Programming Approach
Meltem Soyasal, Mustafa Çimen, Sedat Belbag, Cagri Sel

This paper addresses a Time Dependent Vehicle Routing Problem. Dynamic Programming approach is used for formulating and solving the problem. However, the high memory and computation time requirements of large sized instances render the classical Dynamic Programming approach infeasible. We, therefore, propose a Simulation Based Restricted Dynamic Programming approach to solve large sized instances. Computational analyses show the added value of the proposed model and the heuristic approach. According to the numerical experiments the Simulation Based Restricted Dynamic Programming heuristic can provide promising results within feasible computation times for the Time Dependent Vehicle Routing Problem. It has also been observed that incorporating time dependent travel times into decision support models has potential to improve the performance of resulting routes in terms of transportation emissions and travel cost.

2 - Vehicle Routing Problem with Ridesharing and Walking
Olivier Gallay, Marc-Antoine Coindreau, Nicolas Zufferey

This work is motivated by the network of a large energy provider, in which the workers have to visit clients at spread locations to perform a variety of small maintenance jobs. In that context, it has been observed that the workers frequently leave their vehicle and perform continuous jobs on foot even if their given planning would recommend to drive to their next jobs. This situation is particularly enhanced in an urban context, where distances between jobs often allow for walking, and furthermore where the traffic is generally congested and parking spots are limited. In order to evaluate the potential benefit offered by such type of multi-modality, we propose a generalization of the static day-ahead Vehicle Routing Problem with Time Windows, where walking between jobs is allowed, and where a car can transport multiple workers. We come up with a dedicated variable neighborhood search that is able to efficiently address this new problem formulation, in particular when tackling the additional complexity resulting from the appearance of necessary synchronization constraints between the routes. This ultimately allows us to substantially reduce both the total transportation costs and the vehicle fleet size, which are the two main objective functions typically considered in Vehicle Routing Problems.

3 - Extensions to the Correlated Orienteering Problem for Emergency Surveillance
Katharina Glock, Anne Meyer, Guido Tack

In case of emergencies such as fires involving harmful substances, emergency crews rely on the quick assessment of potentially affected areas. Unmanned aerial vehicles (UAV) are a possibility for providing this information by using remote sensors for surveilling a designated area.

Based on a preliminary image from high altitude, low altitude flights of UAV are planned in a way that as much information as possible is collected within the available flight time. An important aspect during the flight planning is the spatial correlation, which describes the relation of observations at different points and allows making inferences for neighbouring points not visited by the UAV. In literature, this planning problem is modelled as a Correlated Orienteering Problem (COP), which accounts for the spatial correlation in a simplified manner.

In this talk, we propose improved models describing this correlation more accurately based on the observed distribution of the contaminant. Furthermore, we discuss three utility measures relevant for our application: the concentration of a contaminant, high interest points, and the uncertainty about the available information and hence the need to gather more data. For solving our extended versions of the COP, we present a Constraint Programming based Large Neighbourhood Search. Correlation models and utility measures are evaluated using examples from real-world scenarios, notably a use case in firefighting.

**NB-12**

**Thursday, 11:00-12:30 - WGS|BIB**

**IBM Business Session – On Deploying successful Decision Optimization applications**

Stream: Business Track  
Parallel session  
Chair: Sofiane Oussedik

1 - IBM Decision Optimization cloud offering
Sebastian Fink

IBM Decision Optimization on Cloud delivers a compelling, easy, self-service experience to help users harness the power of optimization-based decision support without the install, deployment and maintenance burdens of traditional on premise infrastructures. During this presentation we’ll go thru the offering and present an example.

2 - Designing and building new aircrafts case study
Sofiane Oussedik

The presentation of the use case will highlight the importance of having the right tools and choosing a good modeling option in order to cover the client’s needs. Designing and building a new aircraft is complex and requires to schedule a few millions of activities such as product design, parts design tools design and assembly tasks, we’ll discuss the functional needs of such application and how the needs were satisfied.

**NB-13**

**Thursday, 11:00-12:30 - RVH/1**

**Smart Services and Internet of Things**

Stream: Business Analytics, Artificial Intelligence and Forecasting  
Parallel session  
Chair: Maria Maleshkova
1 - Smart Components for Value-driven Service Adaptation
Maria Maleshkova

Current market trends, in the context of product as well as service offerings, are characterized by shortening of the lifecycles and increasing demand for customized solutions. Both market competitiveness and new technology developments push companies towards constantly reshaping and improving the organizational, controlling and development aspects of product and services, having individualized customer needs determine not only the final result but also the actual design, development, implementation and delivery process steps, as well as the associated business models. Up to date, the main driving forces behind IT products and services have been the market demand, and the level of technology maturity and innovation. Therefore, the technology has dictated, in a lot of cases, the functionalities and features that are offered to the client. Very little attention has been paid to addressing specific customer value preferences (e.g. customers might require the same product but have very different value needs in terms of, for example, fairness, protection and privacy).

Our work aims address precisely this challenge by bridging the gap between customer value preferences and the technical requirements for a solution. In particular, we make two main contributions - 1) we present an approach for translating user value preferences into technical requirements that can be realized via reusable and functionalized software components and 2) we show how smart components can be reconfigured and adapted in order to fit the specified values, without modifying the overall implementation of the solution. We use a use case from the predictive maintenance domain as a running example in order to demonstrate the applicability of our approach.

2 - Towards Self-governed Smart Services
Sebastian Bader

Currently the World Wide Web is shifting from a human-centered to a more and more machine-processable environment. Especially global trends like the Internet of Things demonstrate how the established principles of the Web provide an infrastructure for basically any kind of information exchange. In addition to traditional, human-oriented websites, an increasing number of consistent and functionalized data, which can be composed to powerful, federated applications. Unfortunately one current limitation is that the integration process is a sophisticated task that requires profound knowledge of the APIs and their specific constraints.

In this context we propose the notion of modular, self-governed Smart Services which, relying on standard Web technologies, can autonomously select and realize actions. Based on the semantic data format RDF, the proposed components consume, manipulate and send both data and the associated logic in a single consistent manner. Interfaces are built on Linked Data standards combine data handling with service in-vocations, thus, being capable to invoke, trigger and even reprogram each other autonomously and thereby create complex distributed systems.

We present how semantic API descriptions on input and output data, functional and non-functional aspects assure to configure the data exchange between self-governed Smart Services. In order to increase the possibilities to find suitable functionality providers, the Smart Services are enabled to compromise on and even neglect conflicting aspects. Therefore, the outlined components encapsulate aspects of the integration problem and reduce the required manual implementation effort.

3 - Optimizing Data Flows in Loosely Coupled Distributed Applications at Runtime
Felix Leif Keppmann

Recent developments such as the Internet of Things, Industrie 4.0, and Smart Factories, imply the composition of applications based on a very heterogeneous landscape of components, including both hardware and software. In specific scenarios, components, which are developed and produced by different stakeholders, must be adapted to communicate with each other to provide the overall value-added functionality of the application. While approaches (e.g., the Smart Component approach) enable this adaptation at runtime, based on Web and Semantic Web technologies, we focus in this work on the challenge of self-adaptation within such applications, e.g., to enable the optimization of data flows without external intervention.

With respect to this challenge, we present the following contributions: 1) The concept of a Self-adapting Application based on the Smart Component approach. While the Smart Component approach enables the adaptation of loosely coupled components at runtime, we extend this approach by allowing adjustments between components at runtime, e.g., to enable the optimization of data flows at runtime without external intervention. 2) The implementation of a Rule-based Optimization by translating a simple mathematical algorithm to rules that can be decentrally deployed within the self-adapting application. The optimization with respect to throughput of data is based on the data producing and data consuming frequencies of the involved components. 3) The Performance Evaluation of a self-adapting application to evaluate the deployment of rules and the rule-based optimization with respect to overhead, throughput, and overall processing frequency.
the corresponding network optimization problem is computationally intractable.

We present the application of the well-known Frank-Wolfe decomposition scheme to this network revenue management problem. Starting from a reformulation of the problem, we develop the Frank-Wolfe iteration and discuss its convergence for some network instances. The resulting subproblems consist of dynamic programs for each single inventory unit. These dynamic programs can be solved to optimality within a couple of seconds.

As a prerequisite for the decomposition approach, we present a revenue-consistent computation of reconstrained forecasts for each product on each inventory unit. As part of the evaluation of the convergence of our algorithm we discuss the practical interpretation of the scaling factors of the reconstrained forecasts on single unit and network level.

**TB-15**

**Thursday, 11:00-12:30 - RVH-I/II**

**Modelling and Simulation for Operations and Logistics**

Stream: Simulation and Statistical Modelling

Parallel session

Chair: Yony Fernando Ceballos

1 - Integration of Order Acceptance into Optimization-Based Order Release models

*Pia Netzer, Stefan Haeussler, Hubert Mischbauer*

Attaining short and reliable lead times and at the same time high output and good due-date performance is crucial to remain successful in Make-To-Order (MTO) companies. Hierarchically organized multi-stage workload control (WLC) strategies that introduce the control stages “order release” and “order acceptance” have the potential to attain these requirements. Interestingly, there is no such hierarchical WLC approach that integrates order acceptance into optimization based order release models. We close this gap by developing a new hierarchical WLC concept that combines order acceptance with optimization-based order release and analyze the performance by using a simulation model of a MTO job shop. More precisely, we develop and analyze a hierarchical WLC approach consisting of an optimization based order release model (a clearing function model) and various order acceptance rules as well as an optimization based order acceptance model. Results show that the performance increases when integrating order acceptance into optimization based order release models. Thus, this paper highlights the potential of integrating higher decision levels into optimization based order release models.

2 - Analysis of machine use in sport center in Medellin, Colombia

*Yony Fernando Ceballos, Salomé Naranjo, Carlos Hernandez*

Discreet event simulation was applied on El Molino Sport Center located in Medellin, Colombia. This was done to analyze the difficulties presented there and primarily to find alternatives for the improvement of the performance in the routines designed by personal trainers for the users. It was found that bottleneck machines when more than one routine crosses another and users get limited in their routines due to the congestion in the use of them. A scenario analysis was completed for the efficiency of the service and a routine redesign avoiding machine’s intersection. Also, was analyzed the increase of the number of machines, especially Back Pulley and Triceps Pulley with buying and accommodation costs. Finally, we simulate an ideal scenario were people that visit the sport center remove machines weights and leave them in the initial position (without weights). We found that three scenarios were possible, some with less investment than others, but all with the mandatory cooperation of users.

**TB-16**

**Thursday, 11:00-12:30 - RBM/1102**

**CANCELLED: Miscellaneous**

Stream: Production and Operations Management

Parallel session

Chair: Gabriel Trazzi

**TB-17**

**Thursday, 11:00-12:30 - RBM/2204**

**Treatment Planning and Health Care Systems**

Stream: Health Care Management

Parallel session

Chair: Stefan Nickel

1 - Preventing Hot Spots in High Dose-Rate Brachytherapy

*Björn Morén, Torbjörn Larsson, Åsa Carlsson Tedgren*

High dose-rate brachytherapy is a method of radiation therapy, used in cancer treatment, where the radiation source is placed inside or close to a tumour. In addition to give a high enough dose to the tumour it is also important to spare nearby organs. Mathematical optimization is increasingly used at clinics for dose planning of the treatment, in which the source irradiation pattern is decided. The recommended way to clinically evaluate dose plans is based on dosimetric indices. Such an index quantifies the discretised portion of the tumour that gets at least (or for organs, at most) the prescribed dose. There are optimization models for dose planning that take homogeneity of the dose into account, but there are none, to our knowledge, that also includes the spatial distribution of the received dose. Insufficient spatial distribution of the dose may result in hot spots, which are contiguous volumes in the tumour that receive a dose that is too high (e.g. more than 200% of the prescribed dose). This aspect is a reason of concern because of risk for complications. With a given dose plan that satisfies the targets in terms of dosimetric indices, a common clinical practice is to inspect the spatial dose distribution before approving the dose plan and if the hot spots are too large, adjust the dose plan. We study this adjustment process by means of mathematical optimization and introduce criteria that take spatial distribution of dose into account with the aim to spread out or reduce the size of hot spots. This results in large-scale mixed-binary models that are solved using non-linear approximations. We show that it is possible to improve a dose plan in this respect while at the same time maintaining good values with respect to dosimetric indices.

2 - Kidney exchange programs with a priori crossmatch probing

*Filipe Alvelos, Ana Viana*

Kidney exchange programs rely on the definition of pools of incompatible donor-patient pairs and on preliminary information about the compatibilities of donor and patients of different pairs. Assuming some objective, e.g. maximizing the number of transplants, a set of transplants can be planned such that the donor of the pair of a patient receiving a kidney also donates. Commonly, after a transplants plan is defined, actual crossmatch tests are performed for each pair involved in that plan, in order to confirm compatibility between the patients and donors selected for transplant. If the result of the test is positive, it reflects incompatibility and the planned transplant must be canceled, as well as the others transplants involved in the exchange. We discuss a different approach: to conduct actual crossmatch tests before a plan is decided. First, we select a potential transplant and conduct the actual crossmatch test. Based on its result, another potential transplant is selected and the same procedure is repeated. Since conducting crossmatch tests involves time and money, the approach is limited by a maximum number of tests that can be performed. We propose two different methods to decide which pairs should be selected for a priori crossmatch tests and compare results, in terms of transplants performed, with the standard procedure.
3 - Evaluating the Performance Criteria of Health Information Systems by Using Fuzzy Type-2 Multi Criteria Decision Making Methodology
Bettül Özkan

Health Information Systems help to improve the effectiveness and quality in hospitals. An effective used system will provide many advantages on patients and doctors. There are many different criteria that affect the performance of a health information system. Evaluating these performance criteria is a multi criteria decision making problem. In this paper, the criteria for evaluating the performance of a used health information systems are considered by using fuzzy type-2 Analytic Hierarchy Process (AHP). Type-2 fuzzy numbers are used to deal with uncertainty and vague situations. First, the criteria are determined by experts and from the studies in literature and then type-2 fuzzy AHP is applied to determine the weights of main and sub-criteria. These obtained weights will show which criteria have more importance on the performance of the used system and managers in hospitals will evaluate the system according to these criteria.

4 - A fuzzy robustness measure for the scheduling of commissioned product development projects
Matthias Gerhard Wichmann, Maren Gäde, Thomas Spengler

Due to a considerable degree of uncertainty, the generation of robust schedules for the execution of product development projects is a crucial planning task. In the area of robust project scheduling, one basic option is to apply surrogate robustness measures as estimates of schedule robustness. Although project managers typically possess vague information about activity variations, most surrogate measures neglect this knowledge and are entirely based on deterministic data. In this contribution we therefore present the "fuzzy overlap", that is a surrogate robustness measure which accounts for fuzzy activity duration. We provide a mathematical formulation and embed the fuzzy overlap in a two-stage planning approach for the scheduling of product development projects, which aims at balancing the minimization of project costs as the basic scheduling objective with the maximization of schedule robustness. In a numerical study, we compare the performance of our proposed approach with comparable deterministic surrogate robustness measures. The results indicate that the consideration of fuzzy information enhances schedule robustness compared to the application of traditional deterministic surrogate robustness measures.

1 - Impact Assessment Based Sectoral Balancing in Public R&D Project Portfolio Selection Problem
Sinan Gürel, Musa Çağlar

Government funding agencies provide considerable amount of R&D funds through funding programs. While constructing R&D project portfolio, Decision Maker (DM) wants to balance program budget over sectors or scientific disciplines. Existing approaches in the literature assume budget share of each sector is known at the beginning. However, in practice, the DM wants to decide on sectoral budgets. In this study, we incorporate results of so-called "sectoral impact assessments" into public R&D project portfolio selection decisions. We develop a two-stage model. In the first stage, the DM deals with sectoral budget decisions to maximize the total impact of the budget while ensuring relative sectoral budget balances. In the second stage, the DM wants to maximize the total score of supported projects under allocated sectoral budgets. We illustrate proposed approach on an example problem. We show the value of the proposed approach by comparing it with alternative policy options to give managerial insights to the DM.

2 - Success of projects with respect to their characteristics
Arik Sadeh

Success of projects is an important goal for their stack holders. Therefore identification of the causes to projects’ success is very attractive. In this study the success of projects was measured and reported using several variables, by project managers and or stack holders. The projects are classified in four dimensions: (i) the level of project’s novelty, (ii) the complexity of projects from the management point of view, (iii) the level of technological uncertainty at the beginning of projects, and (iv) the pace of completion of projects. This is in accordance with the diamond approach suggested by Shenhar and Dvir (2007). In the context of the diamond approach the four dimensions are commonly abbreviated to NTCP. The characteristics of 400 projects were measured according to these four dimensions NTCP, where each dimension has 3 or 4 ordinal values. The success levels of those projects with respect to those four dimensions were statistically analyzed using structural equations modeling framework. Certain interest was in innovative projects with high levels of novelty and technological uncertainty.

3 - A new Simulation-based optimization Approach for multi-mode resource-constrained project scheduling problems
Parham Azimi

This research addresses a new model along with the appropriate solving method for a resource constrained project scheduling problem (RCPSP) with multiple models for the tasks while the preemption of activities are allowed. To model and solve this NP-hard problem, a new general optimization via simulation (OvS) approach has been developed which is the main contribution of the current research. The OvS connects the solutions of the mathematical model to the simulation model, efficiently. Finally, the best solutions are selected and imported to a genetic Algorithm (GA) as initial population where the optimization process is carried out. The results were tested over several test problems and show the efficiency of the approach not only for this problem but also for many similar combinatorial optimization problems.
2 - An Iterative Matheuristic Approach for the Flexible Tour Scheduling Problem
Seyda Topaloglu Yildiz, Mustafa Avci

Employee scheduling issues are crucial for many service organizations like hotels, banks, restaurants and airports which encounter variable demand patterns for service during the day and across the days of a specified planning horizon. The main problem addressed in this study is called as the tour scheduling problem which assigns work shifts and work days to employees such that the time-varying customer demand is satisfied with minimum cost. Organizations may implement a variety of flexible scheduling policies to deal with this variable customer demand. Applying flexible shift start times is one of the scheduling policies that may lead to a significant reduction in labor cost. However, this policy may assign work shifts to employees which start at different hours on each working day of the employee. Since the shift start times of an employee may vary a great deal across the working days, shift start time bands should be implemented to reduce the shift start time variations to a certain level. Another policy that can increase the scheduling efficiency is the flexible break assignments. In this policy, break time windows are used to provide flexibility in break time assignments. Additionally, managers may obtain flexibility in employee schedules by including different shift lengths and days-on-patterns. The main objective of this study is to develop an iterative decomposition based matheuristic that can solve the TSP covering all of these flexible scheduling policies. The developed algorithm utilizes a working set generation mechanism together with a local search procedure. The performance of the proposed approach is tested on a set of randomly generated problem instances. The proposed approach can provide efficient and effective solutions for the TSP.

3 - Comparison between Rule- and Optimization based Workload Control Concepts
Stefan Haucssler, Pia Netzer

An important goal in Production Planning and Control (PPC) systems is to achieve short and predictable flow times, especially where high flexibility in meeting customer demand is required. Besides achieving short lead times, one should also maintain high output and due-date performance. One approach to address this problem is the workload control concept. Within workload control research two directions have been developed largely separately over time: Rule based order release mechanisms which determine the release times of the orders following a set of rules and secondly optimization based models that optimize the order releases for a certain planning horizon with respect to an appropriate objective function. A comparison of the most advanced (and used) order release models form both streams is still lacking. Therefore, this study makes a thorough comparison between the rule based “LUMS COR” (Lancaster University Management School corrected order release) mechanism and the optimization based “clearing function” model. We use a simulation study of a hypothetical job shop that integrates both approaches in a rolling horizon setting. Performance is measured by looking at the resulting inventory levels and the due date performance. Preliminary results show that the optimization model outperforms the rule based mechanism, but with considerably higher computation time.

TB-20
Thursday, 11:00-12:30 - RMB/4403
Hierarchical Demand Fulfillment
Stream: Supply Chain Management
Parallel session
Chair: Konstantin Kloos

1 - Deterministic allocation models for multi-period hierarchical demand fulfillment
Jaime Cano Belmán, Herbert Meyer

In Make-to-Stock environments with a hierarchical sales organization and heterogeneous customers (i.e. profit-based segmented customer), the optimal matching of available resources (in form of Available-to-Promise - ATP) with demand is a challenging task if resources are scarce. Demand Fulfillment in a first step allocates these scarce resources as quick as forecasted demand. In a second step, these reserved quotas are consumed (promised) when actual customer orders arrive. In a multi-stage sales hierarchy, this allocation process often has to be executed level by level, on basis of decentral, aggregate information only. Decentral, deterministic, multi-period linear and non-linear programming models are proposed approximating the first-best benchmark of a central allocation planning with full information. These allocation models have been tested in a rolling-horizon simulation applying rule-based, dedicated consumption. The numerical experiments show in which situations the non-linear allocation model is favorable as compared to the linear one, to a traditional rule-based allocation and to a first-come-first-served policy without preceding allocations.

TB-21
Thursday, 11:00-12:30 - RMB/4404
Modelling for Business and Society
Stream: OR in Engineering
Parallel session
Chair: Achim Koberstein

1 - The odyssey from business to research data – ideas, concepts, and obstacles explained on gas network data
Oliver Kunst, Friedrich Dinsel, Sascha Witte, Uwe Gotzes, Thorsten Koch

Reliable data is a corner stone of operational research. In the most simple setting you have a central software system collecting all data needed for your analysis, e.g online stores. But in many other cases the data is provided by different sources. Which is prone. We cooperate with the biggest German transport system operator (TSO) of natural gas. Gas networks where partly built when typewriters dominated the offices. Over the years, different software systems...
2 - Solution Algorithm for Capacity Expansion Problem on Networks
Takayuki Shina, Jun Imaizumi, Susumu Morito

We consider a capacity expansion problem on networks. In our approach, integral feasible solutions are provided as a basic step in the process. We develop a multistage stochastic programming model in which some of the variables are restricted to integer values. Given the distribution of the demand, the problem of minimizing the expected value of the total investment cost is considered. The problem is formulated as a problem with first stage integer variables and continuous second stage variables. An algorithm based on the Benders decomposition is proposed to solve this problem. After this, the application of the model is considered. It is supposed that several railway lines were constructed and the abolition of tram lines continued with the progress of motorization. Considering the declining population, introduction of a new transportation system is being studied in order to consolidate homes and workplaces into the city center in the future, and design a new city. Although it is difficult to construct a new railway or subway, we consider the expansion problem of the existing system which supports the conventional public transport network, and computational results are presented.

3 - Using mixed integer programming for the optimal design of water supply networks for slums
Lena Charlotte Altherr, Peter Peitz

The UN sets the goal to ensure access to water and sanitation for all people by 2030 as one of the Sustainability Development Goals to transform our world. To address this goal we present a combined approach for designing water supply networks in urban settlements by applying mathematical optimization methods. Currently, the UN estimates that 663 million people are still without water and at least 1.8 billion people globally use a source of drinking water that is fecally contaminated. Especially, informal settlements, which in many countries are a defining part of urban areas, are often characterized by the lack of an appropriate water supply. We developed a multidisciplinary approach to design an optimal water supply system for informal settlements within a city. For this purpose, the required information on the slum location as well as size is taken from remote sensing and used as input data for the decision problem. The problem is modeled as a mixed integer problem (MIP) aiming to find a network describing the optimal supply infrastructures. Hereby, we choose between different central and decentral approaches with combined supply by motorized vehicles as well as installed pipe systems. This MIP captures investment as well as operating costs, flow conditions and water need requirements. In addition, primal heuristics are employed to reduce the runtime for solving the MIP. To illustrate the approach, we analyze a small slum cluster in Dhaka and present our results for a low cost water supply.

1 - Comparison of City Sustainability Performances with a Hybrid Fuzzy Multi-Criteria Decision Making Method: A Case Study of Turkey
Abdullah Yildizbaş, Ahmet Çalış, Turan Paksoy

Due to the rapid development of technology and globalization, more than half of the world’s population lives in cities. Increasing urbanization brings with it various environmental problems such as global warming, energy consumption, increasing housing density, exporting wastes, and greenhouse gasses. The importance of green city assessments has become popular for scholars and researchers in many fields. Therefore, cities should be evaluated in terms of various criteria in order to increase the quality of life and sustainability of the environment. The existence of these criteria in the assessment of green cities reveals the need for multi-criteria decision-making tools. This paper proposes a hybrid approach based on fuzzy Analytical Hierarchy Process (AHP) and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) for evaluation of green cities regarding selected criteria such as biodiversity and ecosystem, infrastructure and transportation, use of forestry, agriculture, energy alternatives, and buildings. Fuzzy AHP method is applied to obtain the weight of criteria according to different decision makers’ judgments. Decision makers consist of city planners, academicians and experts from municipalities and Turkish ministry of environment and urbanization. Then, TOPSIS method is applied for ranking cities by using the weights obtained from AHP methodology. A case study on the sustainable green city performance evaluation of top 10 crowded cities in Turkey is implemented. A comparative analysis was carried out by evaluating the sustainability performances of these cities with the developed approach.

2 - From Right to Reality: The Children’s Daycare Planning Problem
Catherine Cleophas, Martin Weibelzahl, Christina Büsing

As one of the current social challenges in Germany, a well-organized provision of families with daycare adds a high value to the community by enhancing social mobility, the integration of migrants, and equal employment opportunities for women. Despite its importance, an efficient planning of daycare has not been the focus of urban planners in the past. For this reason, the present paper explicitly deals with the current problems associated with daycare planning by proposing a first model for a centralized matching process. We assume different daycare facilities that employ nurses, who differ in the types of group constellations that they can supervise. On the one hand, our childcare allocation problem comprises the assignment of nurses to rooms of the daycare facilities with a corresponding group constellation. On the other hand, both existing and applying children must be assigned to one of the available nurses. This assignment accounts for various bounds on rooms, on group constellations, and on daycare facilities. Our centralized daycare planning maximizes the overall satisfaction of families with the assigned nurses, which is measured by the aggregated valuations of the facilities from the perspective of families. In a second step, we address the problem of symmetric solutions of our daycare planning model. Symmetry arises, as in practice many nurses will have similar characteristics that allow them to supervise the identical group constellations. In particular, we present a reformulated version of our model that circumvents solution symmetries.

3 - Economics of Crisp and Intuitionistic Fuzzy Information
Olga Metzger, Thomas Spengler, Tobias Volkner

The evaluation of the economic benefit of information and the corresponding considerations of (not) obtaining it is one of the most important requirements when making economically rational decisions, not least in the area of knowledge management. A common approach to analytical information assessment (see, for example, Emery, 1969 and Laux, 1979) is based on the use of statistical processing crisp values. Basically, the gross information value is determined by the difference between the expected profit of the decision with additional information (without information costs) and the expected profit without information. In this paper, we present and discuss variations of the information valuation approach according to Emery in the version of Laux. In this context, we analyze the role of a possible negative information value, its ex post evaluation as well as its significance for the rationality of decisions. Additionally, the relevance of uncertain information and its impact on the information value are discussed. Whereas traditional approaches for information valuation deal with crisp beliefs regarding the prediction of states of nature and further elements of the decision field, we also want to take account of the vagueness of information by using instruments from the LP theory and the intuitionistic fuzzy set theory.
1 - Tropical spectrahedra and mean payoff stochastic games
Stephane Gaubert, Xavier Allamigeon, Mateusz Skomra

One of the basic algorithmic questions associated with semidefinite programming is to decide whether a spectrahedron is empty or not. It is unknown whether this problem belongs to NP in the Turing machine model, and the state-of-the-art algorithms that solve this task exactly are based on cylindrical decomposition or the critical points method. We study the nonarchimedean analogue of this problem, replacing the field of real numbers by the field of Puiseux series. We introduce tropical spectrahedra, defined as the images by the valuation of spectrahedra over the latter field, or as “log-limits” of spectrahedra over the reals. We show that the elements of tropical spectrahedra can be identified to the potentials (winning certificates) of stochastic mean payoff games. This allows us to apply mean payoff games algorithms to nonarchimedean semidefinite programming.

2 - Mean Payoff Games in Products of Simplices
Georg Loho

It is known that finding a winning strategy in a mean payoff game, a feasible schedule for an and-or-network or a feasible point for a tropical polyhedron are polynomial-time equivalent. These problems are in NP and in co-NP but no polynomial algorithm has been found what makes them particularly interesting.

On the other hand, the combinatorics of a tropical polyhedron can be expressed as a subdivision of a product of two simplices. Equivalently, it can be described by a set of bipartite graphs which are composed of minimal matchings.

Combining the geometric point of view with the algorithmic problem allows us to consider a generalization of the feasibility problem. We present a method to solve the feasibility problem in the generalized setting. The algorithm is even pseudo-polynomial when applied to the original setting. This gives new insights in the structure of the problem and connects it with methods from combinatorial geometry.

3 - Tropical Geometry and Mechanism Design
Robert Crowell

In economic theory, mechanisms serve as game theoretic models of abstract institutions e.g. auctions, voting procedures and contracts. We will discuss the basic terminology from mechanism design theory, focusing in particular on auctions. We will then introduce some tools from tropical convex geometry and tropical combinatorics that can be used to study such problems in a unified way. The talk will be based on joint work with Ngoc Tran.

1 - Strong Stability of degenerated C-stationary points in MPCC
Daniel Hernandez Escobar, Jan-J Ruckmann

We consider Mathematical Programs with Complementarity Constraints (MPCC). The study of strong stability of C-stationary points plays a relevant role in sensitivity analysis and parametric optimization.

In 2010, H. Jongen et al. characterized the strong stability of C-stationary points for MPCC under the assumption that the Linear Independence Constraint Qualification (LICQ) holds. Here, we focus on the characterization of strong stability of C-stationary points when LICQ does not hold. We provide an upper bound on the number of constraints as a necessary condition for strong stability as well as a lower bound when a Mangasarian-Fromovitz-type constraint qualification does not hold. We introduce a weaker constraint qualification which turned out to be necessary for strong stability.

2 - Maximization of homogeneous polynomials on the simplex: structure, stability, and generic behavior
Faizan Ahmed, Georg Still

The presentation describes maximization of homogenous polynomial over a unit simplex. Optimality conditions and stability properties are described. Maximization of homogenous polynomial over a unit simplex is known to link with evolutionary stable strategy from biology. We show that generically any local maximizer is a stable ESS.

3 - Quadratic support functions in quadratic bilevel programming
Oleg Khamisov

We consider bilevel problem in the following formulation. The follower problem is a convex quadratic problem which linearly depends on leader variable. The leader problem is a quadratic (not necessarily convex) problem. We are looking for an optimistic solution. Optimal value function of the follower problem is used to reformulate bilevel problem as a standard (one-level) optimization problem. By this way we obtain nonconvex multietremal problem with implicit nonconvex constraint generated by the the optimal value function. We show how to construct explicit convex quadratic function which is support to the optimal value function at a given point. Usage of the support functions allows us to approximate the implicit one-level problem by a number of explicit nonconvex quadratic problems. In our talk we describe an iterative procedure based on such approximation. This procedure generates a sequence of auxiliary solutions every accumulation point of which gives a solution to the initial bilevel problem. Auxiliary solutions are obtained as optimal solutions of auxiliary explicit quadratic problems. We give a detailed description of the suggested approach and provide preliminary results of numerical experiment.

1 - An Optimization Model to Develop Efficient Dismantling Networks for Wind Turbines
Martin Westbonke, Jan-Hendrik Piel, Michael H. Breitner, Peter Nyhuis, Malte Stonis

In average, more than 1,275 wind turbines were installed annually since 1997 in Germany and more than 27,000 wind turbines are in operation today. The technical and economic life time of wind turbines is around 20 to 25 years. Consequently, dismantling of aging wind turbines will increase significantly in upcoming years due to repowering or decommissioning of wind farms and lead to millions of costs for operators. An option to supersede the costly and time-consuming dismantling of wind turbines entirely on-site is to establish a dismantling network in which partly dismantled wind turbines are transported to specialized dismantling sites for further handling. This network requires an optimization model to determine optimal locations and an appropriate distribution of disassembly steps to dismantling sites. The challenge is to consider the network’s dependency on
the trade-off between transportation and dismantling costs which in turn depends on the selection of dismantling depths and sites. Building on the Koopmans-Beckmann problem, we present a mathematical optimization model to address the location planning and allocation problem. To permit a proof-of-concept, we apply our model to a case-study of a selected region in Northern Germany. Our results show that our model can assist wind farm operators to arrange efficient dismantling networks for wind turbines and to benefit from emerging economic and logistical advantages.

2 - On generating a fleet composition for offshore wind farm maintenance operations
Eligius M.T. Hendris, Alejandro Gutierrez Alcoba, Inmaculada García Fernandez, Dag Haugland, Elin E. Halvorsen-Weare, Gloria Ortega

The offshore wind energy industry is expected to continue its growth tendency in the near future. The European Wind Energy Association expects in its Central Scenario by 2030 a total installed capacity of 66 GW of offshore wind in the UE. Offshore wind farms (OWFs) are large scale infrastructures, requiring maintenance fleets to perform operations and maintenance (O&M) activities in the installed turbines. Maintenance gives a major costs of running an OWF installation.

Optimising the efficiency of the resources used for the O&M activities of an OWF, requires an adequate estimate of the costs involved in the maintenance scheduling. However, this scheduling, typically depends on the weather circumstances. We first show a deterministic model formulation that is based on scenarios. As no future events can be used as input information, our question is how scheduling heuristics may provide a better estimate of the maintenance costs and what is the consequence of that for the fleet composition. This paper has been supported by The Spanish Ministry (TIN2015-66680), in part financed by the European Regional Development Fund (ERDF).

3 - On a design of economically near optimal nuclear fuel reload patterns
Roman Cada

The talk deals with the problem related to the design of nuclear fuel reload patterns. It is basically a multi-criteria nonlinear combinatorial problem, where values of many goal function are obtained by solving huge systems of differential equations by using a suitable discretisation method.

A nuclear reactor operates in cycles. Usually every year a part of burned-up fuel is exchanged by fresh one. A basic task is to find a set of fresh fuel assemblies among admissible fuel types to fit the given schedule (duration of cycles) provided the use of fuel during each cycle is as economical as possible.

The schedule of outages is usually planned a few years beforehand. We will distinguish an equilibrium schedule for theoretical conclusions useful for some practical considerations and planning and a typical real world schedule where cycles are not of equal length. We point out potential problems for optimisation methods arising in real world scenarios.

In the talk we present a typical workflow during the design of a sequence of near-optimal nuclear fuel reloading patterns. We focus on the problem of obtaining close to optimum sequences of reload patterns to fit the given scenario of outages within a time available during an outage.

In this article, we study inventory decisions in a multi-period newsvendor model under rational and behavioral assumptions. In particular, we analyze how two different incentive schemes affect ordering decisions: cash-flow and accounting profit. We derive optimal inventory policies for both schemes and find that the order-up-to levels for the accounting profit incentive are greater than or equal to the order-up-to levels for the cash ow incentive. Further, we show that the optimal order-up-to levels for the cash flow incentive decrease toward the end of the planning horizon. Next, we test both incentive schemes in a laboratory environment. We find that the subjects have higher-than-optimal order-up-to levels in the first period. We link this to an underweighting of the holding cost and an overweighting of future sales opportunities. In the second period, subjects have lower-than-optimal order-up-to levels. As a result, we observe an inverse inventory hockey-stick effect that is based on both the incentive schemes and behavioral biases of inventory managers.

2 - Explanatory Power of Experience Weighted Attraction in Individual Decision Making Compared to Simple Decision Rules - a Simulation Study
Heike Schenk-Mathes, Christian Koester

Experience weighted attraction (EWA) (Camerer and Ho 1998) combines reinforcement learning with fictitious play models and has proven to perform well as an explanatory model in economic experiments on individual decision making (cf. Bostian, Holt and Smith 2008; Köster and Schenk-Mathes 2016), especially in explaining experimental data on the newsvendor problem. Yet, EWA is a relatively complex model with a rather large number of free parameters and includes characteristics of simpler decision models, which might explain its good performance on laboratory data in the past. We present a simulation study which uses different models (including EWA) to generate order decisions in a newsvendor setting. Next, maximum likelihood estimations of these models are executed on the generated data and the fit of the models is evaluated using information criteria. Attention is focused on the performance of EWA. Furthermore, we present analyses on the parameter mix of EWA if more parsimonious models or a mix of these simpler models are used. Hereby, a deeper understanding about the explanatory power of EWA and its eliability as a model for individual decision making is gained.

3 - Should the Retailer or Supplier Exercise Effort to Increase Demand?
Anna-Lena Sachs, Yingshuai Zhao, Ulrich Thonemann

Demand promotion activities, such as advertisements, enlarge market size and accordingly increase sales profit. In a supply chain, promotion activities can be exercised by any echelon member. We consider a supply chain which is composed of two members, a supplier and a retailer. We investigate whether the supplier or the retailer should exercise the effort of demand promotion activities. We conduct laboratory experiments and compare supply chain performance for retailers or suppliers exercising effort under a Stackelberg game framework or a negotiation framework.
Thursday, 13:30-14:15

■ TC-22
Thursday, 13:30-14:15 - HFB|A

Semi-Plenary Meinolf Sellmann

Stream: Semi-Plenaries
Semi-plenary session
Chair: Stefan Lessmann

1 - Meta-Algorithms
Meinolf Sellmann

Meta-algorithmics is a subject on the intersection of learning and optimization whose objective is the development of effective automatic tools that tune algorithm parameters and, at runtime, choose the approach that is best suited for the given input. In this talk I summarize the core lessons learned when devising such meta-algorithmic tools.

■ TC-23
Thursday, 13:30-14:15 - HFB|B

Semi-Plenary Hans-Georg Zimmermann

Stream: Semi-Plenaries
Parallel session
Chair: Ralph Grothmann

1 - Data Analytics, Machine Intelligence and Digitalization at Siemens
Hans Georg Zimmermann

Data Analytics, Artificial Intelligence and Digitalization are general megatrends in research and industry. The big data trend was initiated by the increasing computer power and the internet. But data alone are only information about the past; we have to find structures and causalities between the variables. Based on such models we can compute information about possible futures and go on to decision support or control. The view of artificial intelligence is to solve the above problems with human analog methods. Especially neural networks and deep learning play an important role in such an effort. Siemens has a focus on technical and not internet applications, so we call our development machine intelligence instead artificial intelligence. Finally, digitalization describes the way from physical processes (and production lines) to virtualization, using the digital copy of the processes for optimization and online control.

In a final part of the talk I will show in form of examples, that in an industrial research center research plays an important role: First, we have to confront problems which were unsolved otherwise. Second, the knowledge accumulation in lasting teams opens unique selling points for the company.

■ TC-24
Thursday, 13:30-14:15 - HFB|C

Semi-Plenary Alexander Martin

Stream: Semi-Plenaries
Semi-plenary session
Chair: Martin Skutella

1 - Network Flow Problems with Physical Transport
Alexander Martin

Looking at network flow problems from a combinatorial point of view the flow is typically assumed to be constant in time and flows without additional requirements such as pressure differences. This is no longer true if we look at energy networks such as water or gas networks. To appropriately model the physics of these flows partial or at least ordinary differential equations are necessary resulting even in simplified settings in non-linear non-convex constraints. In this talk we look into the details of such models, motivate them by problems showing up in the transmission of the energy system and present first solution approaches with many hints to future challenges.

■ TC-25
Thursday, 13:30-14:15 - HFB|D

Semi-Plenary Arne Strauss

Stream: Semi-Plenaries
Semi-plenary session
Chair: Catherine Cleophas

1 - Last Mile Logistics
Arne Karsten Strauss

Last-mile logistics providers are facing a tough challenge in making their operations sustainable in the face of growing customer expectations to further decrease lead times to same-day or even same-hour deliveries, and/or to offer narrow delivery time windows. The providers respond to this challenge by investing in their analytic capabilities to make their last-mile logistics efficient and intelligent as possible.

In addition, innovative and disruptive business models are currently on trial, e.g. asset-lean start-ups use crowdsourced drivers or drivers on demand-dependent contracts. Several companies are experimenting with delivery drones or robots, and how to collaborate with each other (‘shared economy’).

Many of these developments entail exciting new challenges for operations researchers. In this talk, I will review some of the most recent developments and reflect on future research directions.
Thursday, 14:45-16:15

■ TD-01
Thursday, 14:45-16:15 - WGS|101
Applications of Uncertainty
Stream: Optimization under Uncertainty
Parallel session
Chair: Christine Markarian

1 - Influence Maximization with Deactivation in Social Networks
Kübra Tannınmış, Necati Aras, I. Kuban Altinel

Influence Maximization Problem (IMP) is one of the prominent problems in social network analysis. It is defined as selecting an initial set of k nodes in a social network such that the total number of affected nodes is maximized at the end of the influence spread. In this study, a competitive version of IMP, a Stackelberg game on a social network is considered. The leader of the game tries to maximize its influence spread by selecting a set of influential nodes and the follower tries to minimize the leader’s influence by deactivating a subset of the influential nodes. The deactivated nodes cannot affect their neighbors, nor they spread an opposite idea or information. As is the case with all Stackelberg games, it is assumed that the follower has complete knowledge about the leader’s decisions. Once the leader and the follower make their decisions, the influence propagates according to the well-known Linear Threshold (LT) diffusion model until no more nodes can be affected. The problem is modeled as a stochastic bi-level integer programming formulation. To deal with the uncertainty in the node threshold parameter of the LT diffusion model used in the lower level problem, a three-stage sample average approximation (SAA) scheme is implemented. To solve the bilevel problem, we propose a matheuristic method. Namely, a simulated annealing heuristic is applied to perform search in the solution space of the upper level problem (i.e., the selection of the influential nodes). Then, for each candidate solution generated for the upper level problem an SAA procedure is implemented in the lower level problem to find the optimal set of deactivated nodes which constitutes the optimal response of the follower.

2 - Decision support for tactical planning of maintenance activities - a use case for the INFRALERT project
Ute Kandler, Axel Simroth

The on-going H2020 project INFRALERT aims to provide Infrastructure Managers with IT tools to support the decision-making process when planning maintenance activities and interventions. In this talk, we will focus on the application of the INFRALERT decision support toolkit to a road pilot from Infraestruturas de Portugal (IP), where we concentrated on the tactical planning level. In this pilot, the decision maker has to allocate major interventions over a 5-year time horizon. The interventions are aggregated as single events over 500m-segments of certain road sections to avoid multiple traffic interruptions on the same section. The monthly allocation of interventions include: i) The allocation of a starting month for intervention events. ii) The selection of a limit for the minimum degradation level for a section. Further, several restrictions e.g., not falling below a certain quality level, meeting budget restrictions or capacity limits for supervisory staff, has to be satisfied. We aim to optimize simultaneously the costs, the quality index and the availability of the network. The allocation and selection of interventions is based on alerts generated by the INFRALERT Alert Management toolkit, which depends on predicted future conditions resulting from the Asset Condition toolkit. Thus, the input for the decision support are no concrete work orders but predicted work orders and the corresponding probabilities of occurrence. Due to this uncertainty the tactical planning problem becomes a stochastic optimization problem, that calls for specific modelling and solution techniques. The corresponding mathematical optimization model and the handling of uncertain information realized via a scenario approach will be subject of the talk.

3 - Online Leasing with Penalties
Christine Markarian

Online Leasing with Penalties

We study online leasing problems in which clients arrive with time and need to be served by leasing resources at minimum possible costs. There are K different lease types each with a different duration and price: a longer lease costs less per unit time. Online leasing problems studied thus far assume that all clients need to be served. In practice, this is not always true: e.g., a client arrives on a day that is not profitable to lease a resource. In this work, we introduce an online leasing variant in which a client need not be served as long as a penalty associated with it is paid. We also study a variant in which each client has a deadline and can be served any day before its deadline as long as for each delayed day a penalty is paid: no penalty is paid if served on the day of arrival. In an earlier work, we studied a special case in which no penalty costs are incurred as long as the client is served within its deadline (i.e., all penalties are set to 0). The goal is to minimize the total cost of purchased leases and penalties paid. Should we know the sequence of clients in advance, the two problems (offline version) can easily be solved optimally using Dynamic Programming. Nevertheless, the clients are only revealed to us with time and so we seek algorithms that provide provably good solutions without knowing the future (online version). We give deterministic online primal-dual algorithms, evaluated using standard competitive analysis in which an online algorithm is compared to the optimal offline algorithm which is optimal and knows the entire sequence of clients in advance.

■ TD-02
Thursday, 14:45-16:15 - WGS|102
Deployment of Optimization Models
Stream: Software Applications and Modelling Systems
Parallel session
Chair: Franz Nelissen

1 - Developing optimization web apps with Xpress
Johannes Müller, Susanne Heipcke, Yves Colombani

FICO Xpress Mosel, originally designed as a modelling, solving and programming language for working with the Xpress Solvers, has gradually been extended to support parallel and distributed computing, going along with a host of new data connectors (including the possibility to act as HTTP client or server), interfaces to tools such as the analytics suite R, and additional solvers for non-linear and constraint programming. The deployment options (cloud, on premises, desktop) of Mosel programs via a web-based multi-user interface find increasing use in large-scale projects, including from non-optimization users. A prominent example is the recently released FICO Decision Optimizer 7.0 that has been fully re-implemented with Mosel. It integrates various analytic components such as decision trees, scorecards and decision impact models. We shall comment on recent enhancements to the Mosel environment, including improved general programming capabilities (remote debugging, code coverage, definition of metadata via annotations) and new language features (e.g., access to Amazon S3 buckets), and demonstrate the new web-based development environment for model and web-application development, including its deployment and debugging capabilities for optimization web apps.

2 - Recent Advances for Building and Deploying Analytical Solutions using AIMMS
Ovidiu Listes

We present recent developments in the AIMMS software platform which facilitate fast and flexible building of analytical decision applications as well as their deployment in enterprise wide systems with client-server architectures and advanced user interfaces.

3 - A distributed Optimization Bot/Agent Application Framework for GAMS Models
Franz Nelissen

In this talk we will present a prototype of an optimization bot/agent application framework for GAMS models based on the GAMS .NET API. After the introduction we will show the basic architecture, features and the different elements of the system and illustrate them through an example.
3. Swapping all-pair shortest path and maximal flow matrices: Theory and applications
Horst W. Hamacher

Given a network (V,E; u,c,b) with node set V, arc set E, capacity and cost function u defined on the arcs, and weight function c defined on the nodes, the following two all-pair matrices are well-known. The all-pair shortest path matrix D and the all-pair maximal flow matrix F, where (i,j)-th entry is the length of a shortest path between nodes i and j, and the value of a minimal cut separating nodes i and j, respectively. All-pair matrices play an important role as subproblems in more complex optimization models, have various applications (for instance, in locational analysis and transportation planning) and can be computed in polynomial time. In this presentation, we consider optimization problems in which the roles of all-pair shortest path and multi-commodity matrices are swapped. In this way we obtain, for instance, network location problems with min-cut distances and source location problems in which the network flows are replaced by network tensions. We will discuss properties and solution methods for the new network models and show their potential as modeling tool for real-world problems.

4. Network Flows
Ronny Hansmann

Railway freight shunting is the process of departing trains from arriving freight trains in rail yards. The shunting procedure is complex and rail yards constitute bottlenecks in the rail freight network, often causing delays to individual shipments. Planning for the allocation of tracks at rail yards is difficult, due to limited resources (tracks, shunting engines, etc.). The required schedules highly depend on the particular infrastructure of the rail yard, on the configuration of inbound and outbound trains, and on the business objectives. Thus, optimization tools as active decision support for the dispatchers have to be tailored to the actual processes. In this talk, an overview of complexity results for several variants of the underlying Classification Problem is given that stem from fruitful relations to graph coloring, sequence partitioning, and scheduling. We focus on new complexity results for variants that allow a maximum degree of freedom for outbound car moves. Finally, we briefly mention how to compute optimal schedules and we outline the need for future research.

5. Scheduling Problems
Cor Hurkens

We propose a MIP model to design a private charging infrastructure for a fleet of electric vehicles operating in large urban areas. Examples of such a fleet include taxicabs and small vans used in the city logistics or shared vehicles. The fleet is composed of vehicles equipped with an internal combustion engine, but the operator is wishing to replace them with fully electric vehicles in the near future. It is required to design a private network of charging stations that will be specifically adjusted to the operation of the fleet. We use GPS traces to characterize actual travel patterns of individual vehicles. We formulate a location-scheduling optimization model that determines the maximum number of vehicles that can be recharged without affecting their routes and parking behaviour and finds the corresponding design of the charging infrastructure. The model assumes that all vehicles possess complete information about all other vehicles. To study the role of available information, we evaluate the resulting charging designs under coordinated charging when vehicle drivers reveal to each other departure times, and uncoordinated charging when vehicle drivers know only actual occupation of charging points.

6. MIP and Heuristics for Multi-Earth-Observing Satellites Scheduling
Xiaoyu Chen, Gerhard Reimelt, Guangming Dai

We address a problem of multiple satellites scheduling with limited observing ability, which is a highly combinatorial problem due to the large search space for potential solutions. By preprocessing the problem, we cope with some constraints, thus the input of the problem are only the available resources, the requested missions and the eligibility of resources for missions. We first construct a mixed integer programming (MIP) optimization model for the problem and solve it with Gurobi. On one hand, after analyzing the distribution features of the available time windows of missions, we investigate two-stage heuristics in generating optimal feasible solutions. The first stage involves the determination of observing sequence and the generation of feasible schedule scheme. We develop the time-based and weight-based greedy algorithms. The second stage is some further improvement strategies facing different resource contentsions, thus prevent results from trapping into local optimum. On the other hand, we develop a priority-based and conflict-avoid differential evolution (DE) algorithm for solving it. For the problem, we design several different kinds of instances to test the efficiency and applicability of the algorithms. According to the simulation results, we can figure out that the Gap between the optimal results and solutions solved with algorithms proposed in this paper. The improved DE algorithm shows a significant improvement.
3 - Solving integer programming models for the mid-term production planning of high-tech low-volume industries
Joost de Kruijf, Cor Hurkens, Ton de Kok

We studied the mid-term production planning of high-tech low-volume industries. We developed two integer programming models to allocate resources to the production of different products over time and coordinate the associated inventories and material inputs such that demand is met. The models support general supply chains, multiple production modes and semi-flexible capacity constraints. The first model assigns resources explicitly, but scales poorly because of the number of constraints. The second model doesn’t assign resources explicitly and is solved by a branch and cut method based on Benders decomposition, which uses a maximum flow problem to find feasibility cuts. Our goal is to solve these problems as fast as possible.

In this talk, we will present a number of improvements on the above mentioned solving methods. Among others, we will discuss the impact of having integer or continuous inventory variables. Furthermore, we will investigate the information contained in the maximum flow to find more valuable constraints.

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**TD-06**
Thursday, 14:45-16:15 - WGS|105

**Demand and Load Balancing in Networks**

**Chair:** Christoph Helmberg

1 - Predictive Analytics Based Energy Pricing Approach for Smart Grids
Jan Keidel, Peter Gluchowski

Because of the transition towards sustainable energy, the availability profile of energy changes drastically. By using decentralized renewable energy sources such as solar energy, wind energy or hydroelectricity it is much more difficult to compensate regional and temporal differences in energy generation and consumption in smart grids.

With the help of advanced information and communication technologies (ICT), different energy management techniques such as dynamic pricing schemes, forecasting of energy load and generation as well as appliance resp. customer scheduling can be implemented to reduce peak loads, costs or carbon dioxide/greenhouse gas emissions, to ensure power systems stability and reliability and to prefer renewable energy sources.

Main objective of the ESF founded research project SyNErgy is to develop control mechanisms for smart grids with focus on the ability to respond to different energy generation and consumption scenarios of locally distributed data centres (Virtual Network Embedding). This approach uses real example data of wind power plants and data centres to forecast generation and consumption as a basis for direct smart grid control via energy pricing. The functionality of the approach and some basic results will be presented.

2 - Virtual Machine Migration and Resource Reallocation: A Multi-Step Approach
Nguyen Tuan Khai, Andreas Baumgartner, Thomas Bauschert

Virtual Machine Migration (VMM) is a process of relocating a virtual machine (VM) from one host to another. VMM is desirable e.g. in case of server maintenance and significant changes in resource demands or if the operational costs of the data centers considerably change (e.g. due to changes in the local energy prices). VMM also requires the rerouting of inter-VM traffic flows. If the migration process must be conducted within a fixed time limit (migration deadline), certain constraints are imposed on the data center network. For instance, before the process is triggered, a minimum capacity needs to be available in the network to perform the migration within the deadline. However, for one-step VMM, due to the limited network resources, solely relying on the residual capacity is not adequate to ensure a feasible migration solution. In this work, we consider a multi-step migration approach and take into account the so-called "soft bottlenecks", which refer to capacity bottlenecks caused by the preoccupation of capacity due to existing virtual networks and other migration processes. By taking advantage of the possibilities for releasing and relocating these soft bottlenecks, the hosting capability of the data center infrastructure can be fully explored, and VMM can be made feasible while guaranteeing the fulfillment of the migration deadlines. Our new migration model is based on a mixed integer program (MIP), whose objective is to minimize the required migration steps. It is applied on a realistic network topology instance taken from SNDlib. The results show that situations might occur in which, contrary to our multi-step approach, single-step migration is not feasible.

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**TD-07**
Thursday, 14:45-16:15 - WGS|106

**Computational Mixed-Integer Programming 3**

**Chair:** Ambros Gleixner

1 - Recent developments in the CPLEX solver
Roland Wunderling

We will discuss the most recent improvements in CPLEX 12.7.1.

2 - Current Status and Future Developments of the SAS MILP Solver
Philipp Christophel

We give an overview of the current status of the SAS mixed integer linear programming (MILP) solver and outline future development efforts.

3 - Recent Advances in Gurobi 7.0
Michael Winkler, Tobias Achterberg

We will give an overview on new features of the current Gurobi release including multi-objective support, the new solution pool capabilities, and the improved new modeling features. Additionally we will talk about performance improvements and our new Instant Cloud.

4 - SatNl’s Solving Genie: The SolveEngine
Vito Tumas, Youri Moskovic

The SolveEngine provides optimisation-as-a-service. We aggregate, maintain and license a wide range of best-in-class solvers. Users simply submit a problem (SAT, MILP, CP, GP and soon, MINLP) to a cloud server, and the SolveEngine selects the best-suited solver for that particular problem. The SolveEngine is algorithm agnostic, and is constantly updated with algorithms from both academic and commercial communities, ensuring the system is consistently cutting edge. User’s pay only for the SolveTime they use, and algorithm providers generate revenue from royalties.
In this talk, we will outline which solvers, algorithms, modeling languages and solve systems have already been integrated into the SolveEngine. We will describe how everyday users can access the SolveEngine, and for more advanced users, explain how existing systems can access the SolveEngine through our API’s. We will provide details of our beta version, and explain how machine learning will be used to extract features from your problem in order to determine which solver to send it to and continuously improve the performance of the SolveEngine. We will conclude with a description of how algorithm creators can seamlessly integrate their own algorithms into the SolveEngine and start generating revenue to fund future developments, as well as gain and insights into the performance of their creations to support further development and advancement.

**TD-08**

**Thursday, 14:45-16:15 - WGS 107**

**Urban Transport**

**Parallel session**

Chair: Jörn Schönberger

1. **An Integrated Optimization-Simulation Approach for Sustainable Urban Transport**
   Marcus Brandenburg, Werner Jannernegg, Matthias Kannegiesser, Manfred Paier, Tina Wakoiblinger

Urban transport is exposed to massive sustainability challenges, e.g. emissions and air pollution, costs and congestion, time delays, negative social health impact, consumed space, population growth and further urbanization. A fundamental transformation of urban transport towards sustainability over the next decades is required. New powertrain technologies, mobility models and changed user behavior provide opportunities for the transformation. The strategic planning problem is substantially complex and dynamic. Thus, city decision makers and other stakeholders need advanced decision support tools to understand, plan and manage the transformation. We present the cornerstones of a new research project that aims at developing a decision support approach to answer, if, when and how a transition towards sustainable urban transport can be reached and which alternative transition scenarios exist. The real-life planning problem needs to consider active decision making and optimization (e.g. infrastructure investment decisions), dynamics of influencing external scenario drivers (e.g. technology cost developments or demographics) as well as the interplay of stakeholders (e.g. in negotiations on regulation options for city logistics). We present the scope, requirements and research approach as well as initial hypothesis and interim results. The model architecture foresees a new integrated optimization-simulation approach that combines multi-objective time-to-sustainability optimization for urban transport with system dynamics and multi-agent simulation to model external parameters. Heuristics are applied for model integration and handling of sub-problems. We plan to numerically analyze three real-life cities (Vienna, Berlin and Kassel) with the integrated approach.

2. **Traffic Speed Prediction with Neural Networks**
   Umut Çakmak, Mehmet Serkan Apaydın, Bülent Çatay

Traffic speed and flow prediction has started attracting more attention in contemporary transportation research with the growing interest in creating Smart Cities. Neural networks have been utilized in many studies to tackle this problem; yet, the proposed methods have focused on the short-term traffic prediction while longer forecast horizons are needed for more reliable mobility and route planning. This study aims to fill this gap by addressing the mid-term forecasting as well as the short-term. Our approach employs a feedforward backpropagation neural network that combines different time series forecasting techniques such as naïve, moving average and exponential smoothing where the predicted speed values are fed into the network as inputs. We train our neural networks and select the hyper-parameters of the backpropagation neural network. We will outline which solvers, algorithms, modeling languages and solve systems have already been integrated into the SolveEngine. We will describe how everyday users can access the SolveEngine, and for more advanced users, explain how existing systems can access the SolveEngine through our API’s. We will provide details of our beta version, and explain how machine learning will be used to extract features from your problem in order to determine which solver to send it to and continuously improve the performance of the SolveEngine. We will conclude with a description of how algorithm creators can seamlessly integrate their own algorithms into the SolveEngine and start generating revenue to fund future developments, as well as gain and insights into the performance of their creations to support further development and advancement.

**TD-09**

**Thursday, 14:45-16:15 - WGS 108**

**Robust Combinatorial Optimization (i)**

**Parallel session**

Chair: Jannik Matuschke

1. **New MIP Formulations for the Steiner Forest Problem**
   Daniel Schmidt, Bernd Zey, Francois Margot

We compare linear programming bounds obtained from various Steiner Forest integer programming formulations in an experimental study and propose two new directed formulations for the problem. It turns out that the new formulations provide strong linear programming bounds.

2. **Robust Randomized Matchings**
   Jannik Matuschke, Martin Skutella, Jose Soto

The following zero-sum game is played on a weighted graph: Alice selects a matching M and Bob selects a number k. Then, Alice receives a payoff equal to the ratio of the weight of the k heaviest edges of M to the maximum weight of a matching of size at most k in the graph. If M guarantees a payoff of at least 1, then it is called L-robust. In 2002, Hassin and Rubinstein gave an algorithm that returns a sqrt(1/2)-robust matching, which is best possible.

In this talk, we will see that Alice can improve on the guarantee of sqrt(1/2) when allowing her to play a randomized strategy. We devise a simple algorithm that returns a 1/ln(4)-robust randomized matching, based on the following observation: If all edge weights are integer powers of 2, then a lexicographically optimum matching is 1-robust. We prove this property not only for matchings but for a very general class of independence systems that includes matroid intersection, b-matchings, and strong 2-exchange systems. We also show that our robustness results for randomized matchings translate to an asymptotic robustness guarantee for deterministic matchings: When restricting Bob’s choice to cardinalities larger than a given constant, then Alice can find a single deterministic matching with approximately the same guaranteed payoff as in the randomized setting.

3. **Mixed Integer Reformulations of Robust b-Matching Problems**
   Frauke Liers, Lena Maria Hupp, Manu Kapolke, Alexander Martin, Robert Weismantel

In this talk, we consider robust two-stage bipartite b-matching problems with one or several knapsack constraints. Following the approach of Baader, Hildebrand, Weismantel, and Zenkussen (2016), we show how to reformulate the integer programming (IP) formulations of the two-stage bipartite b-matching problems as MIPs that only use few integer variables. To preserve integrality, an appropriate affine TU decomposition of the constraint matrix needs to be found. In the case of the two-stage bipartite b-matching problem with only one knapsack constraint, we present an affine TU decomposition and show that in a
specific MIP reformulation the number of integral variables only depends on the number of nodes in one shore of the graph. For the two-stage bipartite matching problem with several knapsack constraints, an appropriate affine TU decomposition cannot be derived in a straightforward way. However, we present a similar decomposition of the constraint matrix and prove that this decomposition preserves integrality and thus allows a MIP reformulation with less integer variables. Applications of such robust two-stage bipartite b-matching problems are in robust runway scheduling in air traffic management. Each aircraft is assigned a time slot at the first stage before the uncertainty reveals. If an aircraft remains on the main conveyor of an order-picking system. A distribution conveyor pushes the bins out to several buffer conveyors. Robotic arms are placed at the end of these buffer conveyors where each arm picks up the first bin of one of the buffer conveyors and moves it onto a pallet located at stack-up positions. In this paper we present an online algorithm to distribute bins to the buffer conveyors, and we analyse how many stack-up places are required to palletize the bins with respect to this distribution.

2 - Optimizing Address Mappings of DRAMs with Fixed Access Patterns
Marco Natale, Sven Krumke

Dynamic Random Access Memories (DRAMs) are fundamental components of today’s computers, which allow volatile data storage at a very high density. However, due to architectural limitations only a certain amount of data can be cached and made available for fast access. Accessing non-cached data comes at high costs in both time and energy. Therefore, the efficiency of a DRAM is highly dependent on how the data is stored internally. In general purpose systems like personal computers it is not fully determined in advance how the data is accessed and decisions can be made only online. Nonetheless, numerous systems, such as embedded systems, possess regular or fixed access patterns. This global view allows storing of the data such that the time and energy consumption is minimized. In our model a DRAM consists of several banks each of which is subdivided into rows. Per bank at most one row can be cached and addresses in such a row can be accessed for free. Accessing a non-cached address, however, comes at one unit cost. The goal is to remap the addresses such that the cost of a fixed access pattern is minimized. In general this problem is NP-hard to approximate. However, we show that locality properties of the input sequence can be exploited to obtain polynomial time algorithms for a wide class of sequences.

3 - The k-server problem with parallel requests and the corresponding generalized paging problem
R. Hildenbrandt

In this talk we want to discuss several algorithms for solving the k-server problems with parallel requests where several servers can also be located on one point. We are given initial locations of k servers in a finite metric space. Requests for service at several points come in over time. Immediately after the t-th request is received, a sufficient number of servers must be moved from their current locations to the request points in order to fulfil the request. The choice of which servers are moved, must be made based on the current servers configuration and on the requests seen so far. Moving servers cost the distances the servers are moved, and the goal is to minimize the total cost. The (usual) k-server problem, where at most one server must be moved in servicing the request in each step, was introduced by Manasse, Mc.geoch and Sleator in 1988. The investigation of the generalized k-server problem with parallel requests was initiated by an operations research problem which consists of optimal conversions of machines or moulds. Based on well-known algorithms (as the Harmonic or the work function algorithm), we will develop new algorithms and show their qualities for solving the generalized problem. We will also do that for the specific case where all distances are equal (generalized paging problem).
routes for each driver to support the operational service of a food delivery service. However, the optimization model could be used for other business models. For instance, open routes and multiple depots occur in vehicle rental and logistics sector.

3 - A matheuristic based on Variable Neighborhood Search for the Swap-Body Vehicle Routing Problem

Sandra Haber, Jean-François Cordeau, Martin Josef Geiger

This talk presents a solution approach for the Swap-Body Vehicle Routing Problem (SB-VRP), which was announced by the EURO working group on Vehicle Routing and Logistics Optimization (VeRoLoG) in collaboration with the German company PTV Group. We employ a matheuristic consisting of a Variable Neighborhood Search and a set-partitioning formulation. In a first phase, feasible alternatives are computed by means of four standard operators, such as e.g. a 2-OPT and an inter-move that can reposition a customer in another tour. Throughout the search, feasible, distinct routes are kept in memory. After that, routes in the pool are selected, which minimize the total routing cost. Our solution approach is tested for several benchmark instances, which are available on the VRP-repository. Computational results show that several instances can be improved by the matheuristic. However, for some instances the combination does not give an advantage. Currently, we are working on additional operators in order to enhance the pool of routes. One of the ideas is to merge two truck tours in one train tour. Several swap locations for the train tour are tested, which are close to both truck tours.

TD-13
Thursday, 14:45-16:15 - RVH/I
Smart Services and Internet of Things II
Stream: Business Analytics, Artificial Intelligence and Forecasting
Parallel session
Chair: Maria Maleshkova

1 - Exploring the Formation of Blockchain-driven Business Networks
Stefan Seebacher

It is hypothesized that blockchain technology has the potential to affect a vast variety of different industries and services, thereby, disrupting existing business models and market structures. Until now, current research has mostly focused on the assessment of the technical characteristics as well as on the potential impacts of blockchain technology. However, other aspects remain still unexplored. For instance, it is not investigated how business networks form in such a setting and how smart contracts and the blockchain’s underlying chain code can be efficiently composed to facilitate the realization of blockchain projects. The goal of the research at hand is to close this gap, bridging technical and economic aspects, therefore, trying to answer the following research question: “What kind of patterns can be identified, assessing blockchain-driven business networks, to facilitate their modularization and chain code?”

Existing business networks that apply blockchain technology serve as the main data source for this research inquiry. In particular, the data is collected by assessing existing Hyperledger projects. In this regard, a semantic model is developed, which describes all relevant aspects of a blockchain-driven business network. For the pattern analysis, open coding and clustering algorithms (e.g., PCA, k-medoids) are applied to potentially identify different levels of patterns. Based on these patterns, network components, such as smart contracts, are modularized with respect to the corresponding use case and domain. Thereby, the research inquiry extends the body of knowledge concerning blockchain, on a business network level, and gives guidance to practitioners who are aiming to integrate the technology into their current business networks.

2 - Estimating Downtime Costs using Simulation
Clemens Wolff, Michael Vössing

Recent trends in industrial maintenance have indicated a shift from traditional transactional maintenance towards long-term maintenance contracts, in which the service provider guarantees a certain predefined equipment availability level. Due to this development, industrial manufacturers need to be able to determine suitable long-term equipment availability levels for contracting. One approach of doing so is by using Service Level Engineering (SLE). SLE identifies a cost-optimal equipment availability by balancing the costs of additional equipment up-time against the costs of missing up-time - in other words, downtime costs. When calculating the cost of downtime, opportunity costs, such as lost production output, must be considered. While for simple production systems, production loss quantities can be calculated analytically through Graph Theory, more complex systems require new sophisticated models. In this work, we propose an approach for estimating production output losses due to individual asset downtime through simulation. The production output shortages can then be monetarized and accounted for when calculating downtime costs.

By including manufacturing dependencies between multiple production assets as well as production unit flexibility, we aim to estimate production system-wide costs of downtime that are associated to individual assets downtime within the production system. There are three promising areas of application for these insights: First, knowledge of downtime costs of individual assets can be used to prioritize maintenance activities. Second, we aim to look at maintenance scheduling from a system perspective, thus also taking downtime costs of customers into account. Third, they can be used to apply SLE.

TD-14
Thursday, 14:45-16:15 - RVH/I
Human Decision Making in Revenue Management
Stream: Pricing and Revenue Management
Parallel session
Chair: Catherine Cleophas

1 - Prediction and Learning with Expert Advice in Airline Revenue Management
Stefan Franz, Esther Mohr, Christiane Barz

We introduce a new approach for determining booking limits for the static single-leg revenue management problem in absence of a probabilistic model for the demand. Aiming at a minimization of regret, our approach is based on prediction with expert advice. We evaluate our approach in a simulation.
2 - Considering Human Decision Making in Revenue Management Given Diverse Decision Tasks

Claudia Schuetze, Catherine Cleophas

Revenue management has become a crucial success factor for many service industries such as ho-tels, car rentals, and airlines. It embodies the idea of maximizing revenue by optimizing the set of offered products, given limited capacity and predicted demand. To complement automated revenue management systems, firms employ revenue analysts. In consequence, the interaction between sys-tem and analysts plays a decisive role for revenue management in practice. Therefore, we investigate human decision making in a revenue management setting to draw conclusions for the design of decision support systems.

On the one hand, analysts can be tasked to balance multiple objectives, such as short-term revenue managerial KPIs, such as market share or capacity utilization. Currently, automated revenue management sys-tems rarely consider multiple criteria, but intensively focus on maximizing revenue. We analyse how well analysts are able to balance those multiple objectives given different framings of the task in a controlled experiment.

On the other hand, analysts influence system parameters rather than deciding whether to accepting individual customer requests or how many seats to assign to a booking class. While existing research mainly focuses on those decision tasks, we test the effect when the analysts’ influence is framed in a more indirect way, given aspects of anchoring and algorithm trust.

3 - Balancing Revenue and Load in Capacity-Based Revenue Management

Felix Geyer, Christina Büssing, Catherine Cleophas

In revenue management, maximizing revenue and secondary business objectives play a significant role for the long-term success. An important objective is the number of sold units, also expressed as load, as it is related to strategical targets and stock valuations. For instance, after launching a new service, the firm may want to maximize the number of early adopters and stimulate the demand in the short-term to increase long-term revenue potential. In practice, automated systems are used to maximize revenue by optimizing inventory controls for capacity-based revenue management. But the revenue-maximal solution may not align with the secondary objective of maximizing load. Hence, analysts manually overrule the automated optimization to improve the secondary objective. Such manual interventions are unlikely to achieve an optimal balance of objectives. Thus, we suggest to include the secondary objective in the optimization model to calculate a Pareto-curve based revenue management. The results of the simulation provide further information. Otherwise, agent-based approaches are sometimes criticized as ‘toy models’, especially if they lack of empirical foundation and therefore do not adequately represent actual behavior in real markets. Even if empirical grounded, parameters are - more often than not - derived from (aggregated) sociodemographic datasets and individual choice-behavior is therefore not adequately captured. Thus, profound parametrization as well as validation of agent-based models is often neglected, especially in the case of electric vehicles. In order to overcome these limitations, we present an agent-based simulation approach that builds on empirical data derived primarily from a choice-based-conjoint-analysis. Furthermore, a cross-model validation is performed. Our application case focusses on the generation Y’s’ (future) adoption behavior of electric, plug-in electric and conventional vehicles in Germany. The model at hand allows for analyzing various impacts like technological progress (e.g. in range, charging time, consumption costs, or station density), subsidies, marketing, and previously unstudied effects arising from the possibility of home charging.

3 - Simulation of a Service Station in a Public Transportation System

Malte Thiede, Lars Stegemann, Martin Furstenau, Martin Gersch, Hannes Rothe

The simulation of heuristic problems of tabulation and rotation planning is a well-established procedure in the local public transport for years. However, agent-based approaches like MATSim have additional potentials, which extend beyond the usual application. This contribution illustrates one of these potentials using the example of the introduction of a service station in the service system of a public transport provider. In a five-step procedure, this service is analyzed and modeled for the simulation. The results of the simulation provide further direction for the specific requirements of these service stations. The case study shows, on the one hand, the usefulness of simulation in a complex service system. Thus, both service station-specific parameters, such as location combinations, capacity or service life, as well as market-economy data, such as utilization, can be calculated. On the other hand, the case also shows the limitations, such as the high computational cost.
1 - Flexible layouts for the mixed-model assembly of heterogeneous vehicles
Andreas Hottenrott, Martin Granow

The increasing vehicle variety and heterogeneity is pushing the widespread mixed-model assembly line to its limit. In alternative flexible layouts, the assembly stations are no longer arranged in a serial manner and no longer linked by a paced conveyor belt but automated guided vehicles. Such flexible assembly layouts can improve makespan, station utilization and disruption risk resilience in a low volume, high variety product environment. However, these advantages come at the expense of an increase in production and transportation complexity. Our objective is to analyze under which circumstances flexible assembly layouts are in fact superior to mixed-model assembly lines. We provide a mixed-integer linear model formulation and develop a decomposition-based solution procedure to generate flexible layouts for the final assembly of heterogeneous vehicles in static environments. Our solution procedure can be employed as an exact or heuristic approach. We compare the performance of flexible layouts against mixed-model assembly lines.

2 - Using Extreme Value Theory to Model Assembly Line Balancing Problem with Stochastic Task Times
F. Tevhide Atekin

In this study, we deal with the stochastic assembly line balancing problem. We assume the task times are normally distributed with known means and standard deviations. Although the work contents assigned to the stations are also normally distributed, the maximum of these work contents is not normally distributed. Extreme value theory is used to represent similar extreme order statistics of normally distributed samples in various fields such as energy, finance, and engineering. After providing an overview of extreme value theory approaches, we exploit three approximations to model the distribution of the maximum work content by using Gamma, Normal and Gumbel distributions. So as to estimate the parameters of these distributions, we also compare and contrast different approaches to estimate the expected value and the standard deviation of the maximum work content. A comparison of the approximations is provided using examples from the assembly line balancing literature.

3 - Production Sequencing of Multi-level Mixed-Model Assembly Lines
Tobias Kreiter, Ulrich Pferschy

Increasing product variations and highly individual customer requests motivate manufacturers to shift from classical large batch size production environments to mixed-model assembly lines extending towards the separate consideration of each individual product. However, an assembly line should still be run with constant speed and cycle time. Clearly, the consecutive production of different models will cause a highly unbalanced temporal distribution of workload. This can be avoided by moving some assembly steps to pre-levels thus smoothing out the utilization of the main line. In the resulting multi-level assembly line the sequencing decision on the main line has to take the balancing of workload for all pre-levels indirectly into account to assure that the modules or parts delivered from the pre-levels do not cause congestion but are adjusted to the sequence of the main line. One planning strategy aims at mixing the models on the main line to avoid blocks of identical units. We present a Mixed-Integer Programming model (MIP) for this approach and enrich it with a number of relevant practical extension. On the other hand, we illustrate how this strategy and its extensions could be (to some extend) realized in an advanced planning and scheduling environment linked to an Enterprise Resource Planning (ERP) system, namely SAP APO. Then, we also give a MIP model for the actual objective of explicitly balancing pre-level workloads. Finally, we present computational experiments for a real-world production planning problem of a company producing engines and gearboxes. We compare the possibilities and limitations as well as the computational performance of MIP models and the realizations in SAP APO.

1 - Appointment Scheduling Strategies for Medical Group Practices
Julia Block, Lisa Koppka, Matthias Schacht, Brigitte Werners

In a medical group practice consisting of several primary care physicians (PCPs) patient occurrence and demand for medical treatment fluctuates depending on the PCP and the weekday. Walk-in patients (walk-ins) seek for a same-day treatment and join the practice especially at the beginning of the week. In addition, there are patients who book their appointments in advance (preschedules). For preschedules who prefer a given appointment with their personal PCP on a specific time and day, appointment slots are provided. By offering appointment slots on different days, demand can be channeled to match the capacity leading to shorter waiting times. Requests for appointment slots may differ between the PCPs. In order to achieve a more balanced utilization of PCPs, less frequented PCPs may treat more walk-ins than the ones with high demand for appointments. Thus, demand for medical treatment can be shifted in two different ways: firstly, between weekdays and secondly, between the PCPs. We extend current interday appointment scheduling models by integrating multiple PCPs. We present a concept for an extended MILP whose optimal solutions on the tactical level are evaluated in an extensive simulation study on the operational level where uncertain patient occurrence and preferences, treatment times and urgent requests are considered.

2 - A Genetic Algorithm for the Vehicle Routing Problem with time window and temporal synchronization constraints
Stephan Hocke, Christina Hermann, Mathias Kasper

This paper presents a genetic algorithm for the Vehicle Routing and Scheduling Problem with time windows and temporal synchronization constraints. That means that as opposed to the usual procedure, in addition to the usual task covering, some vertexes must be served by more than one vehicle at the same time. The mathematical model relates on a work of Mankowska et al. (2014) who describe a daily planning of health care services carried out at a patient’s home by staff members of a home care company. The chromosome coding used here is based on their proposed solution representation. The genetic algorithm was able to solve the instances of Mankowska et al. (2014) up to 20 patients near to optimality. Even in greater instances with 100 patients the solution quality of the genetic algorithm outperforms the local search presented by Mankowska et al. (2014), however with losses in runtime. In order to get more comparable results, both solution approaches are evaluated at the well-known benchmark instances of Bredström and Rönqvist (2008). This includes the presentation of a simple repair algorithm during the chromosome crossover based on an insertion heuristic in order to achieve the hard time window constraints of the benchmarks.

References

3 - Planning of out-of-hours service for pharmacies
Timo Gersing, Christina Büsing, Ari Koster

The supply of pharmacies is one important factor in a functioning health care system. In the German health care system, every citizen must by law find an open pharmacy at any day and night time within a certain distance. To that end, every pharmacy has to take over some out-of-hours shifts during the course of a year. These shifts are highly unattractive since they are unprofitable and stressful for the pharmacist who has to work for 24 consecutive hours. The out-of-hours service is typically organized locally within small districts as cities or municipalities. In this talk, we present a centralized planning to reduce the load of shifts and to distribute them evenly among the pharmacies. Such an out-of-hours plan has to meet several constraints: the coverage of the whole population; rest periods between two shifts; minimum distance between open pharmacies. As a combination of a set cover, scheduling and independent set problem. Here, this problem is NP-hard. To solve the problem, we present a matheuristic based on a rolling horizon approach. Finally, we analyze the obtained out-of-hours plan for the area Nordrhein in 2017 and compare it with the current out-of-hours plan.
1 - Dynamic resource scheduling problem for audit planning
Ethem Canakoglu, Ibrahim Muter, Onur Adanur

Resource scheduling has been one of the most prominent problems in the operations research literature due to its technical challenges and prevalence in real-life. These problems include a set of tasks, resources to perform these tasks under some constraints (resource capacity, time limitations, etc.). In this paper, we focus on an extension of the parallel machine scheduling problem with additional resources. This problem also arises in audit scheduling in which the local branches of a financial firm are to be audited by a team of auditors with different experience levels. The quantification of the auditor experience and the branch experience requirement enables us to model this problem as an extension of the aforementioned scheduling problem with inter-task constraints and objectives related to the auditing process. Due to the dynamic structure of team building problem, it can be classified as a dynamic resource constrained parallel machine scheduling problem with unspecified job-machine assignment. We build mathematical models for these problems and propose heuristic algorithms to find upper bounds for the problem. We analyze the effectiveness of algorithms through computational experiments on the generated instances.

2 - Strategic planning of new product introductions in the automotive industry
Christopher Valentin Bersch, Renzo Akkerman, Rainer Kolisch

The timing of the introduction of new vehicles is an important strategic concern in the automotive industry and a complex decision problem for a variety of reasons. First, due to the use of platform-based planning, shared modules create many interactions between the individual products. Secondly, new product development projects rely on various shared resources. Furthermore, many potentially conflicting objectives must be considered in such a long-term planning problem. We are addressing this problem by presenting a mixed-integer linear programming model for the timing of the introduction of new vehicles, which is building on modelling concepts of multi-project scheduling. Using data from a major German automotive company, we are presenting the computational performance of our model, when solved with state-of-the-art solvers, as well as managerial insights.

3 - The two dimensional bin packing problem with layer constraints
Markus Seizinger, Andreas Fügener, Jens Brunner, Alessio Trivella

We propose a new variant of Bin Packing Problem, where rectangular items of different types need to be placed on a two-dimensional surface. This new problem type is denoted as two-dimensional Bin Packing with layer constraints. Each bin may consist of different two-dimensional layers, and items of different types may not overlap on different layers of the same bin. By different parameter settings, our model may be reduced to either a two- or three-dimensional Bin Packing Problem. We illustrate real applications, such as paint shops or compartment trucks. We further propose lower bounds, efficient heuristics, and a column-generation scheme that manages to find near-optimal solutions in realistic time. An extreme-point heuristic is applied to approximate the packing subproblem.

1 - Optimization of processing rates in stochastic operations systems
Raik Stolletz, Jannik Vogel

A key challenge in production and service systems is to adapt the resource capacity to a time-dependent and uncertain demand. The aim of this paper is to gain insights on how the information on demand changes influences the optimal control of the processing rate of a stochastic multi-server system. We model that system as a single-stage $M(t)/M(t)/c$-queue. A non-homogeneous Poisson process with instantaneous arrival rate creates arrivals to this system. The decision is to choose optimal processing rates within a given range. The objective function considers holding cost and service cost proportional to the current processing rate. Additionally, a reward for finished items or served costumers is modeled. The reward per unit is assumed to be constant or to be dependent on the current processing rate.

We present a general integrated decision model for optimizing the processing rates. First, closed form solutions are derived with a single decision on the processing rate under stationary conditions. Second, we analyze the system with time-dependent demand and multiple changes of the processing rates. The time-dependent behaviour is modelled with a stationary back-log-carryover (SBC) approach. Since the processing rates are the decision variables, we develop a new SBC-approach that calibrates the period length dependent on the result of the optimization. A numerical study shows the reliability of the new approach. We show numerically that the decision on the processing rate in a current period may depend on future demand changes.

2 - In-Line Sequencing in Automotive Production Plants - A Simulation Study
Heinrich Kuhn, Marcel Lehmann

Nowadays car manufacturers produce vehicles in a great variety of models on the same assembly line. This results in the stringent necessity of applying the concept of In-Line Sequencing (ILS) to parts and vehicles. Otherwise a huge amount of various parts has to be stored close to the assembly line. Delivering the main parts directly to the assembly line in the same sequence as the production schedule of the vehicles reduces inventory, produces greater assembly accuracy, and most of all lowers logistics costs. The purchasing and logistics costs of parts however could be further reduced by predetermining the production sequence of the assembly line exactly for a longer time horizon, e.g., one week. This is not an easy task since in general the assembly sequence originally planned gets into disorder during the preceding production processes of framing and painting. Restoring the original sequence is not possible in all instances and even a large sequencer in front of the final assembly line may not be able to rebuild the sequence.

The question therefore arises to which extent the assembly line sequence can be recreated in a real automotive assembly plant. We analyze the production facility of a major German automotive company in order to reveal stability potentials and to identify influencing factors for scrambling the original sequence. We conduct a discrete event based simulation study, based on real world data for a period of half a year and measure the stability levels of different production stages. The study reveals different stability patterns depending on the underlying layout of the production facilities and the current state of the product life cycle. In addition, we analyze the recreation potential depending on the size of the ASRS.

3 - Minimizing work-in-process inventory in dynamic Kanban systems
Justus Arne Schwarz, Raik Stolletz

The Kanban system is a widely spread inventory control mechanism for production systems, e.g., in the automotive and food industries. In these systems, the maximum work-in-process inventory (WIP) at each stage of the production is limited by the corresponding number of Kanban cards. The inventory between the stages is used to hedge against the randomness of the demand and of the production process. However, the traditional Kanban system is made for static environments. Dynamic changes in the demand characteristics can occur within a production system itself or may be induced by customers, e.g., because of seasonal patterns in demand. We consider a production system with serially arranged stations that serves a stochastic and time-dependent demand from a finished goods buffer. The goal is to minimize the expected value of the average WIP in the system over a finite planning horizon while guaranteeing a service level. We introduce a new
In this study we investigate the governance of concurrent sourcing and aim to make two central contributions: First, we investigate the effectiveness of output monitoring, behavior monitoring and solidarity to mitigate the risk of supplier opportunism in both singular and concurrent sourcing relationships. Second, we further refine our main predictions and distinguish between concurrent sourcing firms that procure most of their requirements for a given input from an outside supplier and firms that produce the larger part internally. Using primary data from the German machinery industry, we overall find support for our predictions regarding output monitoring and solidarity, but not behavior monitoring. Supporting our hypotheses, our results show that output monitoring is more effective at low levels and solidarity at high levels of internal production.

### TD-21

**Thursday, 14:45-16:15 - RBM/4404**

**Advanced Flow Systems**

**Stream:** OR in Engineering  
**Parallel session**

**Chair:** Fabian Gnegel

1. **Polyhedral 3D Models for Natural Gas Compressors and Stations**  
   *René Saitenmacher, Tom Walther, Benjamin Hiller*

   In gas transmission networks, compressor stations are required to compensate for the pressure loss caused by friction in the pipes. They typically comprise several compressor machines that can be operated in different configurations, e.g., in serial or parallel. Modeling all physical and technical details of a compressor station involves a large amount of nonlinearity and discrete decisions, making it hard to use such models in the optimization of large-scale gas networks.

   In this talk, we are first going to describe a modeling approach for the operating range of compressor machines, starting from a complicated physical reference model and resulting in a simple linear polyhedral representation in three dimensions: the throughput in terms of mass flow as well as the pressures at the inlet and outlet node of the machine. We will study some properties and the errors that are taken into account.

   Moreover, combining the compressor machine polytopes according to the configurations allows us to obtain a non-convex disjunctive polyhedral representation of the operating range of an entire compressor station. We will introduce a preprocessing technique based on so-called Approximate Convex Decomposition in order to obtain relaxations for (MILP) and solving it using standard MILP solvers fails to provide good solutions in reasonable time.

2. **A New Approach for the Optimization of Booster Stations**  
   *Jonas Benjamin Weber, Ulf Lorenz*

   Typically, the supply pressure of water companies is not high enough to supply all floors of tall buildings e.g. skyscrapers with drinking water. To guarantee a continuous supply of all consumers so called booster stations are used to increase the pressure of the supplied drinking water for the demanded time-variant flow-rates. In technical terms these booster stations can be described as fluid systems consisting of interconnected components such as pumps, pipes, valves and other fittings.

   Even for a relatively small set of possible components a variety of combination arises. Because of this combinatorial explosion, an algorithmic system synthesis approach is favorable. The main task for the algorithmic synthesis is to find topologies and control strategies with low costs which satisfy the consumer’s demands at any time while obeying the general laws of fluid mechanics. As the problem instances reach a practically relevant size the common algorithmic approach of modeling the optimization problem as a mixed integer linear program (MILP) and solving it using standard MILP solvers fails to provide good solutions in reasonable time.

   Therefore, we developed an approach to overcome this disadvantage. This approach is based on three key components. The optimization problem is modeled in two ways, a graph-based formulation and a MILP. Both views are used simultaneously while addressing the problem with heuristics from the primal and dual side to find good solutions as well as tight bounds. These heuristics make heavily use of problem

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**Chair:** Thomas Mellewigt

**Multiple Suppliers**

**Stream:** Supply Chain Management  
**Parallel session**

**1 - Newsvendor models with unreliable and backup suppliers**  
*Dimitrios Pandelis*

We develop and analyze newsvendor models with two suppliers. At first the retailer places an order to a primary unreliable supplier and reserves the capacity of a backup reliable supplier. Then, the retailer may exercise the option to buy any amount up to the reserved capacity after the delivered quantity from the primary supplier becomes known. In our work we analyze optimization models for several versions of the problem. We consider primary suppliers that are subject to random yield or random capacity and the cases when the option to buy from the backup supplier is exercised before or after the demand becomes known. We derive conditions on the reservation price that make the use of the backup supplier profitable and obtain properties of the optimal order and reservation quantities.

**2 - Finding the optimal fill rate and reorder point by simulating a periodic review stochastic inventory model with two supply modes**  
*Felix Zesch*

In a supply chain setting, the fill rate for articles in a warehouse is a common input parameter for finding optimal inventory parameters. In most cases, the fill rate is decided by management without considering quantitative analytics. We present and apply a methodology for approximating the optimal fill rate in inventory-production systems through discrete-event simulation and curve-fitting for a supply chain with an analytically intractable inventory problem. This supply chain features two supply modes, stochastic demand, stochastic lead time, no backlog and a periodic review $(r;Q)$ policy. As shipments have a stochastic lead time, they are allowed to cross and overtake one another. The simulation runs create a series of cost observations for different fill rates, which can be approximated with a local polynomial regression approach. This yields the optimal fill rate and the corresponding inventory policy parameters for a given input parameter set. The simulation model is usable with different reorder policies and different distributions of both demand and lead times. We apply the model to a real-world business case and find that it is important to not only estimate the average demand for an article but also its standard deviation. Making such estimates makes it possible to find the optimal fill rate and reorder point. We discuss the effects of increased demand variation on inventory and transportation cost and explore the costs related to underestimating and overestimating demand variation. Finally, we compare the optimal reorder points for a supply chain with two supply modes to a supply chain with only one supply mode. Our findings are in line with current inventory theory.

**3 - Does the Effectiveness of Concurrent Sourcing in Reducing Opportunism Depend on the Internal/External Sourcing Balance?**  
*Thomas Mellewigt, Sarah Bruts*
specific and technical knowledge. In a continuative step, we further combined both heuristics in a branch-and-bound algorithm to obtain optimal solutions.

3 - Mixed-Integer Linear Programming for a PDE-Constrained Dynamic Network Flow

Fabian Gnegel, Armin Fügenschuh

To compute a numerical solution of PDEs it is common practice to find a suitable finite dimensional approximation of the differential operators and solve the obtained finite dimensional system, which is linear if the PDE is linear. In case the PDE is under an outer influence (control), a natural task is to find an optimal control with respect to a certain objective. In this talk general methods and concepts are given for linear PDEs with a finite set of control variables, which can be either binary or continuous. The presence of the binary variables restricts the feasible controls to a set of hyperplanes of the control space and makes conventional methods inapplicable. We show that under the assumption that all additional constraints of the system are linear, these problems can be modeled as a mixed-integer linear program (MILP), and numerically solved by a linear programming (LP) based branch-and-cut method. If the discretized PDE is directly used as constraints in the MILP, the problem size scales with the resolution of the discretization in both space and time. A reformulation of the model allows to solve the PDE in a preprocessing step, which not only helps to significantly reduce the number of constraints and computation time, but also makes it possible to use adaptive finite element methods. It is further shown that the scaling of state-constraints with finer discretization can be reduced significantly by enforcing them in a lazy-constraint-callback.

We focus on complementarity problems as a special case of MPECs. Even if all functions involved are linear the complementarity condition is non-convex and makes the problem challenging, in general. Several approaches exist in the literature that reformulate the complementarity condition, e.g., dissipative constraints or Schur’s decomposition. Recently also an L-penalty method was proposed in Siddiqui and Gabriel (2012).

In this talk we consider the latter approach from a bicriteria perspective. For linear problems we can easily indicate the solutions of the L-penalty formulation for all positive values of L. We can interpret parameter L as the trade-off between the original objective and the L-penalty term. The larger L the more emphasis is given to the penalty term. We present a new theorem which shows conditions under which this L-penalty approach finds a solution satisfying complementarity for sufficiently large L. We also demonstrate limitations of the proposed L-penalty formulation by indicating examples not satisfying these conditions for which a complementarity solution exists but can not be generated for any positive L.

1 - Approximation Algorithms for Unsplittable Resource Allocation Problems

Antje Bjelde, Max Klimm, Daniel Schmand

We study general resource allocation problems with a diseconomy of scale. In such problems, we are given a finite set of commodities that request certain sets of resources, e.g., paths in a network. The cost of each resource grows superlinearly with the demand for it, and our goal is to minimize the total cost of the resources. A natural distributed approach to solve these problems is local dynamics where in each step a single commodity switches its allocated resources whenever the new solution after the switch has smaller total cost over all commodities. These dynamics converge to a local optimal solution, and we are interested in quantifying the locality gap, i.e., the worst case ratio of the cost of a local optimal solution and a global optimal solution. We derive tight bounds on the locality gap both for weighted and unweighted commodities. By sacrificing an additional small factor, these locality gaps yield deterministic and combinatorial polynomial time algorithms that can be implemented in a distributed manner and provably approximate the optimal solution with approximation guarantee depending on the cost functions on the resources. Our performance guarantees for unweighted commodities asymptotically matches the approximation guarantee of the currently best known centralized algorithm due to Makarychev and Srividenko [FOCS 2014]. In contrast to their algorithm which is based on the randomized rounding of the solution of a convex programming relaxation, our algorithm is deterministic, combinatorial, and requires only local knowledge of the commodities.

2 - Network Design Games with Bandwidth Competition and Selfish Followers

Daniel Schmand, Alexander Skopalik, Carolin Tidau

We study the following network design game. The game is set in two stages. In the first stage some players, called providers, aim to maximize their profit individually by investing in bandwidth on edges of a given graph. The investment yields a new graph on which Wardrop followers, called users, travel from their source to their sink through the network. The cost for any user on an edge follows market principles and is dependent on the demand for that edge and the supplied bandwidth. The profit of the providers depends on the total utilization of their edges, the current price for their edges and the bandwidth. We analyze the existence and uniqueness of Nash Equilibria for the providers in the described game. We provide insights on how competition between providers and the number of providers influence the total cost for the users.
3 - On 1.6-approximate pure Nash equilibria
Alexander Skopulik, Vipin Ravindran Vijayalaksh

Congestion games constitute an important class of games in which computing an exact or even approximate pure Nash equilibrium is in general PLS-complete. Caragiannis et al. [FOCS 2011] presented a polynomial-time algorithm that computes $(2+\epsilon)$-approximate pure Nash equilibria for games with linear cost functions. We show that this factor can be improved to $1.6+\epsilon$ by a seemingly simple modification of their algorithm.

![TD-24](Thursday, 14:45-16:15 - HFB/C)
Nonlinear Optimization 3
Stream: Control Theory and Continuous Optimization
Parallel session
Chair: Mirjam Duer

1 - Looking for the inner set distance
Maksim Barketav, Erwin Pesch

We research the following problem. We are given two sets of vectors. All vectors of the first set are less or equal to all vectors of the second set that is the difference of each vector of the second set and each vector of the first set is in some convex cone $K$ in the corresponding space. We try to find a separating vector for these two sets that is the vector that is less or equal to all vectors of the second set and simultaneously that is greater or equal than all vectors of the first set. We upperbound the least possible distance from the vector that is less or equal to all vectors of the second set and the vector that is greater or equal to all vectors of the first set. We consider non-negative euclidean cone, ice-cream cone, semidefinite cone.

2 - Projection method for minimization of polyhedral function over hypercube
Maxim Demenkov

We consider classical problem of nonsmooth optimization - minimization of a convex polyhedral function with interval constraints on variables. Many algorithms are available for this problem, including subgradient methods and Nesterov’s smoothing technique, as well as a simple reduction to the linear programming. Despite that, we investigate a new approach based on the conversion of this problem into finding an intersection between a special polytope (zonotope) and a line, proposed in [1] as a new kind of finitely convergent linear programming algorithm. Zonotope is an affine transformation of n-dimensional cube [2].

Our algorithm has strong geometric flavor and connected with projection methods [3]. Initially we suppose that we know an interior point of the zonotope on the line. In this case it is possible to derive a linearly convergent algorithm based on the bisection of interval between the interior point and a point outside the zonotope. At each iteration we project (using e.g. Frank-Wolfe or Nesterov fast gradient method) a point on the line in the middle of the interval onto the zonotope (which is equivalent to the projection onto a hypercube). Then, if the current point is outside the zonotope, we find an intersection between the boundary of a level set of the distance function passing through its projection, otherwise we take exactly this point to reduce the interval. In any case we reduce the length of the interval at least twice.


3 - A factorization method for completely positive matrices based on alternating projections
Mirjam Duer, Patrick Groetzner

Many combinatorial and nonconvex quadratic problems can be reformulated as linear problems over the copositive and completely positive cones. However, checking membership of a matrix in any of these two cones is an NP-hard decision problem. A certificate for a matrix to be completely positive is its nonnegative factorization.

We present a method to derive such a factorization using an alternating projection method between certain nonconvex sets. Alternating projection is a common algorithm to find points in the intersection of two convex sets. This method has recently been extended to alternating projection on manifolds and on more general nonconvex sets, as used in our approach. Our method provides factorizations for almost all matrices in a few seconds.

![TD-25](Thursday, 14:45-16:15 - HFB/D)
Energy-oriented scheduling
Stream: Energy and Environment
Parallel session
Chair: Magnus Fröhling

1 - Energy-efficient multi-objective scheduling
Damian Braschczok, Andreas Dellinitz, Andreas Kleine, Jonas Ostmeyer

In classical scheduling problems, time goals are the most common objectives. Multi-objective scheduling approaches usually include additional cost aspects. The expansion of renewable energies influences energy market prices increasingly and, hence, the production costs as well - this the more the more energy-intensive a production process is. Consequently, in scheduling problems time goals and, in addition, energy costs should be considered. This is subject of so-called energy-efficient scheduling.

Furthermore, besides the concept of energy efficiency, sustainability plays an important role in the economic context. Often sustainability of a production process is measured via its carbon emissions. Therefore, this contribution wants to create twofold transparency by addressing the following questions: What is the meaning of energy efficiency and sustainability in the field of scheduling theory? What is an appropriate mathematical model to combine both perspectives? The discussion of these questions leads to a multi-objective scheduling problem with three conflicting goals - time, costs and emissions. Finally, a small numerical example demonstrates the applicability of the new approach.

2 - Energy-oriented scheduling of parallel machines considering peak demand charges and labor costs
Lukas Strob, Thomas Völling

The trend towards an increasing share of renewables leads to large fluctuations in prices for electric energy. These fluctuations are a chance for industrial firms to lower their electricity bill if they manage to shift energy intensive operations to periods with low energy prices. However, there are potential conflicts with other costs. Shifting operations could increase demand charges, which are - in addition to energy charges - typically part of the electricity bill. Additionally, shifting operations could result in increased labor costs due to a lower productivity or unfavorable working time models. Determining energy-oriented schedules therefore requires an integrative perspective considering these conflicts between energy related costs and labor costs.

We propose a mathematical model (MILP) for the energy-oriented scheduling problem with parallel machines. The model comprises time-dependent labor costs and energy related costs while simultaneously determining optimal job assignments, job sequences and machine operation modes. We consider a common electricity tariff structure that consists of time-varying energy charges as well as a peak load-dependent demand charge. Drawing upon an application-oriented numerical example, we compare the performance of the model with a conventional scheduling approach that only minimizes labor costs. The results indicate that significant cost reductions can be achieved under a wide range of conditions. The potential is especially pronounced if the degree of capacity utilization is low to medium and job durations are short.

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1 - Performance of inventory policies under scarcity - a behavioral perspective
Sebastian Schiffels

Simple inventory policies are widely used in practice since they are easily applicable. A well-known behavioral phenomenon related to the inventory of a retailer, but often neglected in inventory management, is the scarcity effect, i.e. the demand for a product increases if the inventory is low. Our research addresses the question of how scarcity behavior impacts the performance of two common classes of inventory policies - periodic and continuous policies. Since the fill rate, i.e. the fraction of demand that is satisfied directly from stock on hand, is the most common way of measuring service, we configure both inventory policies in order to achieve the same target fill rate. To investigate the influence of the scarcity effect on the two policies and vice versa, we set up an experiment with human decision makers acting as buyers. For both policies, we consider a treatment with a high fill rate and a treatment with low fill rate. Our preliminary results indicate that scarcity behavior can already be observed in settings with few buyers and a theoretical stock-out probability close to zero, verifying that it is a strong effect and furthermore, we find that scarcity behavior negatively impacts the performance of both inventory policies. Finally, our results show that continuous policies perform significantly better compared to periodic policies in the setting with a low fill rate, a finding which should be taken into account when determining which inventory policies to use.

2 - A behavioral investigation of the effect of strategic buckets in project selection
Andreas Fügener, Sebastian Schiffels, Ulrich Thonemann

This study discusses the selection of risky and non-risky projects. In line with the literature we show that peoples risk aversion leads to an underrepresentation of risky projects in a simplified project selection process. We analyze whether voluntary and mandatory strategic buckets may help to overcome this issue. A strategic bucket defines a sub-budget for a specified class of projects. The underrepresentation of risky projects is a well-known issue in new product development/project management practice and research. The use of strategic buckets has been proposed in practice and tested with theoretical models in the management science literature. A behavioral investigation of project selection and of strategic buckets is still open. In a preliminary experimental study subjects had to choose six projects from a list of twelve projects. Six of the projects were riskless, while the remaining six projects could fail with a probability of 50%. A portfolio maximizing expected value includes three risky and three riskless projects. The preliminary study shows that a) risky projects were underrepresented in portfolios without strategic buckets, and that b) strategic buckets could increase the ratio of risky projects. Thus, we demonstrate that risk aversion on the decision maker level may to some extent explain the underrepresentation of risky projects. Our results further indicate that simple strategic buckets help to overcome this issue. It is noticeable that voluntary buckets achieve the same results.

3 - Behavioral Responses to Disruptions in the Multi-Armed Bandit Model
Abdolhossein Ghayazi, Mirko Kremer, Fabian Sting

How do human decision makers respond to changing business landscapes? Toward answering that question we investigate the well-studied multi-armed bandit model—yet enriched with disruptions, i.e., changes in the stochastic processes that yield the arms’ payoffs. We compare normative results from comprehensive simulation studies with behavioral results from lab experiments. Our findings fundamentally challenge some of the existing theoretical knowledge on exploration-exploitation trade-off in turbulent environments.
1 - A decision support system for last-mile distribution of perishables in e-grocery operations
Christian Fikar
This work introduces a decision support system to investigate dynamic last-mile distribution of organic fresh fruits and vegetables in urban e-grocery operations. It facilitates an agent-based simulation to model uncertainty in demand and food quality with optimization procedures to perform routing and scheduling decisions. Various food quality models are implemented to calculate food spoilage based on scheduled delivery routes as well as on varying storage and transport temperatures. A store-based attended home delivery concept is investigated, i.e., the e-grocery provider operates multiple stores from which products are picked up and delivered these products directly to the customers. Consequently, throughout the day of operation, the provider has to decide which specific products located at one of the provider’s locations are stocked to a customer and further has to select a delivery vehicle, route and time. Food quality functions and various picking strategies are considered to analyze the impact of jointly investigating picking and routing decisions. Computational experiments based on an omnichannel e-grocery provider operating in Vienna, Austria, and 48 food products are presented. Results highlight the importance of considering food specific characteristics in e-grocery distribution. Trade-offs between minimizing travel distances and maximizing food quality at the time of delivery are investigated as well as impacts to store utilization to facilitate efficient e-grocery operations and potentially decrease food waste.

2 - Inventory Routing: Consistency and Split Deliveries
Emilio Jose Alarcon Ortega, Michael Schilde, Karl Doerner, Sebastian Malicki
We present a new methodology to deal with the inventory routing problem in beer businesses where consistency in delivery times is an important aspect for customer satisfaction. We propose a mathematical model for the Consistent Inventory Routing Problem with Time-Windowed and Split Deliveries (CIRPWSSD). Through the consumption of beer per year is quite stable, the demands and characteristics of the customers are quite diverse (bars, restaurants, stands…). We include the possibility for split deliveries in the formulation to cover the case of temporary high demands caused by special events such as sports events or music festivals. This creates the need of delivering commodity with more than one vehicle. Our model assumes deterministic and constant demands during each of the time periods. We also propose a metaheuristic based on the concept of Adaptive Large Neighborhood Search (ALNS) to obtain efficient solutions for large real world instances. First, an initial solution is constructed using a cheapest insertion methodology followed by a local search to avoid single-customer-routes and to balance initial inventory levels. We then apply ALNS to the obtained solution. We developed several destroy and repair operators that target certain aspects of the specific problem in order to obtain good routing and inventory plans. These operators not only deal with distance and inventory costs but, moreover, with inconsistency in the arrival times to the customers. Finally, we present computational results obtained by applying our exact method as well as the proposed metaheuristic to a benchmark set of artificial instances and a set of instances based on real world consumption data.

3 - Inventory Routing: Setting Safety Stock under Stochastic Demands
Sebastian Malicki, Stefan Minner, Michael Schilde
The stochastic inventory routing problem (IRP) merges vehicle routing and inventory management under uncertainty. It is relevant for vendor managed inventory (VMI), a practice used by many businesses in order to reduce inventory costs as well as shortages through integrated planning. The IRP requires three decisions to be made simultaneously, i.e. when to deliver to each customer, which quantity to deliver, and how to combine these decisions efficiently into delivery routes. We consider the stochastic, single-product, multi-period, single-stage IRP with time windows and serially correlated demands. We introduce a mixed integer linear programming (MILP) formulation with dynamic lot-sizing and safety stock planning. Furthermore, we propose a heuristic which is based on the well-known savings algorithm extended with inventory savings. We evaluate the method by solving adapted instances from literature as well as by comparing our results on real-world data sets. We assess the effect of time windows as well as the cost of obtaining service levels and of ignoring correlation. Moreover, we benchmark the heuristic solution quality with commercial MIP solvers for instances which are solvable in a reasonable amount of time. The results show that the proposed approach performs very well in terms of solution quality and computation time.

1 - Modeling uncertainties in supply chains
Christian Timpe
According to many sources, volatility of markets has increased during recent years. Reasons for that are, among others, political disturbances, technological advances and increasing customer expectations. For supply chain planning, this means increasing complexity, while the pressure on cost and inventories remains high. While you will find the basic methods for consumption-driven and forecast-driven planning in all major planning systems, in practice often a mixture of these two approaches is needed, as the demand fluctuations observed will at least partly be explainable by statistic models, and a safety stock is kept for the forecast errors. Despite that, the models used for computing safety stocks and production plans are usually set up completely independent, e.g. the well-known basic safety stock formulas assume a constant leadtime, while in reality the leadtime is a consequence of the resource load, and vice versa, the projected resource load should take the potential necessity of a safety-stock refill into account. This lack of a coherent approach is of particular importance in the process industry, where often many products compete for both production resources and storage space. In this presentation, we will present several examples from BASF, some of which we worked on in university cooperations.

2 - Exam scheduling at United States Military Academy West Point
Frederik Proske, Robin Schuchmann
Each term the United States Military Academy (USMA) needs to schedule their exams. About 4000 cadets taking 5 - 8 exams each, need to be placed in 11 exam periods subject to several soft and hard constraints. Due to the short time frame in which the exams take place, a feasible solution in the sense that no cadet takes more than one exam per period cannot be obtained with a single exam version per course. So called makeups, alternative exams in another period, solve this problem. In order to reduce the extra work for instructors that must prepare those alternative exams, the number of makeups should be minimized. Makeups are also used to improve secondary objectives which occur at USMA West Point like the number of consecutive exams per cadet or to avoid that cadets take exams in certain periods (e.g. because of sport events they should attend). We consider two solution approaches: an integer programming approach using decomposition strategies and a nonlinear approach based on LocalSolver. We report numerical experiments for both methods based on real world data from the USMA West Point.

3 - Generic Construction and Efficient Evaluation of DAEs with Flow Network Structure and Their Derivatives in the Context of Gas Networks
Tom Streubel, Christian Strohm, Philipp Trunschke, Caren Tischendorf
The dispatchers at a transmission network operator (TSO) influences the gas network state by changing settings for controllable network equipment such as valves and compressors. The effect on the overall system is then evaluated by detailed simulation. The ultimate goal is the combination of gas network optimization with a subsequent simulation based verification and adjustment into a back and forth iteration.
We deal with the simulation step. Depending on modeling decisions and after spatial discretization of pipe equations, the simulation problem can be regarded as a system of differential algebraic equations (DAE). Many DAE solvers (e.g. sundials, dassl, etc.) expect the DAE to be solved in form of a black-box program. The black box provides the residual output of the system function and one or two linear operators of partial derivatives for given input. We want to present our experiences and implementation approaches to provide these evaluation procedures generically from the network structure. The derivative operators come naturally in a compressed-sparse-row format (CSR), but are composed of dense derivatives of all the individual model functions of all elements in the network. Their construction and management can be automated. Whereby management means detecting sparsity pattern, initial allocation, reuse and reallocation due to live manipulation of the networks topology and state dependent events. This allows the individual treatment of every element and the combination of various differentiation strategies such as automatic differentiation, analytic formulas and finite differences.

4 - Gigabit at home - How mathematics makes the fiber rollout more efficient!
Roland Wessäly
Fiber-to-the-home (FTTH) is world-wide one of the hottest infrastructure topics. Since the demand for higher and higher bitrates increases rapidly, telecommunications network operators are deploying fiber down to the customers premises. Such an infrastructure rollout is very expensive. Just in Germany the estimated investment is about 80 billion Euro. Therefore, it is utmost importance to find the right balance between investments and revenues. In this presentation we will give an overview how atesio supports network operators to solve a bunch of difficult FTTH network design problems on using an approach which is based at its core on various mixed-integer linear programming models. We will also demonstrate how this helped in projects with network operators to improve the business case significantly.

FA-03
Friday, 9:00-10:30 - WGS|103
Warehouse Management
Stream: Logistics and Freight Transportation
Parallel session
Chair: David Boywitz

1 - Active repositioning of storage units in Robotic Mobile Fulfillment Systems
Marius Merschförmann
In our work we focus on Robotic Mobile Fulfillment Systems in e-commerce distribution centers. These systems were designed to increase pick rates by eliminating unproductive travel time, while ensuring that orders are shipped as fast as possible. This is achieved by employing mobile robots bringing movable storage units (so-called pods) to pick and replenishment stations as needed, and back to the storage area afterwards. One advantage of this approach is that repositioning of inventory can be done continuously, even during pick and replenishment operations. This is primarily accomplished by bringing a pod to a storage location different than the one it was fetched from, a process we call passive pod repositioning. Furthermore, this can be done by explicitly bringing a pod from one storage location to another, a process we call active pod repositioning. In this work we conduct a simulation-based evaluation to investigate the effects of control mechanisms employing the latter technique and compare them to the passive one. By this, we give first insights about the trade-off occurring when using robots for active repositioning, because less robots are available for picking and replenishment.

2 - Order picking with heterogeneous technologies: An integrated article-to-device assignment and manpower allocation problem
Ralf Gössinger, Grigory Pishchulov, Imre Dobos
Current order picking technologies are characterized by different degrees of automation in a range from completely manual to highly automated processing. Which degree can be chosen, primarily depends on the characteristics of the articles to be picked (e.g. weight, shape, size). Some articles can be picked with all technologies; some may require either rather manual or rather automated technology. Irrespective of the automation level, order picking remains a labor-intensive process. Merely the required worker qualification changes with increasing level of automation — from predominantly manual skills to a balanced mix of manual and cognitive skills. Hence the decision to apply specific technologies and the decision on labor utilization are interdependent in warehouses with a heterogeneous set of articles, where order picking has to be performed by different technologies. To simplify management decision-making and reduce computational effort, both problems can in fact be tackled in an isolated way, by successively applying the respective planning approaches. However, this would not exploit synergies of coordinated problem solutions, due to the existing interdependencies. In the intended contribution we develop a planning approach that integrates both decision problems and therefore coordinates their solutions to a maximum extent — by utilizing a flexible assignment of articles to order picking devices and a flexible allocation of manpower to picking zones. In order to capture the value of coordination, we conduct numerical experiments with the integrated and sequential planning approaches using real data and hypothetical data of a pharmaceutical wholesaler. The comparison refers to the performance of both, the order picking system and the planning approaches.

FA-04
Friday, 9:00-10:30 - WGS|104
Random Keys and Integrated Approaches
Stream: Metaheuristics
Parallel session
Chair: Franz Rothlauf

1 - A Biased Random-Key Genetic Algorithm for the Liner Shipping Fleet Repositioning Problem
Daniel Müller
In stack- and queue-based storage systems, items stored behind the foremost position are only accessible once all blocking items have been removed. A prominent example are deep-lane storage systems, which are often applied in the refrigerated warehouses of the food industry. The price for the high space utilization of these compact storage systems is, thus, a larger retrieval effort whenever items are not properly stored according to increasing due dates. Due dates, however, are often bound to uncertainties, e.g., due to untimely arrivals of the outbound vehicles picking up the stored items. This paper introduces a new way to derive robust storage assignments, such that excessive retrieval effort is avoided in spite of due date uncertainty. Specifically, we aim to maximize the minimum time difference between due dates of items dedicated to different vehicles and stored in the same stack or queue. The resulting optimization problem is defined, computational complexity is proven, and suited solution procedures are derived. Furthermore, a simulation study investigates whether our novel storage assignments are indeed more robust against unforeseen delays than previous approaches.
As liner carriers adjust their network of cyclical routes throughout the year, vessels must be moved from one route to another in a process called fleet repositioning. Although heuristics such as simulated annealing and reactive tabu search have been used to solve the liner shipping fleet repositioning problem (LSFRP), there is still room for improvement considering the gap to the optimal solution and the computational time. We propose solving the LSFRP with a biased random key genetic algorithm (BRKGA), as it can more effectively avoid infeasible solutions than the currently available heuristics. The inherent learning mechanism of the algorithm helps to identify solutions with good objective values. We perform an experimental analysis of this approach on publicly available LSFRP instances and compare it to the existing simulated annealing and hybrid reactive tabu search approaches. Furthermore, we integrate this approach in a previously presented decision support system.

2 - Generalized Random Key Algorithms for Heuristic Optimization
Kevin Tierney

We show how continuous optimization heuristics can be used for finding solutions to discrete optimization problems through the use of a so-called random key. A random key is a sequence of continuous values between 0 and 1 that are used for decision making within a heuristic construction algorithm. Random keys have been used with success in (biased) random key genetic algorithms (BRKGAs) to guide heuristic construction processes for discrete and continuous optimization problems, thus allowing genetic algorithms to be applied to problems where effective recombination and mutation operators are either difficult to create or too expensive to use in practice. We show that the BRKGA is a special case of a wider class of biased-random key approaches that we call generalized random key algorithms (GRKAs). GRKAs allow existing continuous optimization metaheuristics, such as the covariance matrix adaptation evolutionary strategy or particle swarm optimization, to solve discrete problems in a solution construction process without rounding decision variables. We perform an experimental analysis showing the benefits of GRKAs over BRKGAs and other construction techniques on several different operations research problems.

3 - The inola AOC - a proved and tested self-learning metaheuristic for optimization in logistics and transportation
Thomas Scheidl

The ever-expanding requirements in our present-day society provide increasing challenges for today’s software solutions. Lots of data with complex models and relations shall be processed as fast as possible and should lead to most accurate solutions. People who are responsible for processes need at least support in their decision-making which leads to an increasing demand on optimization in all sectors. This lecture shows how the inola Optimization Core, a self-learning, metaheuristic optimization technology, based on object-oriented programming, makes it possible to implement and solve a multi-objective quadratic assignment problem. We call generalized random key algorithms (GRKAs) to guide heuristic construction processes for discrete and continuous optimization problems, thus allowing genetic algorithms to be applied to problems where effective recombination and mutation operators are either difficult to create or too expensive to use in practice. We show that the BRKGA is a special case of a wider class of biased-random key approaches that we call generalized random key algorithms (GRKAs). GRKAs allow existing continuous optimization metaheuristics, such as the covariance matrix adaptation evolutionary strategy or particle swarm optimization, to solve discrete problems in a solution construction process without rounding decision variables. We perform an experimental analysis showing the benefits of GRKAs over BRKGAs and other construction techniques on several different operations research problems.

4 - A Novel SDP Relaxation for the Quadratic Assignment Problem using Cut Pseudo Bases
Maximilian John, Andreas Karrenbauer

The quadratic assignment problem (QAP) is one of the hardest combinatorial optimization problems. Its range of applications is wide, including facility location, keyboard layout, and various other domains. The key success factor of specialized branch-and-bound frameworks for minimizing QAPs is an efficient implementation of a strong lower bound. We propose such an implementation that transform the QAP to a different lower-bound-preserving quadratic program. The key concept of this transformation is the notion of cut pseudo bases, which we introduce in this paper. The cut pseudo bases allow for small semidefinite programming relaxations, leading to an efficient generation of lower bounds for the original problem. This whole transformation is self-tightening in a branch-and-bound process.

5 - Optimizing Special Character Entry: the Case of the French Keyboard Standard
Anna Feit, Antti Oulasvirta

We present the optimization of the new French standard for keyboard layouts. The typical French keyboard layout made it overly complicated or even impossible to type all French characters, punctuation marks, and other symbols. The goal of this new standard was to enable and facilitate the correct spelling of French, and allow the entry of symbols common in programming languages, mathematical expressions, and other European languages. Therefore, we had to assign over 115 characters to 148 slots on the keyboard, optimizing their placement with respect to each other and to the numbers (0-9) and non-accentuated letters (a-z) that were kept unchanged. In interaction with an expert committee, we identified four objectives: input performance and ergonomics, similarity to the prior keyboard, and coherent placement of similar symbols. We collected extensive performance data, language statistics, expert ratings on character similarities, and ergonomic scores to implement a multi-objective quadratic assignment problem. In an iterative process, we computed and adapted a range of solutions in interaction with language experts. The resulting design unifies mathematical bounds with expert opinions and constraints. The new French keyboard layout is the first modern standard where computational optimization methods were used in interaction with domain experts to implement an optimal keyboard design.

6 - Layout Design with Combinatorial Optimization
Niraj Ramesh Dayama, Antti Oulasvirta

Organization of user-actionable elements is a basic tenet of layout design. This topic has been extensively studied in the context of element size, orientation, color, location and other parameters. The current paper proposes a mathematical model that optimizes the layout of elements on a canvas. The combinatorial optimization model is implemented in terms of a mixed integer linear program that can be solved via standard commercial solvers. A broad range of design objectives (including grid alignment, clutter reduction, symmetry/balance, etc.) are addressed within this model; further the implementation is flexible enough to cater to other additional objectives and constraints as required by the designer.

7 - Combinatorial Optimization in User Interface Design
Antti Oulasvirta

Optimization methods have revolutionized almost every field of engineering design, so why not user interface design? I review progress and challenges in model-driven user interface optimization. The challenge is to incorporate predictive models of human perception, behavior, and experience in the objective function to anticipate users’ responses to computer-generated designs. Examples are presented in the design of input devices, menus, web pages, and visualizations.

8 - Disciplined Optimization for User-Interface Design (i)
Chair: Andreas Karrenbauer
Chair: Antti Oulasvirta

Stream: Discrete and Integer Optimization
Parallel session

Stream: Graphs and Networks
Parallel session
Chair: Isabel Beckenbach
1 - An Empirical Study on Online Frequency Assignment Problem (FAP)  
Selin Bayramoglu, Berkin Tan Arici, Ali Özgür Çetinok, Tinzin Ekim

Online FAPs arise in wireless networks in various forms. In this work, we consider traveling radiophones as communication agents. Calls occurring below a certain distance from each other cause interference if they use the same frequency. Given a set of available frequencies, we need to assign a frequency to each call as soon as it happens while avoiding interference. If no frequency can be assigned, the call is dropped. The objective is to minimize the number of dropped calls. A snapshot of the dynamic network can be shown by a graph where vertices represent the locations of outgoing calls and edges are present whenever calls are close enough to each other to cause interference. Then, the objective is to color this graph with a minimum number of colors where no two adjacent vertices get the same color. The problem has an online nature as vertices and edges appear/disappear over time. The online graph coloring problem has been widely studied from a theoretical point of view where the competitive ratios of various algorithms have been analyzed. However, to the best of our knowledge, few computational study has been conducted on this topic. Here, we present and compare experimental results of various online graph coloring algorithms. In addition, we develop an IP model to find optimal solutions and compare with our heuristic results. It should be noted that, unlike many exact solutions to which online algorithms’ results are compared, the solution the IP model returns is realizable when the instance is considered online. That is if a frequency is available at the time a call has arrived, we can’t drop this call, as expected in an online instance is considered online.

2 - k-Budgeted Matching Problems  
Martin Comis, Christina Büsing

The k-budgeted matching problem is a weighted matching problem with k different edge cost functions. For each cost function, a budget constraint requires that the accumulated cost does not exceed a corresponding budget. When k is part of the input, we show that the k-budgeted matching problem is strongly NP-hard on bipartite graphs with uniform edge weights, costs and budgets using a reduction from (3,2B)-SAT. For fixed constant k, we propose a dynamic program for series-parallel graphs with pseudo-polynomial runtime. As an extension, we show how this algorithm can be used to solve the problem on trees using a simple graph transformation.

Realizing that both these graph classes have a bounded treewidth in common, we show how one can apply dynamic programming to tree decompositions in order to obtain a pseudo-polynomial algorithm for the much larger class of graphs with bounded treewidth.

3 - Matchings in hypergraphs  
Isabel Beckenbach

We give an overview about matching theory in hypergraphs which generalize graphs by allowing edges to contain more than two vertices. Finding a maximum size or weight matching, or deciding whether a hypergraph has a perfect matching becomes NP-hard and there does not exist a nice matching theory as for graphs. Therefore, we restrict our attention to different classes of hypergraphs with some additional structure generalizing different aspects of bipartite graphs to hypergraphs. It turns out that results and methods used for bipartite graphs carry over to some of these classes; for example König’s Theorem, and Hall’s Theorem. Furthermore, we discuss a matching algorithm for a restricted class of hypergraphs. This algorithm is based on a generalization of the network simplex algorithm to flows on hypergraphs.

1 - SCIP-Jack: a solver for Steiner Tree problems in graphs and their relatives  
Thorsten Koch, Daniel Reißenfeldt, Stephen Maher, Gerald Gamrath, Yuji Shinnano

The Steiner tree problem in graphs is a classical problem that commonly arises in practical applications as one of many variants. While often a strong relationship between different Steiner tree problem variants can be observed, solution approaches employed so far have been prevalently problem-specific. In contrast, we will present a general-purpose solver that can be used to compute optimal solutions to both the classical Steiner tree problem and many of its variants without modification. In particular, the following problem classes can be solved: Steiner Tree in Graphs (STP), Steiner Arborescence (SAP), Rectilinear Steiner Minimum Tree (RSMST), Node-weighted Steiner Tree (NWSTP), Prize-collecting Steiner Tree (PCSTP), Rooted Prize-collecting Steiner Tree (RPSTP), Maximum-weight Connected Subgraph (MWCSP), Degree-constrained Steiner Tree (DCSTP), Group Steiner Tree (GSTP), and Hop-constrained Directed Steiner Tree (HCSTP). This versatility is achieved by transforming various problem variants into a general form and solving them by using a state-of-the-art MIP-framework. The result is a high-performance solver that can be employed in massively parallel environments and is capable of solving previously unsolved instances. SCIP-Jack has participated in the 11th DIMACS Implementation Challenge and been demonstrated to be the fastest solver in two categories. Since the Challenge tremendous progress regarding new solving routines such as preprocessing and heuristics was made, resulting in a reduction of the run time of more than two orders of magnitude for many instances.

2 - Polyhedral Symmetry Handling Techniques Exploiting Problem Information  
Christopher Hojný, Marc Plötsch

In this talk, we present polyhedral symmetry handling techniques that exploit not only symmetry but also problem information. The aim of treating both kinds of information simultaneously is to obtain tighter cutting planes than in an approach that does not use problem information. For example, partitioning orbitopes are discussed in the literature. These polytopes can handle color symmetries in graph coloring problems efficiently by exploiting that each node of a graph is assigned exactly one color. However, graph automorphisms cannot be handled by these polytopes.

To handle graph automorphisms that act on cliques of G, we introduce packing/partitioning symreacks which exploit problem specific packing (or partitioning) constraints and symmetry. For both kinds of polytopes, we derive small integer programming formulations with constant size coefficients, and we derive complete linear descriptions for a specific class of permutations. Both formulations allow us to handle symmetries efficiently, and we present numerical results that show the positive effect of packing/partitioning symreacks on symmetric binary programs.

3 - Experiments with Conflict Analysis in Mixed-Integer Programming  
Jakob Witzig, Timo Berthold, Stefan Heinz

Conflict analysis plays an import role in solving Mixed-Integer Programs (MIPs) and is implemented in most major MIP solvers. The analysis of infeasible nodes has its origin in solving satisfiability problems (SAT). In addition to the technique known from SAT (conflict analysis), dual information obtained from solving Linear Programs (LPs) can be used to render infeasibility (dualray analysis). In this talk, we discuss both techniques in more detail. We present computational experiments conducted within the non-commercial MIP solver SCIP.
1 - Forecasting Energy Consumption for Safety-Assessed In-Car Applications
Dominik Grether, Sebastian Hudert

The rollout of electric vehicles is an ongoing, but challenging task. The most critical technical challenge at this point is still the limited range of electrified vehicles. To this end, in-car applications are developed assisting drivers in saving energy. In order to achieve this goal, these applications heavily rely on information and forecasts on the state of the traffic system and traffic patterns.

This work takes both aspects - the development and seamless roll-out of in-car applications and the forecasting of traffic, - into one strategy. The resulting ecosystem for automotive-apps demonstrates how safety of in-car applications can be assessed virtually using an open development environment even suited for industry certification.

The latter goal addresses how the state of the traffic system can be predicted by coupling multi-agent transport simulations. The prediction is subsequently used to estimate energy consumption of electric vehicles. The case of electric car sharing fleets is used to demonstrate our approach. On top of the estimates optimization models are developed to improve user experience.

2 - Electric Vehicle Scheduling under extreme conditions at the police
Kerstin Schmidt, Felix Saucke, Thomas Spengler

As a pioneer and role model in society, the police integrate electric vehicles into their fleets. This new generation of patrol cars reduces environmental pollution and has lower energy costs compared to conventionally fueled vehicles. Moreover, the electric vehicles are nearly noiseless, leading to advantages for some operation strategies for the police. However, the challenges related to the use of electric vehicles are small distance capacities, long recharging times, as well as limited availability of the recharging infrastructure. Furthermore, in police use the vehicles have to be nearly 100% available in the service, and patrol duty, while the place and time of usage as well as travel distances are uncertain. To deal with the arising challenges for electric fleet operation under extreme conditions and special requirements at the police is needed. In this contribution, we present an extension of the Electric Vehicle Scheduling Problem (E-VSP) for the police. The model aims to analyze and evaluate the fleet composition under different objectives. On the one hand, a high availability of electric vehicles has to be ensured and on the other hand, the number of vehicles in the fleet should be minimized. To illustrate the benefits and challenges of our approach, a numerical example will be presented.

3 - The Vehicle Rescheduling Problem with Retiming
Dennis Huisman, Rolf Van Lieshout, Judith Mulder

When a vehicle breaks down during operation in a public transportation system, the remaining vehicles can be rescheduled to minimize the impact of the breakdown. In this presentation, we discuss the vehicle rescheduling problem with retiming (VRSPT). The idea of retiming is that scheduling flexibility is increased, such that previously inevitable cancellations can be avoided. To incorporate delays, we expand the underlying recovery network with retiming possibilities. This leads to a problem formulation that can be solved using Lagrangian relaxation. As the network gets too large, we propose an iterative neighborhood batching process also has to decide from which location each product has to be solved, which can be modelled as an instance of a TSP on a special graph.

2 - Convex hull and LP based heuristics for the quadratic travelling salesman problem
Rostislav Staněk, Peter Greistorfer, Klaus Ladem, Ulrich Pferschy

The well-known travelling salesman problem (TSP) asks for a shortest tour through all vertices of a graph with respect to the costs of the edges. In contrast, the quadratic travelling salesman problem (QTPS) associates a cost value with every two edges traversed in succession. We consider a symmetric special case that arises in robotics, in which the quadratic costs correspond to the turning angles or to a linear combination of the turning angles and the Euclidean distances. The order produces two heuristic approaches, first one exploiting the geometric properties of a “good” tour and the latter one making use of auxiliary ILPs. If the quadratic costs correspond to the turning angles, optimal tours usually have the shape of large circles or spirals. In each step of the first algorithm, a convex hull is built and its corresponding vertices are removed from the graph. This step is iteratively repeated leading to a set of nested subtours, which are subsequently patched into one single tour. Our second algorithm uses an LP relaxation and a rounding procedure to obtain a set of paths and isolated vertices. Afterward, these paths are optimally patched into a single tour by means of a small auxiliary TSP instance, which is solved by an ILP-solver. Finally, the resulting tour is enlarged by adding the remaining isolated vertices using a cheapest insertion heuristic. Additionally, we present some further algorithmic enhancements to both approaches. Finally, all constructive results can be improved by running a classical 3-opt improvement heuristic. We provide exhaustive computational results, which illustrate that both algorithms introduced significantly outperform the best-known heuristic approaches from the literature with a dominance of the LP based approach.

3 - Routing and order batching in a non-standard warehouse
Ulrich Pferschy, Joachim Schauer

We consider the warehouse logistics system of Blue Tomato, a sporting goods and apparel sales company with a strong e-commerce business. We focus on the order picking process in its central warehouse where every day articles for a few thousand orders are manually picked from the shelves. This is done by human pickers, who use a cart to store at most 15 different orders comprising a total of at most 40 articles. The resulting planning task consists of two parts: At first, the orders have to be partitioned into batches allowing an efficient picking tour in the warehouse. Secondly, for each batch a routing problem for the picker has to be solved, which can be modelled as an instance of a TSP on a special graph.

There are a number of non-standard aspects to consider: The warehouse consists of parallel aisles with two cross aisles and additional shelf space of irregular structure. Moreover, the warehouse consists of two floors which are connected by two elevators. For most products copies are stored in several different storage locations. Thus, the rescheduling process also has to decide from which location each product should be picked.

We develop a heuristic strategy for order batching which tries to build batches in a close spatial neighborhood. The definition of this neighborhood is based on a general graph model which allows a fast motion and an easy adaptation to changes in the warehouse structure. The subsequent routing problem can be solved to optimality by a TSP algorithm. However, we also employ an insertion type heuristic with k-opt improvement, which deviates from the optimal TSP solution by less than 1% for the considered real-world instances. The resulting algorithmic framework yields a significant improvement on the total tour lengths of 34.4% on average.

1 - The multi-stripe travelling salesman problem
Eranda Cela, Vladimir Deineko, Gerhard Woeginger

In the classical Travelling Salesman Problem (TSP), the objective function sums the costs for travelling from one city to the next city along the tour. In the q-stripe TSP with q larger than or equal to 1, the objective function sums the costs for travelling from one city to each of the next q cities along the tour. The resulting q-stripe TSP generalizes the TSP and forms a special case of the quadratic assignment problem. We analyze the computational complexity of the q-stripe TSP for various classes of specially structured distance matrices. We derive negative (NP-hardness) results as well as a number of positive results. One of our main results generalizes a well-known theorem of Kalman and from the classical TSP to the q-stripe TSP.
1 - Mixed-Integer Programming Model for the Joint Placement and Routing of Function Sequences

Dimitri Papadimitriou

In function-oriented networks, each node may execute concurrently a set of atomic functions such that demands which are described by source-destination pair, size and a finite sequence of ordered operations $f_1,f_2,...,f_n$ can be satisfied when exiting the network. Note that the same operation may appear multiple times as part of the same sequence of operations. The problem consists of allocating the node processing and arc bandwidth resources such that set of commodities (service chains) can be handled at minimum cost by the deployed functions at each node. The goal is thus to jointly select the subset of nodes where to place operators and finds a demand assignment (without exceeding both node processing and arc capacity) that minimizes the sum of location, supplying/running and transportation/routing costs. In this paper, we propose a mixed-integer programming formulation which combines a variant of the multi-product capacitated location (with precedence constraints to account for the ordering in the sequence) together with the fixed-charge multi-commodity flow problem; thus, as a variant of the location-routing model. Next, in order to cope with demand variations over time (e.g., size and operation sequence), we extend our formulation to multi-period problems. This so-called dynamic location-routing model aims at enabling adjustment of operators’ placement and routing decisions at minimum reorganization cost, e.g., by limiting the number of changes in running demands. Note that accounting for operator relocation cost yields a quadratic formula. Then, we propose computational methods and evaluate their performance over representative scenarios and compare the results with those obtained when solving both placement and routing problems independently.

2 - A Benders decomposition approach for location of stations in an electric car sharing system

Hatice Calik, Bernard Fortz

The increasing number of privately owned cars pushes the city managers to find solutions to the increasing pollution, traffic congestion, and parking problems in urban areas. Electric car sharing systems, which are based on shared use of vehicles owned by a company or an organization, have a high potential of eliminating these problems by reducing car ownership if they are designed and operated in a way to provide high levels of accessibility and flexibility. In this study, we focus on design of a one-way car sharing system with a fleet of identical electric cars. The system under consideration provides flexibility in the sense that the users are allowed to leave the cars to stations different from their pick-up point and no pre-booking is enforced, which leads to uncertainty in demand. We approach the system from a strategic point of view and aim to decide on the location of stations and the initial number of cars available at each station in a way to maximize the expected profit. We introduce multiple demand scenarios to represent the demand uncertainty and formulate the problem as a mixed integer stochastic programming model. The profit function takes into account the expected revenue obtained from the user requests served and the fixed costs of opening stations and purchasing cars. We further develop a Benders decomposition method based on our formulation to solve this problem. In order to improve the convergence speed of our algorithm, we strengthen the master problem with valid inequalities, introduce a stabilization procedure, and propose primal heuristics to obtain good starting solutions. We conduct computational experiments on problem instances obtained from real data based on Manhattan taxi trips to evaluate the performance of our methods.

3 - Using variables aggregation and Benders decomposition for solving large-scale extended formulations

Bernard Fortz, Markus Leitner

Many optimization problems involve simultaneous decisions on high-level strategic decisions such as the location and/or dimensioning of facilities or devices, as well as operational decisions on the usage of these facilities. Moreover, these decisions often have to be taken for multiple demand sets over time or in an uncertain setting where multiple scenarios have to be considered. Hence, a large number of variables (and constraints) is often necessary to formulate the problem. Although sometimes more compact formulations exist, usually their linear relaxations provide much weaker lower bounds, or require the implementation of problem-specific cutting planes to be solved efficiently. A lot of research has focused in recent years on strong extended formulations of combinatorial optimization problems. These large-scale models remain intractable today with traditional solvers, but Benders decomposition gained attention as successful applications of it have been reported. An alternative to these large-scale models is to use more compact formulations, often based on variable aggregations. We propose an intermediate strategy that consists of projecting the extended formulation on the space of aggregated variables with a Benders decomposition scheme, applicable to a large class of problems.

**Stream: Logistics and Freight Transportation**

**Parallel session**

**Chair: Bernard Fortz**

1 - A stochastic vehicle routing strategy for the collection of two similar products

Epaminondas Kyriakidis, Theodosis Dimitrakos, Constantinos Karamatsoukis

We develop and analyze a mathematical model for a specific stochastic vehicle routing problem in which a vehicle starts its route from a depot and visits $N$ customers according to a particular sequence in order to collect from them a two similar but not identical products. The actual quantity and the actual type of product that each customer possesses are revealed only when the vehicle arrives at the customer’s site. It is assumed that the vehicle has two compartments. We name these compartments, compartment 1 and compartment 2. It is assumed that compartment 1 is suitable for loading product 1 and compartment 2 is suitable for loading product 2. However, it is permitted to load items of product 1 into compartment 2 and items of product 2 into compartment 1. These actions cause extra costs that are due to extra labor. The vehicle is allowed during its route to return to the depot to unload the items of both products. The travel costs between consecutive customers and the travel costs between the customers and the depot are known. The objective is to find the routing strategy that minimizes the total expected cost among all possible strategies for servicing all customers. It is possible to find the optimal routing strategy by implementing a suitable stochastic dynamic programming algorithm.

2 - An Approximate Dynamic Programming Based Heuristic for Stochastic Time-Dependent Vehicle Routing Problems

Mustafa Çimen, Muhmet Soysal, Cagri Sel, Sedat Belbag

This paper addresses a Time Dependent Vehicle Routing Problem with stochastic vehicle speeds. A Markovian Decision Process approach has been used to formulate the problem. The model respects time-dependent and stochastic vehicle speeds while calculating routing costs comprising fuel and wage costs. The Time Dependent Capacitated Vehicle Routing Problem is known to be NP-Hard for even deterministic settings. The problem accounting for stochastic vehicle speeds further increases complexity which renders classical optimization methods infeasible. We propose an Approximate Dynamic Programming based heuristic approach for solving the problem. Computational analyses on several instances show the added value of the proposed decision support tool. The results show that incorporating vehicle speed stochasticity into decision support models has potential to improve the performance of resulting routes in terms of travel duration, emissions and travel cost. In addition, the proposed heuristic provides promising results within relatively short computation times.

3 - The Stochastic Delivery Problem: Optimizing the Number of Successful Deliveries of Courier Companies

Alexandre Florio, Dominique Feillet, Richard Hartl
In this talk we introduce the Stochastic Delivery Problem (SDP), an optimization problem relevant to the parcel delivery market. In the SDP, the objective is to maximize the number of successful deliveries to customers. This objective goes hand in hand with customer satisfaction, and also contributes to the reduction of costs related to unsuccessful delivery attempts.

In order to present a realistic description of the problem, we present the concept of a customer availability profile, which to some extent can be considered as a generalization of the time window notion. The availability profiles are essentially functions mapping the entire delivery period into the unit interval, and denote the likelihood of a customer being available for receiving a delivery at a particular moment.

We propose an exact branch-and-price algorithm for solving the SDP. After applying Dantzig-Wolfe decomposition, the resulting problem resembles an orienteering problem (OP) with time-dependent rewards, which we solve with a labeling algorithm. Different from other applications of the framework to routing problems, in our case efficient and strong label dominance rules cannot be derived. Nevertheless, by applying the idea of reduced cost bounding we are able to avoid combinatorial explosion and solve exactly the pricing problem. We adapt bounds from the literature, and we also propose a new bound for the OP. Computational experiments show the effectiveness of the method to solve SDP instances of up to 75 customers.

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### FA-14

**Friday, 9:00-10:30 - RVH1**

**Revenue Management in Transport and Logistics**

Stream: Pricing and Revenue Management

Parallel session

Chair: Arne Karsten Strauss

1. **Simulation-based Learning for Dynamic Time Window Allocation in Attended Home Deliveries**

   **Magdalena Lang, Catherine Cleophas, Jan Fabian Ehmke**

   For attended home delivery services, allocating time windows to delivery requests affects both delivery costs and the future orders that can be accepted given a limited delivery capacity. Revenue management provides approaches to forecast the demand for deliveries per time window and to efficiently control the time window allocation, but it requires to know an order’s capacity consumption and the resulting left-over capacity. For this reason, the capacity of an order depends on the overall set of accepted orders, so that the effect on capacity cannot be finally determined on individual order request arrival. Vehicle routing methods can approximate travel time and costs, vehicle capacity, and the opportunity costs of time window allocation. These opportunity costs can then inform a dynamic allocation decision on request arrival. Moreover, vehicle routing is usually too time-consuming to be computed per arriving order request. Here, we present a simulation-based learning framework to approximate the opportunity costs of time window distribution. This framework provides a systematic approach to inform dynamic allocation decisions. For this reason, it can be used to design policies that are able to efficiently deploy allocation controls. Moreover, vehicle routing is usually too time-consuming to be computed per arriving order request. Here, we present a simulation-based learning framework to approximate the opportunity costs of time window allocation. This framework provides a systematic approach to inform dynamic allocation decisions. For this reason, it can be used to design policies that are able to efficiently deploy allocation controls.
2 - Profit-Maximizing Time Window Selection Under Consideration of Customer Choice in Attended Home Delivery
Claudius Steinhardt, Jochen Mackert, Robert Klein

The interface between revenue management (RM) and vehicle routing (VR) is investigated with increasing attention by a steadily growing research community. Thus profit margins, high service requirements, and the challenge of ensuring efficient operations when delivering to the front door of a customer (known as "last mile delivery") in home delivery service models motivates the application of RM techniques in order to manage demand. In the literature, four general demand management concepts have been identified to be adequate for delivery service models: While Differentiated Slotting and Differentiated Pricing focus on decisions on a tactical level, Dynamic Slotting and Dynamic Pricing have been proposed to enhance operational decisions. Besides giving an overview of the latest research in the field of Attended Home Delivery, this talk especially focuses on a model-based decision support for demand management via Differentiated Slotting. The proposed mixed integer program aims at deciding about how many and which delivery time windows should be on offer for customers in each delivery area of the e-grocer in order to maximize expected total profits. It explicitly incorporates customer choice behavior, allowing the e-grocer to split the market in different customer segments. Linearization techniques are applied to facilitate the application of standard software packages to solve the model.

3 - Realtime pricing in B2B truck logistics
Alwin Haensel

Automated pricing is delicate when it comes to dynamic market prices, especially when prices are mainly based human negotiations. We have developed a pricing algorithm for the logistics platform Cargonexx (www.cargonexx.de/en), which is used to derive the current market price for each individual transport request. Cargonexx is an intermediary between the contractors and the freight carriers. The proposed price must reflect the current market situation on both market sides as precisely as possible. To solve this stochastic problem, we use fuzzification of observations and machine learning techniques to build probability distributions for the price acceptance. In the talk, we will focus on the challenges and solution approaches.

2 - Sensitivity Analysis for Demography Based Microsimulation
Jan Pablo Burgard, Simon Schmaus

With the incorporation of microsimulations into the Federal Statistics Act - BStatG in Germany the Bundestag encourages the use of microsimulation in political decision processes. In many areas of political decision making, e.g. in transport infrastructure, microsimulation has been a strongly applied methodology. Usually such microsimulation make use of agents or representatives to incorporate differing behavior between individuals. With nowadays computer power, also demography based microsimulations come into perspective. Instead of using a subset of the population or just a few agents, with demographic based microsimulations the change is measured for a total population and for each unit within. This enables the modeling of much finer and more diverse behavioral attitudes. Further, as the base population is constructed for a multipurpose framework, many variables are available in a coherent manner easing the extension to new microsimulation tasks. The different transition processes in the population such as births and deaths, relocations, and change in household characteristics are organized in modules, as there exist often multiple opinions on their modeling. These modules and their ordering have an impact themselves on the outcome of the microsimulation. We propose to assess the outcome of a demography based discrete-time stochastic microsimulation using the concept of sensitivity analysis which is well established for indicator assessment in survey statistics. With this concept we can visualize the main effects of the models and their parameters, the modules, and the assumptions made on a microsimulation task. It enables the detection of the influence of single parts and possibly harmful settings.

3 - A network-flow approach to address selection for populations
Ulf Friedrich

Several algorithmic challenges have to be solved for microsimulations in the context of survey statistics. These often involve mathematical optimization problems and typically incorporate constraints on the solution space. The main effects of the models and their parameters, the modules, and the assumptions made in a microsimulation task. It is therefore necessary to employ combinatorial optimization techniques for microsimulation problems.

In this work, the address selection problem in microsimulations is studied. After a population of a given region has been generated in the first step of the microsimulation process, the members of the population have to be assigned to actual addresses in a given region. In doing so, the pure address selection problem (i.e., the decision for addresses or all optimization variables, e.g., to model the simulated members of a population or to describe (binary) decisions within the model. It is therefore necessary to employ combinatorial optimization techniques to many microsimulation problems.

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transportation and scheduling. In this paper, we present a large neighbourhood search heuristic for the nurse rostering problem. By formulating the nurse rostering problem using a work-stretch approach, we are able to solve reasonably large-sized problems quickly, as long as they only involve a small number of shift types. This large neighbourhood search method exploits our ability to solve certain subsets of the larger problems quickly by using mixed integer programming, allowing local improvements on a large neighbourhood of the current solution while maintaining feasibility. We investigate several improvements to such a scheme for the nurse rostering problem. We also test our approach on standard datasets from the literature to show the effectiveness of our approach.

2 - Job scheduling with simultaneous assignment of machines and multi-skilled workers: a mathematical model
Cinna Seifi, Jürgen Zimmermann

The primary task of mining companies is the extraction of mineral raw materials. Based on a planning program, a certain quantity of raw materials is expected to be extracted within a given time horizon. The room-and-pillar mining method using the drilling and blasting technique is characterized by nine process steps each of which has to be executed by some appreciated machine and worker and is associated with a certain amount of raw material. Derived from superordinate planning level as well as a constant comparison of planned and actual data of the excavated raw material, the quantity of material that must be achieved is predetermined for each process step within a work shift. The processing time of a process step (job) depends on the assigned devices and workforces, in particular, on the skill levels of the workforces for the device. In this paper, we formulate a mathematical program for a simultaneous assignment of devices and personnel to a selection of jobs. The aim is to minimize the difference between the predetermined quantity and the amount of extracted raw material, cumulatively over all the process steps, for a work shift. Preliminary results achieved with Xpress shows that our model is suitable for practical problem instances.

3 - The Temp Secretary Problem and Partly-Stochastic Models for Online Scheduling
Thomas Kesselheim, Andreas Tönnis

The Temp Secretary Problem was recently introduced by Fiat et al. [ESA 2015]. It is a generalization of the Secretary Problem, in which commitments are temporary for a fixed duration. This way, the Temp Secretary Problem nicely introduces beyond-worst-case analyses to online scheduling problems. We present a simple online algorithm with improved performance guarantees for cases already considered by Fiat et al. and give competitive ratios for new generalizations of the problem, such as for example different durations. Our algorithmic approach is a relaxation that aggregates all temporal constraints into a non-temporal constraint. Then we apply a linear scaling algorithm that, on every arrival, computes a tentative solution on the input that is known up to this point. This tentative solution uses the non-temporal, relaxed constraints scaled down linearly by the amount of time that has already passed.

FA-18
Friday, 9:00-10:30 - RMB\;2215
Cranes and Robots
Stream: Project Management and Scheduling
Chair: Jenny Nossack

1 - Assignment, Scheduling and Routing of Triple-Crossover-Cranes in Container Yards
Lennart Zey, Dirk Briskorn

In recent years the need for efficient processes in sea ports has grown due to the increasing volume of maritime transport. With the help of Automated Stacking Cranes (ASCs) which store and relocate containers in container yards, the corresponding storage processes can be improved significantly concerning time and productivity. The triple-crossover-crane setting with one large crane that can cross two small cranes of equal height and width, is a setup that promises high productivity in container handling. Nonetheless, with a growing number of cranes working jointly in a storage block, interference between cranes likely increases. Thus, the full potential of the crane setting can only be achieved when taking into account conflicts between cranes in a planning procedure. Aiming at minimal make-span, we develop a branch-and-bound approach that assigns container-jobs to cranes, determines fulfillment sequences and routes the cranes such that the resulting schedules are conflict free. In this talk we present both, an exact as well as a heuristic variant and compare the numerical results.

2 - Optimizing Periodic Schedules in Robot Based Manufacturing Lines
Tobias Hofmann

The employment of industrial robot systems in the automotive industry noticeably changed the view of production plants and led to a tremendous increase in productivity. Nonetheless, rising technological complexity, the parallelization of production processes, as well as the crucial need for respecting specific safety issues pose new challenges for man and machine. Furthermore, the progress shall proceed – production cannot be too fast, too safe or too cheap.

Our goal is to develop algorithms, guidelines and tools that make the commissioning of industrial robot systems more dependable by verifying the programs of robots and logical controllers. This in particular includes optimizing the schedule of the robot systems in order to ensure desired period times as well as conflict free timetables already in the planning stage. The talk will be about the periodic event scheduling problem proposed by Serafini and Ukkonen in 1989 as well as its cycle periodicity formulation. In order to obtain a suitable formulation with a small number of integer offset variables it plays a crucial role to choose an appropriate cycle basis of the underlying precedence graph. Our actual research focuses on the latter aspect. We identified appropriate cycle bases as well as admissible bounds for the remaining integer offset variables.

3 - Preventing Crane Interferences at Automated Container Terminals
Jenny Nossack, Dirk Briskorn, Erwin Pesch

We focus on a container dispatching and conflict-free yard crane routing problem that arises at a storage yard in an automated, maritime container terminal. A storage yard serves as an intermediate buffer for import/export containers and exchanges containers between water- and landside of a maritime terminal. The considered storage yard is perpendicular to the waterside and employs two rail mounted gantry cranes that have different sizes and have thus the possibility to cross each other. The problem at hand evaluates in which order and by which crane the import/export containers are transported in order to minimize the makespan and prevent crane interferences. We solve this problem to optimality by a branch-and-cut approach that decomposes the problem into two problem classes and connects them via logic-based Benders cuts. Furthermore, we propose a heuristic approach and assess the quality of our solution methods in a computational study.

FA-19
Friday, 9:00-10:30 - RMB\;3302
Production and Maintenance Planning
Stream: Production and Operations Management
Parallel session
Chair: Sandra Transchel

1 - Maintenance Planning Using Condition Monitoring Data
Daniel Olivotti, Jens Passlick, Sonja Dreyer, Benedikt Lebeck, Michael H. Breitner

Maintenance activities of machines in the manufacturing industry are essential to keep machine availability as high as possible. Especially in large production sites with a high number of interlinked machines, the fulfillment of maintenance specifications is a major challenge. A breakdown of a single machine can lead to a complete production stop. Maintenance is traditionally performed by predefined maintenance specifications of the machine manufacturers. With the help of condition-based maintenance, maintenance intervals can be optimized
due to detailed knowledge of the machine condition through sensor data. This results in an adapted maintenance schedule where machines are only maintained when necessary. Apart from time savings, this also reduces costs.

A high production utilization is a major goal in the manufacturing industry. It is necessary to link the maintenance activities to the production program to make machines available when they are needed the most. An optimization model for maintenance planning is developed considering the right balance between the production program, the failure probabilities of the machines and potential breakdown costs. The current conditions of the machines are used to forecast the necessary maintenance activities for several periods. A decision support system helps maintenance planners to choose their decision-making horizon flexibly. It can be decided individually how often the maintenance schedule is optimized anew. This flexibility underlines a main goal of the optimization model, the applicability in practice.

2 - Production Planning and Quality Testing Under Random Yield with Two-Dimensional Quality
Sandra Transchel, Candace Yano

We consider a firm operating a co-production system over multiple periods. Finished products are differentiated according to their quality levels, specified in two dimensions. The firm faces uncertain demands for these quality-differentiated products that are sold at different prices, and can fulfill demand using substitute products of equal or higher quality. Our motivating example comes from the semiconductor industry; the two quality dimensions are processor speed and heat resistance. Every week the firm decides the number of wafers to order (each of which contains thousands of "chips"), which will arrive about 10 weeks later. Upon arrival, an initial (quick) test is performed on each chip, which is then classified into one of several quality "bins." At this point, all chips with an acceptable quality level are converted into so-called packaged devices. A more time-consuming test is required to determine the exact quality category; the final quality may be higher or lower than the initial quality. Every week, the firm must also decide how many packaged devices from each initial-quality bin should be tested and for which quality specifications each should be tested. The time required for a test generally increases in the quality level for which the device is being tested and the testing capacity is limited. In addition, the firm must allocate post-final-test chips to satisfy demand, recognizing the opportunity cost of fulfilling demand for low-quality products using higher-quality products. The firm seeks to maximize expected profit. We develop a stochastic dynamic programming model with three types of decisions: (i) the wafer ordering decisions, (ii) the testing policy for the chips, and (iii) the allocation of the post-final-test inventory to demand.

3 - Optimization of Work-Center Cycle Time Target Setting in a Semiconductor Wafer Fab
Hermann Gold, Hannah Dusch

We consider a semiconductor fab which has been given realistic overall cycle time targets by product for the whole manufacturing network but where the task remains to break these overall targets down to individual process steps and work centers, in a way which is realistic, efficient and fair. Our method proposed has the additional advantage that it reduces the fab logistics complexity significantly.

At first we introduce a queueing network perspective to the target setting procedure. Today’s procedure attaches lower normalized waiting time targets to longer jobs, according to a function which is reciprocal to the square root of the physical cycle time. We analyze and discuss the truths and myths of this procedure.

Secondly, we introduce a Kelly queueing network approximate model of our manufacturing system based on the resource pooling principle which application to semiconductor manufacturing has been explained in earlier work by H.Gold. We apply M/G/1-conservation laws together with linear and quadratic programming approaches to the problem of adjusting unified normalized waiting times at resource pool level in a way that overall target cycle times are not violated. It turns out, that our LP approach is more fair, but less efficient than the QP approach, due to the fact, that in the LP approach overall cycle time targets are overreached for a variety of products. With our QP approach overall fab cycle time targets are met exactly.

In the third step we drop the connection to the existing target setting system and establish unified normalized waiting times at the resource pool level merely upon Kelly network analysis. Hereby a new idea to capture the degree of freedom is applied, namely the concept of Shannon entropy from information theory.

Many Original Equipment Manufacturers that engage in the remanufacturing business fully or partially outsource take back activities. Although outsourcing reverse activities seems to be a reasonable option, it may result in significant inefficiencies due to decentralization. Several contracting mechanisms have been proposed to reduce the inefficiencies in the forward chains. However, the effectiveness of these contracts has not been fully investigated in reverse chains. In this study, we investigate a two-echelon reverse supply chain, consisting of a remanufacturer and a collector in a single-period setting. The collector is in charge of acquiring used products from end customers by paying an acquisition price per unit of used products. The collected products are then sold to the remanufacturer who faces a random demand for remanufactured products. We first consider the centralized setting and derive the optimal acquisition price. Then, we study the decentralized setting under remanufacturer’s lead and collector’s lead. In both cases, we demonstrate that as long as the total cost of reverse activities are constant, the channel performance is independent of how these costs are distributed among the parties. Next, we focus on coordination issues and show that there exists a menu of revenue sharing contracts that can coordinate the reverse supply chain and allows for arbitrary allocation of total channel profit between the parties.

2 - When to Offer Upgrades?
Rowan Wang

In this paper, we build a capacity and revenue management model from a consulting project. We consider a firm that sells multiple product models corresponding to multiple classes of demand (customers). Each class of customers requests for one particular product model, and the firm can offer customers free upgrades to more expensive models when there is insufficient stock of the preferred ones. However, customers may not accept the upgrades due to their preferences on their desired models. Customers arrive over time. The firm needs to decide whether or not to offer upgrades upon the arrival of each individual customer. We formulate the problem using a Markov decision process model and prove that the optimal profit function is anti-multimodular. Based on this property, we prove that the structure of the optimal upgrade policy can be described by dynamic thresholds that depend on the inventory levels of all products. Importantly, we show that, with the possibility that customers would reject upgrades, it is optimal to offer upgrades before the stockout of the desired models. Offering upgrades only after stockout could lead to significant profit loss.

3 - A Financial Market Perspective on Value Chain Performance
Gerd J. Hahn, Jochen Becker, Marcus Brandenburg

Approaches to financial performance management in value chains typically involve a top-level financial performance measure and value driver analysis to quantify relevant operational performance levers. In-ternal, accounting-based measures such as EVA, ROCE or DCF are frequently used for this purpose. In contrast, we analyze value chain performance from a financial market perspective to shed light on the question whether and to what extent value driver analysis actually creates value and is appreciated by the stock markets. For this purpose, we apply data envelopment analysis to a large longitudinal data set of listed US companies. Our study covers a diverse set of more than ten industries and investigates value chain competitiveness both within and across industries.
1. **Optimization of non-ideal Multi-component Distillation Processes using Kriging Interpolation**
   Dennis Michaels, Tobias Kessler, Achim Kienle, Christian Kunde, Nick Mertens

Separation processes based on distillation play an important role in chemical industry. Hence, the determination of cost-minimal designs for such processes is of particular interest. This task can often be modeled as a mixed-integer nonlinear optimization problem (MINLP) that needs to be solved globally. Due to the high complexity, global optimization of these problems is in general very challenging. In this talk, ideal and non-ideal multi-component distillation column processes are considered. In order to reduce the computational complexity of the corresponding MINLPs, the column models are approximated with the help of an iterative Kriging interpolation. The approximated models are solved to global optimality, and the results are compared with results obtained by rigorous optimization of the original distillation column. Numerical examples are considered, showing the usefulness of the Kriging approach from a practical point of view.

2. **The Multistatic Sonar Location Problem and Mixed-Integer Programming**
   Armin Fügenschuh, Emily Craparo

Sonar is a technique to detect objects that are underwater or at the surface using sound propagation. In active sonar systems, a sound is emitted from a source and the echoes are received by a receiver, revealing information about nearby objects. In monostatic systems, the source and the receiver are located in the same place. Bistatic sonar uses a source and a receiver in different locations. Multistatic sonar uses several sources and receivers simultaneously. For the surveillance of a large area of the ocean, a number of both types of devices must be deployed. Since the sources are much more expensive than the receivers, one may wish to field a sparse network of receivers and then ensonify the area with a powerful source, such as a large source attached to a helicopter and dipped in the ocean. Alternatively, one may use a network of many sources and receivers, all of which are attached to sonobuoys. In this case, the optimization problem is to find a network design that is able to cover all of a desired area. The detection probability of a target from a single pulse between source and receiver is constant in a nonconvex region due to propagation losses and dead zones. The goal is to raise the detection probability above a desired level, if necessary by combining results from different source-receiver pairs. We present a mixed-integer nonlinear formulation for the multistatic sonar source-receiver location problem and discuss several linearizations. We compare these formulations empirically using topological data from coastline areas around the world and a state-of-the-art solver MIP solver.

3. **A Stochastic Optimization Model for Energy Management of Storage-Augmented Hybrid Multi-Building Districts Considering Battery Aging Costs**
   Timm Weitzel, Maximilian Schneider, Christoph Glock, Stephan Rinderknecht

The share of energy generated decentrally from renewable energy sources in the total amount of energy generated has increased over recent years, and it is expected to increase further in the years to come. To overcome the challenges associated with integrating different heterogeneous energy resources and with securing efficient operations, intelligent microgrids will likely become more important in the future. An application for intelligent microgrids are multi-building districts with local thermal and electrical energy production. Operating such systems is challenging for two reasons. Firstly, thermal and electrical energy demand do not occur simultaneously requiring storages for an efficient operation of coproduction units such as combined heat and power plants. Secondly, renewable production is unsteady and uncertain and does not necessarily follow demand. The work at hand investigates a multi-building district equipped with a Battery Energy Storage System (BESS) and a Thermal Energy Storage System (TESS) that participates in energy markets. The system faces uncertainty from

- renewable production and market prices.
- This work contributes to research by formulating a stochastic optimization model for the Energy Management System (EMS) considering non-linear battery-aging costs and detailed cogeneration models. Since BESS deteriorate depending on usage and surrounding conditions, battery-aging costs are included into the optimization model to ensure feasible and economically viable operations.
- The optimization model is formulated as a stochastic MILP and solved using commercially available solvers. Computational studies are performed to illustrate the merits of the stochastic optimization and the interdependencies that arise between the operation of TESS and BESS.
Network Optimization under Competition (i)

Stream: Game Theory and Experimental Economics

Parallel session

Chair: Tobias Harks

1 - Strategic Contention Resolution with Limited Feedback

Martin Gairing

We study contention resolution protocols from a game-theoretic perspective. We focus on acknowledgment-based protocols, where a user gets feedback from the channel only when she attempts transmission. In this case she will learn whether her transmission was successful or not. Users that do not transmit will not receive any feedback. We are interested in equilibrium protocols, where no player has an incentive to deviate. The limited feedback makes the design of equilibrium protocols a hard task as best response policies usually have to be modeled as Partially Observable Markov Decision Processes, which are hard to analyze. Nevertheless, we show how to circumvent this for the case of two players and present an equilibrium protocol. For many players, we give impossibility results for a large class of acknowledgment-based protocols, namely age-based and backlog protocols with finite expected finishing time. Finally, we provide an age-based equilibrium protocol, which has infinite expected finishing time, but every player finishes in linear time with high probability.

Joint work with: Georgios Christodoulou, Sotiris Nikoletseas, Christosforos Raptopoulos, and Paul Spirakis

2 - A Characterization of Undirected Graphs Admitting Optimal Cost Shares

Anja Huber, Tobias Harks, Manuel Surek

In a seminal paper, Chen, Roughgarden and Valiant [Designing network protocols for good equilibria. SIAM Journal on Comp., 2010] studied cost sharing protocols for network design with the objective to implement a low-cost Steiner forest as a Nash equilibrium of an induced cost-sharing game. One of the most intriguing open problems up to date is to understand the power of budget-balanced and separable cost sharing protocols in order to induce low-cost Steiner forests. In this work, we focus on undirected networks and analyze topological properties of the underlying graph so that an optimal Steiner forest can be implemented as a Nash equilibrium (by some separable cost sharing protocol) independent of the edge costs. We term a graph efficient if the above stated property holds. As our main result, we give a complete characterization of efficient undirected graphs for two-player network design games: an undirected graph is efficient if and only if it does not contain at least one out of few forbidden subgraphs. Our characterization implies that several graph classes are efficient: generalized series-parallel graphs, fan and wheel graphs and graphs with small cycles.

3 - Equilibrium Computation in Atomic Splittable Singleton Congestion Games

Veerle Timmermans, Tobias Harks

We devise the first polynomial time algorithm computing a pure Nash equilibrium for atomic splittable congestion games with singleton strategies and playerspecific affine cost functions. Our algorithm is purely combinatorial and computes the exact equilibrium assuming rational input. The idea is to compute a pure Nash equilibrium for an associated integrally-splittable singleton congestion game in which the players can only split their demands in integral multiples of a common packet size. While integral games have been considered in the literature before, no polynomial time algorithm computing an equilibrium was known. Also for this class, we devise the first polynomial time algorithm and use it as a building block for our main algorithm.
Demand Side Management

Stream: Energy and Environment

Parallel session

Chair: Magnus Fröhling

1 - Impacts of Constraints in Residential Demand-Side-Management Algorithms - A Simulation-Based Study

Dennis Behrens, Cornelius Rüther, Thorsten Schoormann, Klaus Ambrosi, Ralf Knackstedt

Due to various challenges (e.g., climatic changes, growing population) improvements in managing energy grids are required, for example to consider sustainable but volatile energy generation. Demand-Side-Management (DSM) is one possibility to address these challenges by managing, shifting and controlling loads, saving energy or reducing peaks in energy grids. However, many DSM algorithms make assumptions regarding load characteristics. Thus, real world conditions (e.g. energy loads cannot be moved and paused in any order) are not implemented. Based on a prior review of DSM algorithms as well as several expert interviews we identified five constraints: horizontal and vertical separability of loads, time interval of use, environmental effects, and dependencies between loads. Although several experts highlighted the importance so far no investigation shows the impact of these constraints to DSM algorithms. Therefore, our research question is: Which impact do different constraints have to DSM algorithms? To answer this question, we conducted a simulation with representative DSM algorithms. After implementing each constraint individually, we are able to switch these constraints on and off. As data for our simulation, we used artificial datasets with several predefined households derived by statistical analysis. As a result of comparing the outcomes regarding different key indicators, such as costs, savings, peak-to-average-ratio, and mean-squared-error (MSE), we can conclude that the constraints have an impact on the results. For example, (in the worst case) the savings dropped about 10% and the MSE increased about nearly 40%. Therefore we postulate that these constraints should be used in DSM algorithms for practical application and further evaluation in the future.

2 - Robust online planning of on/off-devices in demand side management

Martijn Schout Uitterkamp, Marco Gerard, Johann Hurink

As a consequence of electricity generation based on renewable energy sources, the number of devices like electric vehicles and heat pumps is increasing. Generally, the load of these devices is large compared to other house loads. Therefore, this trend may result in much stress on the residential distribution network, which leads to large power peaks inducing energy losses and decreased power quality. One way to overcome these problems is to integrate the new devices in a smart grid and use demand side management (DSM) to flatten the load profile of a house or a whole neighborhood. In this research, we first propose an online load profile flattening algorithm to control an individual on/off-device in a house. This algorithm uses the prediction of a single parameter that characterizes an optimal planning, rather than a detailed prediction of the house profile. This is a major advantage, since obtaining accurate and detailed load profile predictions is difficult. Secondly, we extend this approach to the case where multiple houses coordinate their consumption to attain a common objective. We compare the resulting online algorithm to DSM methods that do use detailed power predictions (i.e., offline algorithms) and show that our method achieves near-optimal solutions.

3 - Production Process Modeling for Demand Side Management

Stefanie Kabelitz, Martin Mutek

The electricity supply is growing increasingly dependent on the weather as the share of renewables increases. Different measures can nevertheless maintain grid reliability and quality. These include the use of storage technologies, grid expansion and options for responsiveness of supply and demand. This paper examines the utilization of responsiveness in production processes subsumed under the concept of demand side management, covering two main topics. First, Germany’s energy policy is presented and direct and indirect incentives for businesses to seek as well as provide responsiveness capabilities are highlighted. Converting this framework into a mixed integer program leads to multi-objective optimization. Realistically mapping the different objectives that affect business practices directly and indirectly in a variety of laws is the challenge inherent to this method. Second, a sand processing plant’s production processes were modeled. It pumps sand out of a lake, sorts it by grain size, and dries it in a high-energy process. The production processes were modeled in a graph as a flow problem and converted into a mixed integer program. Integrating both continuous and discontinuous batch processes in the model proved to be challenging, as did the modeling of the sand processing plant’s cogeneration unit. Introducing binary variables that represent the starting points of batch processes and directly connecting them with production, flow, storage and energy consumption variables yielded an acceptable problem description with satisfactory computing time.

Renewable Energy Sources and Decentralized Energy Systems

Stream: Energy and Environment

Parallel session

Chair: Dominik Möst

1 - Resource allocation problems in decentralized energy management

Johann Hurink, Thijs van der Klauw, Marco Gerard

Changes in our electricity supply chain are causing a paradigm shift from centralized control towards decentralized energy management. Within the framework of decentralized energy management, devices that offer flexibility in their load profile play an important role. These devices schedule their flexible load profile based on steering signals received from centralized controllers. The problem of finding optimal device schedules based on the received steering signals falls into the framework of resource allocation problems. We study an extension of the traditional problems studied within resource allocation and prove that a divide and conquer strategy gives an optimal solution for the considered extension. This leads to an efficient recursive algorithm, with quadratic complexity in the practically relevant case of quadratic objective functions. Furthermore, we study discrete variants of two problems commonly in decentralized energy systems. We show that these problems are NP-hard and formulate natural relaxations of both considered discrete problems that we solve efficiently. Finally, we show that the solutions to the natural relaxations closely resemble solutions to the original, hard problems.

2 - Renewable energy deployment in the UK: a spatial analysis of the opportunities and challenges

James Price

The decarbonisation of electricity production is key to achieving the Paris Agreement goal of limiting global mean surface temperature rise to well below 2°C. It is highly likely that the large scale deployment of variable renewable energy sources (VRES) such as wind and solar will play an important role in meeting this challenge. Given the relatively low spatial energy density of VRES compared to conventional electricity generation, a significant growth in VRES often faces questions around social and environmental acceptance as well as technical limitations. Typically modellers optimise the whole energy system of a country at once at low spatial resolution and so do not consider locally specific social, environmental and technical constraints. Here we seek to study the impact of different levels of these constraints in a UK context, a country which has high public support for VRES at the national level but significant local opposition. To do this we take the following approach: 1) a detailed spatial analysis to develop scenarios of low, medium and high social, environment and technical constraints on VRE deployment, 2) input these into the UK focused cost optimising, high spatial and temporal resolution electricity system model highRES and 3) compare costs, deployment patterns and emissions across scenarios. We find that the costs of highly renewable electricity systems are considerably cheaper if the system optimal sites are developed, i.e.
3 - Assessing the Impact of Renewable Energy Sources: Simulation Analysis of the Japanese Electricity Market
Keisuke Yoshihara, Hiroshi Ohashi

The Great East Japan Earthquake on March 11, 2011 revealed many challenges of Japanese electricity system. The Strategic Energy Plan approved by the Cabinet in April 2014 provides the fundamental direction of energy policy such as lowering dependency on nuclear power generation to the extent possible through energy conservation and introducing renewable energy (RE) sources as well as improving the efficiency of thermal power plants. Among them, introducing RE sources is primarily of importance in terms of improving energy self-sufficiency ratio and reducing the volume of CO2 emissions. This paper evaluates the impact of RE sources on market outcomes in Japan. We develop a simulation model to compute the kWh-market equilibrium, and conduct simulation exercises for 2015 and 2030 based on the publicly available data. Our model is positioned as part of the optimal generation mix model and enables us to simulate power plants’ hourly operations that minimize the total variable cost under several constraints such as demand-supply balances and transmission constraints. Using scenarios proposed by the government, we find that the diffusion of RE sources would lower the kWh-market prices and greenhouse gases by reducing fossil fuel consumption in 2030. It would also mothball many of the thermal power plants, which were active and profitable in 2015. This finding indicates a need for new revenue mechanism where they earn revenue based on the volume of electricity output (kWh).

Friday, 10:50-11:35

■ FB-22
Friday, 10:50-11:35 - HFB|A
Semi-Plenary Anna Nagurney
Stream: Semi-Plenaries
Semi-plenary session
Chair: Stefan Minner

Anna Nagurney

Blood is a unique product that cannot be manufactured, but must be donated, and is perishable, with red blood cells lasting 42 days and platelets 5 days. Blood is also life-saving. A multi-billion dollar industry has evolved out of the demand for and supply of blood with the global market for blood products projected to reach $41.9 billion by 2020. The United States constitutes the largest market for blood products in the world, with approximately 21 million blood components transfused every year in the nation and approximately 36,000 units of red blood cells needed every day.

Although blood services are organized differently in many countries, such supply chain network activities as collection, testing, processing, and distribution are common to all. In this talk, I will focus on the United States, but the methodological tools can be adapted to other countries. Specifically, in the US, the blood services industry has been faced with many challenges in the past decade, with a drop in demand for blood products and increased competition. Revenues of blood service organizations have fallen and the financial stress is resulting in loss of jobs in this healthcare sector, fewer funds for innovation, as well as an increasing number of mergers and acquisitions.

In this presentation, I will overview our research on blood supply chains, from both optimization and game theoretic perspectives. For the former, I will highlight generalized network models for managing the blood banking system, and for the design and redesign for sustainability. In addition, a framework for Mergers & Acquisitions (M&A) in the sector and associated synergy measures will be described. A case study under the status quo and in the case of a disaster of a pandemic in the US will be presented. Finally, a novel game theory model will be highlighted, which captures competition among blood service organizations for donors.

■ FB-23
Friday, 10:50-11:35 - HFB|B
Semi-Plenary Sven Crone
Stream: Semi-Plenaries
Semi-plenary session
Chair: Claudius Steinhardt

1 - The Rise of Artificial Intelligence in Forecasting? Hype vs real world Success Stories
Sven F. Crone

Artificial Intelligence and Machine Learning have become household names, hot topics avidly pushed by the media, with companies like Facebook, Google and Uber promising disruptive breakthroughs from speech recognition to self driving cars and fully-automatic predictive maintenance. However, in the forecasting world, reality looks very different. An industry survey of 200+ companies shows that despite substantial growth of available data, most companies still rely on human expertise or employ very basic statistical algorithms from the 1960s, with even market leaders slow to adopt advanced algorithms to enhance forecasting and demand planning decisions. This reveals a huge gap between scientific innovations and industry capabilities, with opportunities to gain unprecedented market intelligence being missed.

In this session, we will highlight examples of how industry thought leaders have successfully implemented artificial Neural Networks and advanced Machine Learning algorithms for forecasting, including FMCG
Manufacturer Beiersdorf, Beer Manufacturers Anheuser Bush InBev, and Container Shipping line Hapag-Lloyd. I will leave you with a vision not of the future, but of what’s happening now, and how it can enhance supply chain and logistics planning.

Key learnings:

- What Artificial Intelligence and Machine Learning are, how they work, and their relevance to forecasting
- Real case studies of AI and ML algorithms employed by leading manufacturers
- The power of forecasting algorithms that learn, adapt to context and find hidden insights

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**FB-24**

Friday, 10:50-11:35 - HFB(C)

**Semi-Plenary Dorothea Wagner**

Stream: Semi-Plenaries

**Semi-plenary session**

Chair: Rolf Möhring

1 - Route Planning in Transportation - New Results and Challenges

Dorothea Wagner

Nowadays, route planning systems belong to the most frequently used information systems. The algorithmic core problem of such systems, is the classical shortest paths problem that can be solved by Dijkstra’s algorithm which, however, is too slow for practical scenarios.

Algorithms for route planning in transportation networks have recently undergone a rapid development, leading to methods that are up to several million times faster than Dijkstra’s algorithm. For example, for continent-sized road networks, newly-developed algorithms can answer queries in a few hundred nanoseconds; others can incorporate current traffic information in under a second on a commodity server; and many new applications can now be dealt with efficiently. Accordingly, route planning has become a showpiece of Algorithm Engineering demonstrating the engineering cycle that consists of design, analysis, implementation and experimental evaluation of practicable algorithms.

Recently, new aspects like multimodal route planning, personalized journey planning with respect to multiple criteria or energy-aware route planning for electric vehicles come up. This talk provides a condensed survey of recent advances in algorithms for route planning in transportation networks.

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**FB-25**

Friday, 10:50-11:35 - HFB(D)

**Semi-Plenary Christoph Klingenberg**

Stream: Semi-Plenaries

**Semi-plenary session**

Chair: Alf Kimms

1 - Improving on-time performance at Deutsche Bahn

Christoph Klingenberg

This presentation outlines a framework for improving the on-time performance of a public transport provider from a practitioners’ point of view.

In setting the goal for the on-time performance we differentiate between the punctuality for the passenger journey including transfer between trains and the punctuality for each service (train). Besides a differentiated goal you need a simple cost estimate per minute delay, again for a passenger minute and a train minute.

The basic analytic work is to carry out various comparisons of scheduled versus actual values for travel times between stations, stopping times at stations, transfer times between services, maintenance duration or rotation plans for trains. For each analysis, we filter the erratic component (as represented by the standard deviation) from the systematic “plan-error” component (difference between the mean value and the plan value). This leads to the two basic directions to take for improving the on-time performance:

- stabilize operations, i.e. eliminate erratic disturbances and
- adjust the plan to the mean value of actuals or some value close to the mean value

This implies departing from static scheduling as introduced in the 50ies and still employed by most major railways and introducing a dynamic scheduling approach using OR methods.

The main obstacle to adjusting the schedule to accommodate the systematic errors is an overcrowded train system with very limited room for time-shifting train paths (schedules). We discuss options to solve this impasse within the given framework through a comprehensive optimization approach (unfreeze the system).
Friday, 11:45-13:15

■ FC-01
Friday, 11:45-13:15 - WGS|101
Long-haul Transportation
Stream: Logistics and Freight Transportation
Parallel session
Chair: Alexander Kleff

1 - Learning from the past - Risk Profiler for intermodal route planning in SYNCHRO-NET
Denise Holfeld, Axel Simroth

The on-going H2020 project SYNCHRO-NET aims to provide a powerful and innovative platform to identify improvement opportunities by quickly analyzing and calculating the impacts and benefits of smart steering and synchronomodality on the whole supply chain. The ecoNet shows different trip alternatives, using different transportation modes, and gives the possibility to compare them easily. For this purpose, additional key risk indicators (KRI) are provided in addition to the classic key performance indicators (KPI). In this way the reliability of supply chains can be improved.

To assess risks of a specific route already existing knowledge and experience of nodes and links corresponding to this route should be included in the analysis. Therefore, real-time information is not only used to react and adapt the route if a problem occurs, but also to set up a database in order to analyze different kind of risks for future planning.

A Risk Profiler is developed to identify responsible nodes or links for a cause deviations of the execution of a planned route and to collect a cause of such deviations. This historical database, collected by the system itself, is used to define stochastic information needed in a simulation based setting, combining macroscopic simulation of trains in the railway network with microscopic simulation of passengers at stations. We illustrate the system by a small example.

While possible changes of passengers’ itineraries due to missed connections are included in a few publications, the actual physical behaviour of passengers at stations has not been considered within delay management so far. What do travellers do if a transfer is likely to be missed? People running from one platform to another in a hurry can interfere with others, heavy luggage may slow them down and increase the time they need for changing trains, and crowds in the station building may further obstruct their passage. In some situations, particular patterns of passenger flow can even cause additional train delays when, for instance, a steady trickle of people stepping in prevents the doors from closing. In this talk, we will show how such a model can be built in an agent-based setting, combining microscopic simulation of trains in the railway network with microscopic simulation of passengers at stations. We illustrate the system by a small example.

2 - Polynomial time algorithms for truck driver scheduling problems with multiple time windows
Alexander Kleff

We study the problem of finding optimal schedules for truck drivers who have to abide by regulations regarding breaks and rests while they visit a sequence of customers. For example, the regulation in the United States stipulates that a truck driver must not continue driving after 8 hours have elapsed unless a break of at least 30 minutes is taken. A feasible schedule respects the driving times between customers, the time windows and the service times at customers, and the appropriate provisions affecting drivers’ working hours. Little is known about the complexity of this truck driver scheduling problems, and there is no result in the case of multiple and arbitrarily distributed time windows per customer. We present the first polynomial time algorithms for the problem variants of the European Union and the United States and a planning horizon of one day.

■ FC-02
Friday, 11:45-13:15 - WGS|102
Delay Management and Route Choice under Delays
Stream: Traffic, Mobility and Passenger Transportation
Parallel session
Chair: Marie Schmidt

1 - Railway Delay Management in Face of Train Capacity Constraints
Eva König, Cornelia Schoen

Delay management for railways is concerned with the question if a train should wait for a delayed feeder train or depart on time. The answer should not only depend of the delay, but there are other factors to consider, for example capacity restrictions. We present an optimization model for delay management in railway networks that accounts for capacity constraints on the number of passengers that a train can effectively carry. While limited capacities of tracks and stations have been considered in delay management models, passenger train capacity has been neglected in the literature so far, implicitly assuming an infinite train capacity. However, even in open systems where no seat reservation is required and passengers may stand during the journey if all seats are occupied, physical space is naturally limited and the number of standing seats constrained for passenger safety reasons. In this talk, we present the model formulation, solution procedures and results from a numerical experiment analyzing the impact of train capacity restrictions on delay management decisions.

2 - Simulating Passengers and Trains for Better Decisions in Delay Management
Sebastian Albert, Philipp Kraus, Jörg Müller, Anita Schönöl

Delay management in rail transportation decides how to react to delays of trains. From a passenger-oriented point of view, the wait-depart decision is crucial: Which of the connecting trains should wait for changing passengers from a delayed feeder train, and which of them should rather depart on time? Furthermore, delays can entail conflicting spatio-temporal overlaps of multiple trains’ projected routes. It is therefore also necessary to decide which train gets priority over another when two or more trains simultaneously require the same piece of track.

While possible changes of passengers’ itineraries due to missed connections are included in a few publications, the actual physical behaviour of passengers at stations has not been considered within delay management so far. What do travellers do if a transfer is likely to be missed? People running from one platform to another in a hurry can interfere with others, heavy luggage may slow them down and increase the time they need for changing trains, and crowds in the station building may further obstruct their passage. In some situations, particular patterns of passenger flow can even cause additional train delays when, for instance, a steady trickle of people stepping in prevents the doors from closing. In this talk, we will show how such a model can be built in an agent-based setting, combining microscopic simulation of trains in the railway network with microscopic simulation of passengers at stations. We illustrate the system by a small example.

3 - The traveler’s route choice under uncertainty
Marie Schmidt, Paul Bouman, Leo Kroon, Anita Schönöl

A traveler in a periodic public transportation system suddenly faces a disruption of unknown lengths on his planned route. Should he commit to the disrupted route, switch to an alternative route immediately, or wait at the station for a while to see whether the disruption is resolved soon? Robust, stochastic, and online optimization provide different views on the question of an ‘optimal strategy’ for the traveler in this situation. We discuss how to compute ‘optimal’ solutions with respect to different concepts for optimization under uncertainty. Furthermore, we compare the recommendations made by robust, stochastic, and online optimization.

■ FC-03
Friday, 11:45-13:15 - WGS|103
Green Transportation
Stream: Logistics and Freight Transportation
Parallel session
Chair: Martin Hrusovsky

1 - Efficient Truck Platooning in the Autonomous Driving Possibility: An Artificial Bee Colony Approach
Abtin Nourmohammadzadeh, Sven Hartmann

Platooning means driving vehicles behind each other in close proximity as a file and like a string which has been considered as a capable strategy to reduce the cost of transportation companies and also to alleviate the environmental effects of fuel combustion. There are significant benefits for Truck Platooning. Firstly, decreasing the fuel usage by the aerodynamic drag reduction resulted from driving in the slip-stream of other vehicles. Then, relieving the traffic congestion because of the shorter inter-vehicle distances. Moreover, by the possibility of
Parallel session

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1 - Metaheuristics for the vehicle routing problem with backhauls and soft time windows
Jose Brandao

The vehicle routing problem with backhauls and soft time windows (VRPBTW) contains two distinct sets of customers: those that receive goods from the depot, who are called linehauls, and those that send goods to the depot, named backhauls. In each route the linehauls have to be served before the backhauls. To each customer is associated an interval of time (time window), during which each one should be served. If the time window can be violated it is called soft, but this violation implies an additional cost. We solve the VRPBTW using two different metaheuristics: iterated local search and tabu search. The performance of these two methods is tested and compared using a large set of benchmark problems from the literature. On the other hand, these methods are also compared with other methods for the VRPBTW that have been published before.

2 - An Evolutionary Approach for the Traveling Thief Problem
Mahdi Moeini, Daniel Schermer, Oliver Wendt

The Traveling Salesman Problem (TSP) and the Knapsack Problem (KP) are two classical and well-known problems in combinatorial optimization. Recently, a new variant of the TSP has been introduced in which the Knapsack Problem (KP) is integrated in the TSP. The new combinatorial optimization problem is called the Traveling Thief Problem (TTP). In this problem, there is an interdependency between TSP and KP components, e.g., the weight of the knapsack and the gained profit of the picked items have influence on the speed and the final gain the thief as well as his/her TSP tour. This fact (i.e., the interdependency) makes TTP, in comparison to other TSP variants, very difficult to solve. In this study, we are interested in addressing TTP and in solving it by a hybrid evolutionary approach. Our approach is based on an effective combination of a Genetic Algorithm (GA), Local Search (LS), and Variable Neighborhood Search (VNS). We evaluate the efficiency of the hybrid algorithm by solving the TTP for some benchmark instances. We compare our results with the best of 21 existing algorithms. According to our observations, the proposed approach is able to improve some of the best known results of the literature.

3 - Scheduling an Indoor Football League: a Tabu Search Based Approach
David Van Bulck, Dries Goossens, Frits Spieksma

The "Liefhebbers Zaalvoetbal Cup (LZV Cup)", is an amateur indoor football league founded in 2002 and currently involving 477 teams, grouped in different divisions in which each team plays against each other team twice. The goal is to develop a schedule for each of the divisions, which avoids a close succession of matches of the same team in a limited period of time. This scheduling problem is interesting, because matches are not planned in rounds. Each team provides dates on which they can play a home game, and dates on which they can not play at all (e.g. during the Christmas and New Year Period). Furthermore, in contrast to professional leagues, alternating home and away matches is hardly relevant in amateur leagues. The main reason is that the home advantage is quite limited since there are usually few spectators. As the LZV Cup problem turns out highly demanding to solve with integer programming (Gurobi), we have developed a heuris-
tic based on tabu search. The core component of this algorithm solves a transportation problem which schedules (or reschedules) all home games of a team. Besides, we have also developed fix-and-relaxed methods, based on the teams as well as on time intervals. We used the tabu search based method to generate schedules which have been implemented in practice, much to the satisfaction of the participating teams. Overall, the quality of this heuristic is comparable to that of Gurobi, however, the reduced computation time, and the absence of expensive licenses makes the heuristic implementation more suitable for (amateur) competitions such as the LZV Cup. In rare occasions where not all matches could be scheduled, the organizers appreciated that our approach outputs a partial solution and the conflicting teams to be contacted.

4 - NSGA-II algorithm optimization based workflow scheduling for medical applications in cloud
Khaled Sellami, Rabah Kassa, Abdelouhab Aloui, Pierre F Tiako

Cloud computing platform has attracted worldwide attention in a variety of applications like Health Care by deploying large scale medi-
cal workflow applications. These applications can be executed cost-effectively in IaaS cloud service model, as it provides scientific users with infinite pool of heterogeneous resources and pay-per-use billing
model. In the proposed work, the medical science applications are mapped to the HaaS resources based on the billing scheme and the resource billing granularity. Our approach is validated by simulating a complex Epigenomic medical workflow application.

## FC-05
**Friday, 11:45-13:15 - WGS 104a**

**Algorithms for Graph Problems (i)**

**Stream: Discrete and Integer Optimization**

**Parallel session**

**Chair:** Frauke Liers

### 1 - A Local-Search Algorithm for Steiner Forest
**Melanie Schmidt, Martin Groß, Anupam Gupta, Amit Kumar, Jannik Matuschke, Daniel Schmidt, Jose Verschae**

We give a local-search-based constant-factor approximation for the Steiner Forest problem. The algorithm is the second combinatorial algorithm for this problem and brings new techniques to an area which has not seen too many improvements in a while. We hope that it might inspire a combinatorial algorithm for the more general survivable network design problem. Using local search to obtain a constant factor approximation is also interesting because a local search algorithm was crucial for tackling the dynamic Steiner *Tree* problem, and the dynamic Steiner *Forest* problem is wide open.

### 2 - The Primal-Dual Greedy Algorithm for Weighted Covering Problems
**Andreas Wierz, Britta Peis, Jose Verschae**

Many interesting problems can be formulated as so-called integer covering problems. In an integer covering problem, we are given resources and elements. Each element has an associated cost and a non negative weight for each resource. The task is to find a subset of elements (possibly with multiplicity) that covers a demand for each resource. Knapsack cover, set cover, contra-polymatroids and generalized steiner trees are examples of such form. For many problems of this type, a very simple primal-dual greedy algorithm can be used in order to obtain good approximation guarantees. The algorithm uses the dual of the linear relaxation of such a covering problem in order to choose elements that should be added to the solution. If all weights are binary, lots of insight is known regarding the structures that yield good approximation guarantees. That is, the approximation guarantee can be bounded in terms of properties of the inequality system, such as supermodularity of the right hand side. We investigate similar structural properties in the weighted case. We show that the greedy algorithm has bounded approximation guarantee if the matrix and the right hand side are coupled in a certain way. This coupling is present in all of the applications mentioned above. Our approximation guarantee also matches the best known bounds for all these problems. Lower bound instances matching our approximation guarantee are also provided, showing that the analysis is tight.

### 3 - Polyhedral Results for Clique Problems with Multiple-Choice Constraints
**Maximilian Merkert, Andreas Bärmann, Patrick Gemander, Frauke Liers, Oskar Schneider**

We consider multiple-choice feasibility problems in which the items chosen in a solution have to fulfill a given pairwise compatibility relation. Motivated by applications from railway scheduling and piecewise linearization of network flow problems, we examine several special cases in which the structure of the underlying compatibility graph allows us to give a complete linear description of the respective polytope. The results are derived, among others, by using graph-theoretic arguments related to perfect graphs. Furthermore, computational experiments show the potential of using our polyhedral results to improve the performance of a state-of-the-art MIP-solver on instances from the aforementioned applications.

## FC-06
**Friday, 11:45-13:15 - WGS 105**

**Cooperative Truck Logistics**

**Stream: Graphs and Networks**

**Parallel session**

**Chair:** Jörg Rambau

### 1 - New production approach for European truckload cargo industry
**Andy Apfelstädt**

Production of full truck load (FTL) services has no characteristics of industrialisation yet. Main reason for this is a tight coupling between the working time of one driver and the vehicle operating time. Therefore, the value added share of the truck is due to statutory driving and rest periods, and the applicable law on working hours for the driver - lower than 30%. Due to a sequential multiple occupancy of vehicles used in truckload traffic, a significant increase of their temporal utilization can be achieved. It provides first methodological approaches to the implementation of developed new production forms within newly conceived freight transport networks, especially for truck load traffic. This talk is about the quantitative results of developing and simulating a new approach.

Based on known planning problems in groupage and less than truckload networks, a FTL-network was conceptually conceived and correspondingly necessarily strategic, tactical and operational objects of planning are described. Further in a theoretical potential analysis with a data set of more than 1.8 millions of shipments of an online based freight market and a corresponding depot network, a quantitative evidence of the effectiveness of the developed and modeled traffic procedures could be provided for the first time. For this moment, the framework conditions were set very simple. Finally, an economical potential analysis, as part of the presentation, revealed a cost advantage of 5%, compared to the classic production form. Therefore, all respective cost and performance factors of different production processes were elaborated and taken into account as well as the expenditure (transport distance) through dynamical routing.

### 2 - Multi-Routing und Transport-Matching in Cooperative, Full Truckload, Relay Networks
**Bernd Nieberding**

In Germany the actual freight dispatching market consists of small- to middle-sized suppliers, with an average fleet size of 9 vehicles. An important segment of this market is full truck load (FTL), which is described as so-called point-to-point or over-the-road dispatching, with standard curtainsided or box trailers, where the smallest transportation unit is one trailer and a load is directly transported between origin and destination by a single driver. FTL-related production processes are demand-based with short scheduling horizons and lack of planning certainty. Together with an average legally restricted working time of 9.6 hours per day and driver, this situation entails that the operating time of the vehicle and the working time of the driver are directly coupled and the fixed cost intensive vehicle can be utilized in a value-adding manner only for approximately 7 hours a day. A large potential to spread the fixed costs of the vehicle on more productive kilometers is given through the low level of industrialization and standardization of the transport processes related to FTL in German. In this talk we will describe our intended framework, with an cooperative, relay network of different forwarders and processes similar to the processes used in part load dispatching. A mathematical model is used to schedule and route shipments in the network as relays, which allows a restaffing of the truck to enhance the overall calculation. Empty runs play a crucial role in cooperative networks. To this, we describe a matching of transports in the network, which eliminates empty runs. To maximize the matched number of transports handled in the network, each transport is associated with a multiple number of possible network routes, under certain conditions.

### 3 - MILP-Models for Cooperative Truck Networks
**Jörg Rambau**

If trucks of one company cover a long distance, then during the breaks of the drivers the truck is unproductive. However, companies may build a cooperative network in which trailers can be passed on from driver to driver. Then at least some of the transports may be carried out by putting together only near-home trips of the drivers from and to their depots. Given a number of long- and short-distance trips for full-truckloads and certain rules for the composition of long trips from
near-home trips, we search for the best possible way to replace long-distance trips requiring overnight breaks by a sequence of non-empty near-home trips requiring no overnight breaks. Thus, the practical success factors and a basic algorithmic setup for such a business process are discussed in the other talks of this session. In this talk, various Mixed Integer Linear Programming models allowing for various degrees of freedom in the business process and evaluating various objectives are compared on real-world data. The easiest model uses fixed routings for each transport relation whereas a more sophisticated version allows for a set of alternative routings for each transport relation.

Computational Mixed-Integer Programming 5
Stream: Discrete and Integer Optimization
Parallel session
Chair: Ambros Gleixner

1 - Automated Parameter Tuning in SCIP
Ying Wang, Robert Lion Gottwald, Gregor Hendel, Ambros Gleixner, Thorsten Koch

SCIP is a branch-and-cut solver for various classes of optimization problems including mixed-integer programming (MIP) and mixed-integer nonlinear programming (MINLP). To treat instances of practically relevant size, SCIP incorporates numerous solver components such as presolving algorithms, cutting plane separation and primal heuristics, many of which involve a large number of design choices and algorithm-specific parameters. In total, the implemented branch-and-cut algorithm has more than 2000 parameters.

The default values are tuned for a good overall performance on general benchmark sets. Improving the parameter settings for a specific class of problems is a challenging task since an ad hoc, manual tuning process is often incomplete and time consuming, especially for hard MIP instances. Therefore a systematic and automated tuning functionality is desirable from both the developers’ and users’ point of view.

We present an approach that combines parallel sampling and MIP-specific knowledge to guide the search for improving parameter values. It is based on iteratively monitoring several cost measurements to evaluate and compare candidate settings. In addition, we consider multiple random seeds to decrease the influence of performance variability on individual evaluations.

2 - Experiments with concurrency in an MINLP solver
Robert Lion Gottwald, Stephen Maher, Yuji Shinano

Portfolio parallelization is an approach that runs multiple algorithms or solver configurations in parallel and terminates when one of them succeeds in solving the problem. This approach is available in the latest release of SCIP, a state-of-the-art academic MINLP solver. We present computational experiments investigating the effectiveness of the approach. We will particularly focus on SCIP’s feature of distributed domain propagation. This technique shares global bound changes obtained by domain propagation between solvers in the parallel portfolio.

3 - Adaptive large neighborhood search for MIP
Gregor Hendel

One of the most important qualities of a mixed integer programming solver lies in its ability to quickly provide good incumbent solutions. To this end, modern solvers employ dozens of heuristic algorithms in addition to the search. Among the general purpose primal heuristics, large neighborhood search (LNS) heuristics represent a very effective subclass. Since there is usually little a priori knowledge about the performance of an LNS heuristic for an instance, a solver ideally adapts its mixture of LNS heuristics at runtime.

With the aim to improve over existing, state-of-the-art solver application of LNS strategies, this work introduces an Adaptive Neighborhood Search (ANS) heuristic that employs existing and new LNS techniques and an idea from reinforcement learning. First, a novel LNS heuristic, Graph Induced Neighborhood Search (GiNS), is presented. Besides its use as a neighborhood search in itself, a mechanism is introduced that combines GiNS and two other methods to compensate for other neighborhoods that do not reach a desired target fixing rate by themselves.

The second part describes the adaptive behavior of ANS. Besides the control of the individual target fixing rates, ANS learns to rank different neighborhoods based on their success online during search. This approach is motivated by the multi-armed bandit problem.

The efficacy of the ANS heuristic is evaluated in a series of computational experiments on instances from academia and industrial applications using the MIP solver SCIP.

Advanced Choice-Based Optimization
Stream: Traffic, Mobility and Passenger Transportation
Parallel session
Chair: Sven Müller
Chair: Knut Haase

1 - A Lagrangian relaxation method for solving choice-based mixed linear optimization models that integrate supply and demand interactions
Meritxell Pacheco Panque, Shadi Sharif Azadeh, Michel Bierlaire, Bernard Gendron

Integrating customer behaviour in optimization models provides a better understanding of the preferences of the demand-side actors to supply-side operators while planning their systems. On the one hand, these preferences are formalized with discrete choice models, which are the state-of-the-art for the mathematical modeling of demand. On the other hand, the optimization models that are considered to design and configure a system are associated with (mixed) integer linear problems (MILP). The complexity of discrete choice models leads to mathematical formulations that are highly nonlinear and nonconvex in the variables of interest, and are therefore difficult to be included in MILP.

In this research, we present a general framework that overcomes these limitations and is able to integrate advanced discrete choice models in MILP. Since the formulation has been designed to be linear, the price to pay is its high dimension, which results in a computationally expensive problem. To address this issue, and given the underlying structure of the model, we propose a Lagrangian relaxation method by identifying two subproblems with common variables: one concerning the choices of customers and another concerning the design variables of the operator. A subgradient method is characterized in order to approximate the associated Lagrangian dual.

2 - Choice Based Revenue Management with Flexible Substitution Patterns
Sven Müller, Frauke Seidel, Knut Haase

In this paper we present a new single-leg choice based (airline) revenue management (CBRM) optimization model with flexible demand substitution patterns between fare classes. The respective demand model is based on individual utility values that, in sum, represent demand for the choice of airline tickets in certain fare classes. We particularly focus on non-constant substitution between alternatives to capture shifts in demand between alternatives that share common unobserved characteristics from the decision makers perspective. Thus, we are able to relax assumptions applied to revenue management optimization models that employ the multinomial logit demand model. We embed a general random utility model in a simulation-based mixed-integer linear program for revenue maximization. Thereby, we determine the prices for - and the availability of - each fare class and guarantee an optimal allocation of bookings to offered fare classes. We are able to solve instances up to 200 bookings (close) to optimality using GAMS/CPLEX.

By applying an nested logit demand model we find that revenues are increased compared to the application of the multinomial logit model. In section 2 we discuss that applying multinomial logit demand models is usually not appropriate due to the restrictive assumptions. We investigate the loss in revenue due to inappropriate demand models by a series of numerical studies.
3 - Supply chain contract design under asymmetric information: a multi-nominal logit model
Guido Voigt, Sven Müller

We consider a supplier-buyer supply chain. The buyer holds private forecast information (high/low). The supplier offers a non-linear capacity reservation contract in order to align incentives. When all parties act rational and the utility of the contract receiving party is common knowledge, the revelation principle stipulates that one contract for each buyer type (high/low) supports the second-best outcome. We analyze how the number of contracts differs when lifting the rationality and/or common knowledge assumption in a multi-nominal logit model.

3 - New Variants of the Traveling Salesman Problem Motivated by Emerging Applications (i)
Chair: Anja Fischer
Chair: Philipp Hungerländer

1 - Optimal Algorithms for an Extended Version of the Knight’s Tour Problem
Michael Fürsten, Philipp Hungerländer, Anja Fischer

We present the Traveling Salesman Problem with forbidden neighborhoods (TSPFN) with radius of length two that is closely related to the well-known knight’s tour problem. The TSPFN is an extension of the Euclidean TSP in the plane where direct connections between points that have distance two or less are forbidden.

The TSPFN is motivated by an application in laser beam melting. In the production of a workpiece in several layers it is possible to reduce the internal stress of the workpieces by not allowing the consecutive heating of points that are close to each other. The points in this application are typically arranged on grids that are nearly regular. Hence in this presentation we examine the TSPFN on a regular grid that can also be interpreted as a chessboard with respective dimensions.

For the TSPFN with a radius of length two direct connections between points that have distance greater than two are allowed. This means that feasible steps of minimal length between two points on regular grids are knight’s moves. Hence if a knight’s tour can be constructed on a certain chessboard, this knight’s tour is a feasible and optimal solution for the TSPFN with a radius of length two on the respective regular grid.

We connect the existing algorithms for the knight’s tour problem with newly developed methods to solve the TSPFN with a radius of length two on grids with arbitrary dimensions. In most cases our methods are based on the construction schemes used for solving knight’s tour problem, i.e. we connect special tours on grids with small dimensions to generate optimal TSPFN tours on grids with arbitrary dimensions. For some grid dimensions we design completely new approaches that also run in polynomial time.

2 - The Traveling Salesperson Problem with Forbidden Neighborhoods on Regular 2D and 3D Grids
Anna Jellen, Philipp Hungerländer, Anja Fischer

We suggest and examine an extension of the Traveling Salesperson Problem (TSP) motivated by an application in mechanical engineering. The TSP with forbidden neighborhoods (TSPFN) with radius r is asking for a shortest Hamiltonian cycle of a given graph G, where vertices traversed successively have a distance larger than r.

The TSPFN is motivated by an application in mechanical engineering, more precisely in laser beam melting. This technology is used for building complex workpieces in several layers, similar to 3D printing. For each layer new material has to be heated up at several points. The question is now how to choose the order of the points to be treated in each layer such that internal stresses are low. Furthermore, one is interested in low cycle times of the workpieces. One idea is to look for a short Hamiltonian cycle over all layers that does not connect points that are too close so that the heat quantity in each Region is not too high in short periods. In particular in the instances resulting from this application the layers are rectangular and nearly regular grids.

In this presentation we consider the TSPFN on regular 2D and 3D grids, i.e. adjacent vertices all have the same distance from each other. First we suggest an integer linear programming formulation for the TSPFN. Then we examine the TSPFN with radius 0, 1 and square root of 2 on regular 2D and 3D grids and determine construction schemes for optimal tours for these cases. In particular the construction schemes for the 3D case build nicely on the optimal tours for the 2D case.

3 - A linear-time approximation algorithm of the MSTSP for regular grids
Isabella Stock, Jorg Rambau

The Maximum Scatter Traveling Salesman Problem (MSTSP) aims to find a tour through a set of nodes such that the shortest appearing edge is as long as possible. In general, this optimization problem is NP-complete. We present a linear-time algorithm F-Weave(m,n) for nodes on a two-dimensional (m x n)-grid with Euclidean distances. It is an extension of a procedure from Arkin et al. which computes an optimal solution for nodes in one line. F-Weave(m,n) returns an optimal solution of the MSTSP for most grid sizes; for the remaining cases, we can prove asymptotic optimality of F-Weave(m,n). This algorithm can be extended to a three-dimensional grid, conserving optimality for more than half of all possible grid-sizes. For the remaining grid sizes approximation algorithms can be deduced. At the same time, F-Weave(m,n) is asymptotically optimal for the “TSP with forbidden neighborhoods” (TSPFN) with a specific minimum edge length which equals the length of the shortest edge of F-Weave(m,n). In the TSPFN, the shortest tour through a given set of nodes is required such that the used edges are longer than a minimum length. This work was motivated by a minimization of deflections and production times in selective laser melting.
3 - Flexible mobility on demand: integrated choice models and optimization

Shadi Shari Azadeh, Bilge Atasoy, Yousef Maknoon, Michel Bierlaire, Moshe Ben-Akiva

One of the main challenges of operation managers is to decide about how to offer a mix of products to the customers at a given time with the objective of maximizing the expected revenue as well as maximizing the customers’ satisfaction. The expected revenue from an offer set is defined by the price and the demand of each of the offered products. This paper introduces the application of such decision making models inside the framework of an innovative transportation concept called Flexible Mobility on Demand (FMOD), which provides personalized services to passengers (e.g. Uber). FMOD is a demand responsive system in which a list of travel options is provided in real-time to each passenger request. The system provides passengers with flexibility to choose from a menu that is optimized in an assortment optimization framework. The allocation of the available fleet to these different services is carried out dynamically based on demand and supply so that vehicles can change roles during the day. The FMOD system is built based on a choice model. The profits of the operators are expected to increase since the system adapts to changing demand patterns. In addition, these tools are significantly beneficial to provide a more sustainable transportation tool especially in countries with less public transport infrastructure.

FC-11

Friday, 11:45-13:15 - WGS005

Analysis and Optimization of Road Traffic

Stream: Traffic, Mobility and Passenger Transportation

Parallel session

Chair: Elmar Swarat

1 - TWT Map Kernel - simulation based routing for field test planning and technical proof of automotive developments

Bernhard Wieland, Victor Füllner, Melanie Kluge, Alexander Raufäisen

A modern vehicle goes through intensive test cycles before market maturity is reached. It is tested and technically proved in hundreds of thousands of kilometers in most diverse environments. The costs are immense and increasing with additional functionalities of modern vehicles. Can field tests be orga-nized more effectively using digital methods?

We developed a special graph structure to represent relevant map data: the TWT Map Kernel. It in-cludes the road network with connections and restrictions as well as properties such as distance, slope or traffic signs. Parametrizable models of vehicle, driver, traffic and weather are used to generate driving profiles, vehicle simulations are used to evaluate powertrain related quantities.

Critical driving situations are now virtually identified on the map and specific field test scenarios are generated using simulation based rout-ing on graphs. Different methods have been developed to cover different search criteria - from global search of “worst-case” routes (includ-ing e.g. the most critical sit-uations) to “fixed source and sink” routes with specific criteria (e.g. a concrete histogram of operating points).

Actual field tests are now designed in advance for the impact on cer-tain components to enable a targeted and consistent testing. Redundant measurements are reduced and testing is optimized.

In the presentation, theoretical aspects of the graph structure of the TWT Map Kernel and the routing methods are as well shown as further potentials of the method with concrete examples and practical experiences.

2 - Two portable Linear Programming driven Heuristics for Optimal Toll Enforcement

Elmar Swarat, Gerwin Gamrath, Markus Reuther, Thomas Schlechte

We present two heuristics based on linear programming (LP) for a ro-serting problem. The problem is to optimize mobile control tours for toll enforcement inspectors on German motorways. Their task is to en-force the proper paying of a distance-based toll for all trucks weighting 7.5 tonnes or above. In addition, feasible rosters of the inspectors need to be generated. This leads to an integrated tour planning and duty rostering problem; it is called Toll Enforcement Problem (TEP).

We tackle the TEP by a standard multi-commodity flow model with some extensions in order to incorporate the control tours. The first heuristic, called Price & Branch, is a column generation approach to solve the model’s LP relaxation by pricing tour and roster arc vari-ables. Then, we compute an integer feasible solution by restricting to all variables that were priced.

The second contribution is a coarse-to-fine approach. Its basic idea is to project variables to an aggregated variable space, which is much smaller and belongs to a coarse version of the original problem. We aim to spend as much algorithmic effort in the coarse model as possi-ble and to only dive into more detail, i.e., in the fine model, if it turns out to be necessary.

For both heuristic procedures we will show that feasible solutions with high quality can be computed even for very large industrial instances. Finally, it turns out that both ideas are portable in the sense that they can be applied to other combinatorial optimization problems as well.

FC-13

Friday, 11:45-13:15 - RVH1

Forecasting with Artificial Intelligence and Machine Learning

Stream: Business Analytics, Artificial Intelligence and Machine Learning

Parallel session

Chair: Sven F. Crone


Lissy Langer, Jens Weitzbahn, Benjamin Grosse, Lisa Hermann

Electricity spot market prices are increasingly subjected to strong volatility due to growing shares of fluctuating and intermittent renew-able energy sources. Integrating the demand side by the advancement of smart grid technology leads to new possibilities of market participa-tion for players like small manufacturing plants, smart devices or even households, consuming or storing electricity when it is cheapest. Consequently, short-term price prediction becomes more useful and important for more and more market participants. Albeit, not only in-creased revenues for these players can be expected but also a balancing impact on grid utilization, therefore improving the performance and preventing unnecessary line and storage investments. However, hav-ing fewer resources available, these players rely on easy-to-implement algorithms and open-source data to benefit from these developments.

In this paper, hands-on pattern recognition algorithms for the short-term forecast of electricity spot prices are developed using the Python programming language. They are benchmarked for prediction accu-racy as well as computational efficiency, aiming to identify useful features that are based on available data, fast to compute, and contain sufficient discriminatory information. Algorithms with a balanced trade-off are developed, providing ready-to-use open-source code to the reader. A special focus lies on the introduction of renewable energy indicators into the feature selection. In addition, other significant - such as seasonal - features related to electricity spot prices are identi-fied. Hence, looking under the hood of these, commonly ‘black box’, cognitive machine learning algorithms, the effectiveness and efficiency of data selection is improved even for more advanced algorithms.

2 - Neural Network forecasts for time series with Islamic Calendar Seasonality - an empirical evaluation

Sven F. Crone
Forecasting for supply chain planning of fast moving consumer goods (FMCG) entails the prediction of monthly industry sales, which regularly exhibit regular time series patterns of levels, trends, seasonality, and combinations thereof. Despite early research suggesting that Neural Networks cannot effectively forecast time series with seasonality and noise (see, e.g., Zhang and Qi, 2005), various research papers (Crone and Kourentzes, 2009; Crone and Dahwan, 2007) as well as the NN3 competition (Crone et al., 2011) have since refuted these findings. However, whilst past studies and competitions have considered only Gregorian calendar seasonality, none have considered forecasting time series with Islamic Calendars. Gregorian calendars show prominent seasonality from calendar events that fall on the same days, weeks, and months every year, e.g., Christmas, New Years, 1st of May, etc. In contrast, the religious and bank holidays of the Islamic calendar follow the lunar calendar within 12 months of 29 or 30 days length in a year of 354 days, and thus shift in week and month from year to year. As the Islamic calendar drives consumption patterns, and thus to forecast FMCG demand in the Middle-East, we seek to assess the efficacy of forecasting Islamic seasonality with artificial neural networks. We consider a shallow, standard-architecture of Multilayer Perceptrons specified with binary, dummy and sine-cosine seasonality of Islamic Seasonality in comparison to statistical benchmarks of exponential smoothing and ARIMA applying a regular Gregorian calendar approach. All methods are assessed in a rigorous empirical evaluation using a fixed multi-step horizon and rolling origins over a representative subset of industry time series.

3 - Prognosis of EPEX SPOT electricity prices using artificial neural networks
Johannes Hussak, Ralph Grothmann, Merlind Weber

The steadily growing trading volume at the EPEX SPOT day-ahead market for the bidding zone Germany, Austria and Luxembourg reveals the increasing relevance of short-term trading within the European electricity market. Simultaneously, high price volatility due to growing share of intermittent power sources can be observed. Therefore, accurate price forecasts are essential for optimal trading strategies.

In this work, robust, but accurate forecast models to predict the day-ahead price at the EPEX SPOT market using artificial neural networks (ANNs) are developed. In contradiction to many other papers, a large number of possible influencing factors from different countries and on different geographical levels are considered and their impact on the market is evaluated based on a sensitivity analysis. A wide variety of different deep and recurrent neural network setups are deployed and tested. The study identifies the superiority of deep and error correction neural networks (ECNNs) in different seasons throughout the year 2016. The knack of a hybridization of both model setups proves to be the most accurate prediction model.

Since peak prices are hard to predict with these models, a quantile-based scaling approach derived from the field of meteorology and hydrology is applied as a correction factor to get the final model results. Using this technique, a further enhancement in prediction accuracy especially at peak prices is achieved. The overall prediction errors are on a very low level compared to the actual literature and can effectively be used to optimize offers placing at the EPEX SPOT day-ahead market.

2 - Optimal dynamic pricing and lot-sizing for deteriorating items when demand and deterioration are exposed to randomness
Maryam Ghoreishi, Christian Larsen

Most published works concerning dynamic pricing and lot-sizing for deteriorating items assume that the inventory system can be modeled as a deterministic system, though most often both the deterioration and the demand process must be assumed to be stochastic. Therefore, in this paper, we develop a problem of dynamic pricing and lot-sizing under stochastic deterioration and demand and deterioration are exposed to randomness. This stochastic model is based on Markov decision theory. We assume that the inter-arrival times follow an Erlangian distribution. We find the optimal dynamic price policy by using the value-iteration algorithm and in an outer loop we find the optimal lot-size. We assume that at any one time an arriving customer has a reservation price that is perceived by the retailer to be a random variable and the customer only will demand a unit if his reservation price is larger than or equal to the announced prices. For the special case with Exponential distributed inter-arrival times, we also demonstrate how to do joint optimization (pricing and policy-iteration) using the policy-iteration algorithm. These models are developed under the assumption that the replenishment lead-time is zero. Next, we extend our model also to assume Erlangian distributed lead-times and we find the optimal price policy by using the value-iteration algorithm and in two outer loops we find the optimal lot-size and reorder point. In addition to our model developments, we also do some numerical investigations. For the case of zero lead-time we investigate whether the lot-sizing and pricing decision can be decomposed. We observe that this decomposition can lead to a negligible difference if the non-optimal order quantity is close enough to the optimal one.

3 - Time-Consistent, Risk averse Dynamic Pricing
Jochen Gönsch, Rouven Schur, Michael Hassler

Many industries use dynamic pricing on an operational level to maximize revenue from selling a fixed capacity over a finite horizon. Classical risk neutral approaches do not accommodate the risk aversion often encountered in practice. When risk aversion is considered, time-consistency becomes an important issue. However, there is no consensus in the literature on its definition, as several contradicting properties are desirable. In our approach, we use a nested risk-measure to ensure that decisions only depend on states that may realize in the future. In this context, we use the risk measure Conditional Value-at-Risk (CVaR), which recently became popular in areas like finance, energy or supply chain management. A result is that the risk averse dynamic pricing problem can be transformed to a classical, risk neutral problem. To do so, a surprisingly simple modification of the selling probabilities suffices. Thus, all structural properties carry over. In addition, we show additional, risk-related properties. Moreover, we show that the risk averse and the risk neutral solution of the original problem are proportional under certain conditions. This has straightforward implications for practice. On the one hand, it shows that existing dynamic pricing algorithms and systems can be kept in place and easily incorporate risk aversion. On the other hand, our results help to understand many risk averse decision makers who often intuitively use “conservative” estimates of selling probabilities or discount optimal prices.
We work with a company that has a team of 10 people who spend 2 months manually assigning up to 1,000 staff to 2,000 of their clients and 10,000 jobs. It is a massive undertaking, in part because the scale of the problem and in part because the problem is multi-objective with 54 hard and soft business rules. This problem can be formulated as a large-scale scheduling problem. In our work, we demonstrate that by utilizing optimization methods we can unlock enormous savings in company man-hours while finding solutions with superior quality. In this talk, we will outline the heuristic and exact approaches we utilised, describe some of the many challenges of such a real-world problem, and show how we overcame them.

2 - A Bi-criteria Formulation of the Ship Crew Scheduling Problem with Resting Hours Constraints
Anissa Rizvanollı, Alexander Haupt
In the paper "Efficient Ship Crew Scheduling complying with Resting Hours Regulations" (presented at the OR Conference 2016) the ship crew scheduling problem with rest hours constraints has been introduced and a mathematical formulation has been presented with the aim of determining the minimal crew needed for the safe ship operation during a given voyage. The safety of a ship is guaranteed by appropriately qualified seafarers and by a schedule which complies with the resting hours rules determined by the Maritime Labour Convention (MLC). In the mixed integer linear program these rules are represented as hard constraints. In reality some of these rules can be broken at a given level. The trade-off between the optimal crew and the compliance of this crew with the rest hours rules is crucial for the decision making process. In order to determine and analyze the trade-off the computation of the Pareto front is needed. Therefore a bi-criteria formulation of the ship crew scheduling problem with resting hours constraints will be presented in this paper. Numerical experiments with real data will be presented.

2 - Deciding how many cuttings to cut from a mother plant: Combining Linear Programming and Data Mining
Han Hoogeveen
We study a problem that plays an important role in the flower industry: we must determine how many mother plants are required to be able to produce a given demand of cuttings. This sounds like an easy problem, but working with live material (plants) introduces complications that are rarely encountered in optimization problems: the constraints for cutting such that the mother plant remains in shape are not explicitly known.

We have tackled this problem by a combination of data mining and linear programming. We apply data mining to infer constraints that a scheduling pattern, stating how many cuttings to harvest in each period, should obey, and we use these constraints in a linear programming formulation that determines the minimum number of mother plants necessary. We then consider the problem of maximizing the total profit given the number of mother plants and show how to solve it through linear programming.
1 - An integrated loss-based optimisation model for apple supply chain
Parichehr Paam, Regina Berretta, Mojtaba Heydar
Food supply chain (FSC) refers to the processes from production to delivery of food from farmers to customers. It differs from other kinds of supply chains in terms of the perishable nature of food, variability in its price and demand, and consumer awareness toward food security, and climate dependency on the climate. Among the existing FSCs, the agricultural fruit supply chain has been paid the least attention. The fact that the quality of fruits deteriorates along supply chain processes and the lack of planning in different supply chain stages can bring about food loss, which has an impact on food security, insufficiency and profitability. Therefore, reducing food loss will bring important benefits not only to FSC companies, but also to society regarding food provision. The purpose of this paper is to present a dynamic mathematical model for apple supply chain in Australia in order to manage inventory flows in different types of storage rooms for apples from different harvesting periods. Food loss-related decision variables are defined to quantify the amount of apple losses in each type of storage based on the time gap between the harvest and delivery. The objective function of the model is total cost minimization, including penalty costs for apple losses. The model is implemented on a real industrial case study to show its applicability and is solved by Gurobi optimization software of mathematical programming problems.

2 - A decision support model for sustainable management of catering supply chains
Cagri Sel, Mustafa Çimen, Mehmet Soysal
The problem of food waste is currently on an increase and identifying sustainable solutions is a necessity in food supply chain management. Hereby, the purpose of this study is to introduce a decision support model for an environmentally conscious catering supply chain. Demand uncertainty has an impact on food waste in the catering sector. To address this problem, we develop a mixed integer linear programming model that accounts for Poisson distributed demand. The uncertain demand is estimated by a simulation. The key performance indicators of the model are the total waste and total shortage. These indicators enable to assess the sustainability performance of the catering supply chain. The numerical study reflects real settings from a catering organization of a University cafeteria in Turkey. The added value of the proposed decision support model has been shown through the analysis on the base case.

3 - Simulating fresh food supply chains by integrating product quality
Magdalena Leithner, Christian Fikar
The logistics of perishable goods differs significantly from non-perishable items due to various sources of uncertainties related to seasonable fluctuating supply and demand, unpredictable weather conditions that influence harvest time as well as quality and quantity of the products. Consequently, supply chain designs have to be accurately adapted to the individual product characteristics and cope with uncertainties to reduce food losses and maintain good qualities. Operational research models represent powerful tools to handle the growing complexity and uncertainties of fresh food supply chains. This work focuses on the integration of product quality in supply chain design and aims to minimize food losses during storage and transport. A generic keeping quality model, which models quality losses based on storage temperatures and durations, is implemented in a discrete event simulation. Furthermore, transport routes are optimized to either minimize food losses, maximize qualities or reduce driving distances based on decision makers' preferences. To test the model, the strawberry supply chain in Lower Austria - beginning at the farm and ending at the retail stores - is investigated. The impact of integrated shelf-life information in stock rotation schemes, varying cold chain designs and fleet configurations of producers and warehouses are discussed. In addition, the impacts on food losses are analyzed and the optimized transport routes of various objective functions are compared. Results indicate that stock rotation schemes, which integrate product qualities, the integration of cooling conditions at the producers' location as well as adequate truck capacities and fleet sizes can substantially reduce food losses.

4 - Impact of shelf life on the trade-off between economic and environmental objectives: a dairy case
Bryndis Stefánssdóttir, Verena Depping, Martin Grunow
Consumer awareness of product sustainability has increased significantly. Especially in the food sector, manufacturers introduce more environmentally sustainable manufacturing processes. However, these often go along with a reduction of product shelf life, which negatively affects the economic performance due to limited storage duration. We systematically analyze the impact of shelf life on the trade-off between economic and environmental performance of dairy products. We develop a multi-objective optimization model, covering profit and the relevant environmental indicators. A real-life case study is used to contrast traditional milk powders against novel milk concentrates. Concentrates require less energy in processing but have a shorter shelf life. Environmental impacts of the products are determined through a detailed life cycle assessment. Furthermore, objective reduction with the delta-error method is carried out to identify relevant trade-offs. To capture the impact of price uncertainty, the optimization model is implemented in a rolling horizon scheme, in which skim milk powder futures traded at the EEX AG are used as price predictors. Our numerical investigation based on historical data shows the extent, to which the volatility in historical product prices affected the economic evaluation of powders and concentrates. Due to their longer shelf life, powders are economically preferable in periods of large price fluctuations.
1 - Sequential Posted Price Mechanisms with Correlated Valuations
Bart de Keijzer

We study the revenue performance of sequential posted price mechanisms and some natural extensions, for a setting where the valuations of the buyers are drawn from a correlated distribution. Sequential posted price mechanisms are conceptually simple mechanisms that work by proposing a "take-it-or-leave-it" offer to each buyer. We apply sequential posted price mechanisms to single-parameter multi-unit settings in which each buyer demands only one item and the mechanism can assign the service to at most k of the buyers.

For standard sequential posted price mechanisms, we prove that with the valuation distribution having finite support, no sequential posted price mechanism can extract a constant fraction of the optimal expected revenue, even with unlimited supply. We extend this result to the case of a continuous valuation distribution when various standard assumptions hold simultaneously (i.e., everywhere-supported, continuous, symmetric, and normalized (conditional) distributions that satisfy regularity, the MHR condition, and affiliation). In fact, it turns out that the best fraction of the optimal revenue that is extractable by a sequential posted price mechanism is proportional to the ratio of the highest and lowest possible valuation.

We prove that a simple generalization of these mechanisms achieves a better revenue performance; namely, if the sequential posted price mechanism has for each buyer the option of either proposing an offer or asking the buyer for its valuation, then a fraction of the optimal revenue can be extracted that is inversely proportional to the "degree of interdependence" d in the valuation distribution. The latter value d is a parameter that ranges from complete independence (d = 0) to arbitrary dependence (d = number of buyers).

2 - Posted price mechanisms for a random stream of customers
Tim Oosterwijk, José Correa, Patricio Fonseca, Ruben Hoeksma, Tjark Vredeveld

Posted price mechanisms constitute a widely used way of selling items to strategic consumers. Although suboptimal, the attractiveness of these mechanisms comes from their simplicity and easy implementation. In this talk, we investigate the performance of posted price mechanisms when customers arrive in an unknown random order. We compare the expected revenue of these mechanisms to the expected revenue of the optimal auction in two different settings. Namely, the nonadaptive setting in which all offers are sent to the customers beforehand and the adaptive setting in which an offer is made when a consumer arrives. For the nonadaptive case, we obtain a strategy achieving an expected revenue within at least a 1-1/e fraction of that of the optimal auction. We also show that this bound is tight, even if the customers have i.i.d. valuations for the item. For the adaptive case, we exhibit a posted price mechanism that achieves a factor 0.745 of the optimal revenue, when the customers have i.i.d. valuations for the item. Along the way, we prove a basic result about Bernoulli random variables that we believe can be of independent interest.

3 - Revenue Gaps for Discriminatory and Anonymous Sequential Posted Pricing
Felix Fischer, Paul Duetting, Max Klimm

We consider the problem of selling a single item to one of $n$ bidders who arrive sequentially with values drawn independently from identical distributions, and ask how much more revenue can be obtained by posting discriminatory prices to individual bidders rather than the same anonymous price to all of them. The ratio between the maximum revenue from discriminatory pricing and that from anonymous pricing is at most $2-1/n$ for arbitrary distributions and at most $1/(1-1/n)$ for a geometric distribution. These bounds are tight for all values of $n$ and can in fact be attained by using one of the discriminatory prices as an anonymous one. For an important class of distributions that includes uniform and exponential distributions we show the maximization of revenue to be equivalent to the maximization of welfare with an additional bidder, in the sense that both use the same discriminatory prices. The problem of welfare maximization is the well-known Cayley-Moser problem, and we use this connection to establish tight bounds on the revenue gap of approximately $1.0375$ for uniform and $1.0735$ for exponential distributions.

FC-24
Continuous Optimization and Applications
Friday, 11:45-13:15 - HFB/C
Chair: Gerhard-Wilhelm Weber

1 - Decisions on Pricing, Capacity Investment, and Introduction Timing of New Product Generations in a Durable-Good Monopoly
Andrea Seidl, Richard Hartl, Peter M. Kort

The aim of the present paper is to analyze how firms that sell durable goods should optimally combine continuous-time operational level planning with discrete decision making. In particular, a firm has to continuously adapt its capacity investments, but only at certain times it will introduce a new version of the durable good to the market and determine its price. The launch of a new generation of the product attracts new customers. However, in order to be able to produce the new version, production facilities need to be adapted leading to a decrease of available production capacities.

A firm should increase its production capacity most upon introduction of a new product. Then the stock of potential consumers is largest so that then the market is most profitable. The extent to which existing capacity can still be used in the production process for the next generation has a non-monotonic effect on the time when a new version of the product is introduced as well as on the capital stock level at that time.

We briefly discuss the boundary value problem which we use to numerically find a solution of the given problem.

2 - Semi-supervised supports vector machines: A semi-infinite programming formulation
Farida Umhreem, Muhammad Faisal Iqbal, Faizan Ahmed

In this paper we present the cone programming reformulation of Semi-supervised support vector machine. The current cone programming reformulation relies on doubly non-negative or Semi-definite relaxation.

We look at the dual of the cone programming relaxation for solution, which is a copositive program that can be cast as the semi-infinite optimization problem. The discretization method for semi-infinite program is guaranteed to converge with proven convergence rate. We use this fact to our advantage to develop an algorithm to approximate the copositive program underlying Semi-supervised support vector machine. Numerical results are presented to compare our approach with the existing methods for semi-supervised support vector machine.

3 - Extracting the relevant trends for applied portfolio management
Theo Berger

As financial return series comprise relevant information about risk and dependence, historical return series describe the underlying information for applied portfolio management. Although market quotes are measured periodically, the data contains information on short-run as well as long-run trends of the underlying return series. A simulation study and an analysis of daily market prices reveal the relevance of short-run information for applied portfolio management.

Energy and Optimization
Parallel session
Chair: Dogan Keles

1 - Optimal Looping of Pipelines in Gas Networks
Ralf Lenz, Robert Schwarz
Natural gas is transported through networks of pipelines. Network capacity can be increased by placing new pipe segments parallel to existing ones. In this paper, we present two alternative models for the problem of finding the cost-minimal expansion plan. One allows for pipe segments of arbitrary length, while the other always expands pipes along their entire length. We then compare the feasible regions of these approaches and discuss model properties such as convexity and monotonicity.

2 - An optimization algorithm for the planning of virtual power plants
Lars-Peter Lauven

In the context of expanding shares of renewable energy, the management of fluctuating power production from wind turbines or photovoltaic cells is becoming a critical part of energy supply. Operators of virtual power plants, which consist of numerous flexible power supply and demand actors to compensate production fluctuations, need to identify the most profitable way to react to the development of prices on the different electricity markets. As these markets are organized as auctions, both initial bids and reactions to auction results must be considered. On the demand side, flexible power consumption in household applications, industrial processes and electric vehicle charging can potentially be incorporated into virtual power plants. The flexibility of such flexibility options is curtailed by the limited feasibility of operation times, postponements and charging times, e.g. for electric vehicles. On the supply side, both renewable and fossil power plants can be included into the system. The extent to which these can be used flexibly is limited e.g. by the available storage capacities in biogas plants. A Python-based algorithm consisting of both cost minimization models for power consumers and revenue maximization models for producers and energy storages is proposed to address the problem.

3 - Models and heuristic approaches for a large scale multi-period offshore power-grid extension planning problem
Philipp Hahn

The offshore power grid extension planning problem aims at building and locating wind farms in the north sea and dimension the power grid connecting them to the onshore grids. The dimensioning of the grid should be in such a way that under different weather conditions and thus, potentially very different in-feeds, the power can always be transported to shore. Additionally, neighboring countries can trade energy which needs to be considered in the dimensioning as well. The goal is to minimize the cost of such a potential grid under several technical, political and environmental constraints. Since this is a long term planning the construction plan should ensure operational intermediate stages. This is a large scale optimization problem due to the huge number of potential locations for wind farms, the variety of technologies that can be used and the large number of different weather scenarios. We model the problem as a network flow problem including (linearized) power flow losses on the lines. Technical equipment (e.g. lines, platforms, converters, etc.) is available in integer quantities and a sufficient amount needs to be installed according to technical constraints. The model is then formulated as a MINLP. In order to speed up the branching process, we want to find good initial heuristic solutions. We compute solutions of simplified versions of the problem (e.g. Min-Cost-Flow Formulation) and extend them to a solution of the original instance. Those solutions are used to reduce the size of the branching tree later on. The structure of the problem also allows for decompositions that we investigate as well.

2 - An Adaptive Discretization Algorithm for the Design of Water Usage and Treatment Networks
Sascha Kuhnke, Arie Koster

In this talk, we consider the design of water usage and treatment systems in industrial plants. In such a system, the demand of water using units as well as environmental regulations for wastewater have to be met. To this end, wastewater treatment systems may be installed and operated to clean the water. The objective of the design problem is to simultaneously optimize the network structure and the water allocation of the system. Due to many bilinear mass balance constraints, this water allocation problem is a nonconvex mixed integer nonlinear program (MINLP). Standard nonlinear solvers have difficulties to even find feasible solutions for larger instances. We present a problem specific algorithm to iteratively solve this MINLP. This algorithm deals in each iteration with a mixed integer linear program (MILP) and a quadratic constrained program (QCP). First, the MILP approximates the original problem via discretization and its solution provides a suitable network structure. Then, by fixing this network structure, the original MINLP turns into a QCP which yields solutions to the original problem. To improve the accuracy of the generated structure, the discretization of the MILPs is adapted after each iteration based on the previous MILP solution. In many cases where nonlinear solvers failed, this approach leads to feasible solutions with good solution quality in short running time.

3 - Design and development of a decision support system for water distribution networks
Michaela Beckschäfer, Corinna Hallmann

Drinking water supply systems are important components of the public infrastructure because water fulfills essential functions. A steady supply is required due to the all-purpose need of water in private households as well as in companies and public facilities. Since water consumption per capita on a daily basis in Germany has decreased significantly contrary to forecasts in the last 25 years, many components of the drinking water supply system are not dimensioned to work efficiently. This causes unnecessary costs and therefore the planning of new and the adaptation of existing water supply systems is even more important. We will present the design and development of a decision support system for the planning of water supply networks. The basis for this is an existing prototype upon which the graphical interface and processes are extended and improved. During the usage of different evaluation techniques it becomes clear that the decision support system shows large improvements compared to the prototype. This includes especially the completion of different tasks for the modification and processing of water network models.
Friday, 13:45-15:00

FD-27
Friday, 13:45-15:00 - HFB/Audimax

Plenary Lecture and Closing Ceremony

Stream: Plenaries

Plenary session

Chair: Natalia Kliewer
Chair: Ralf Borndörfer
Chair: Jan Fabian Ehmke

1 - On Big Data, Optimization and Learning

Andrea Lodi

In this talk I review a couple of applications on Big Data that I personally like and I try to explain my point of view as a Mathematical Optimizer - especially concerned with discrete (integer) decisions - on the subject. I advocate a tight integration of Machine Learning and Mathematical Optimization (among others) to deal with the challenges of decision-making in Data Science.

For such an integration I try to answer three questions:

1. What can optimization do for machine learning?
2. That can machine learning do for optimization?
3. Which new applications can be solved by the combination of machine learning and optimization?
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Optimization under Uncertainty
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Pricing and Revenue Management
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Business Analytics, Artificial Intelligence and Forecasting
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