universität
wien

EULOG 2016

Workshop in Honor of

Richard F. Hartl

Dear colleagues and friends,

It is our great pleasure to welcome you to the 5th EULOG meeting in Vienna. The abbreviation EULOG stands for decision support in logistics ("**E**ntscheidungs**u**nterstützung in der **Log**istik"). Indeed, the previous workshops in this series provided a forum for scientists mostly from German speaking universities as well as researchers from the private sector to present and discuss most recent advances in the area of logistics. This year, however, the EULOG is dedicated to a much broader spectrum of research: While only the second one and a half days of the workshop are devoted to different problems in logistics, the first one and a half days focuses on optimal control theory and applications.

The underlying idea of one workshop bringing together members of these two mostly distinct communities is to gather friends and colleagues of Richard F. Hartl on the occasion of his 60th birthday. Richard Hartl is one of few scientists who are continuously able to contribute to both of these fields in a significant manner. This is impressively documented by over 200 publications in reputable peer-reviewed journals making him one of the most successful researchers in business administration in the German speaking area. He is a highly esteemed and active member of the scientific community; among other activities, he is treasurer of IFORS (International Federation of Operational Research Societies), member of the editorial board of prestigious journals such as Transportation Science, and involved in the organization of many international conferences and workshops. Richard Hartl is a highly regarded professor at the University of Vienna, where he holds the chair for production and operations management now for over 20 years. In these years, he has been a great influence to students taking an active role in teaching and supervising many fruitful theses. Furthermore, he also has been very successful in the support of young researchers in launching a scientific career.

But to be honest - as impressive as the achievements of Richard Hartl might be - our main reason to organize this workshop is more personal than just to pay tribute to an outstanding scientist. What it comes down to is that Richard Hartl is a kind, generous, intelligent and fun person and we feel very privileged to have him as colleague, co-author, mentor and friend. As such, we want to take this opportunity to celebrate his birthday with him in a productive, memorable and enjoyable manner.

We are very happy that you join us for this special event and we wish you an exciting and fruitful workshop.

Karl F. Dörner, Gustav Feichtinger
Carina Artner-Konecny, Andrea Seidl

This event is kindly supported by:

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Workshop Venue

University of Vienna

The University of Vienna was founded in 1365. With more than 180 degree programs and about 92,000 students, the University of Vienna is the largest and most diverse educational institution in Austria. The University of Vienna is a research university enjoying high international visibility. Its profile reflects the characteristics of the area it is located in, and understands research as a global challenge.

The conference venue is the brand new building of the Faculty of Business, Economics and Statistics of the University of Vienna:

University of Vienna
Oskar-Morgenstern-Platz 1
1090 Vienna

This is an attractive location in close vicinity to the very city center. The location is

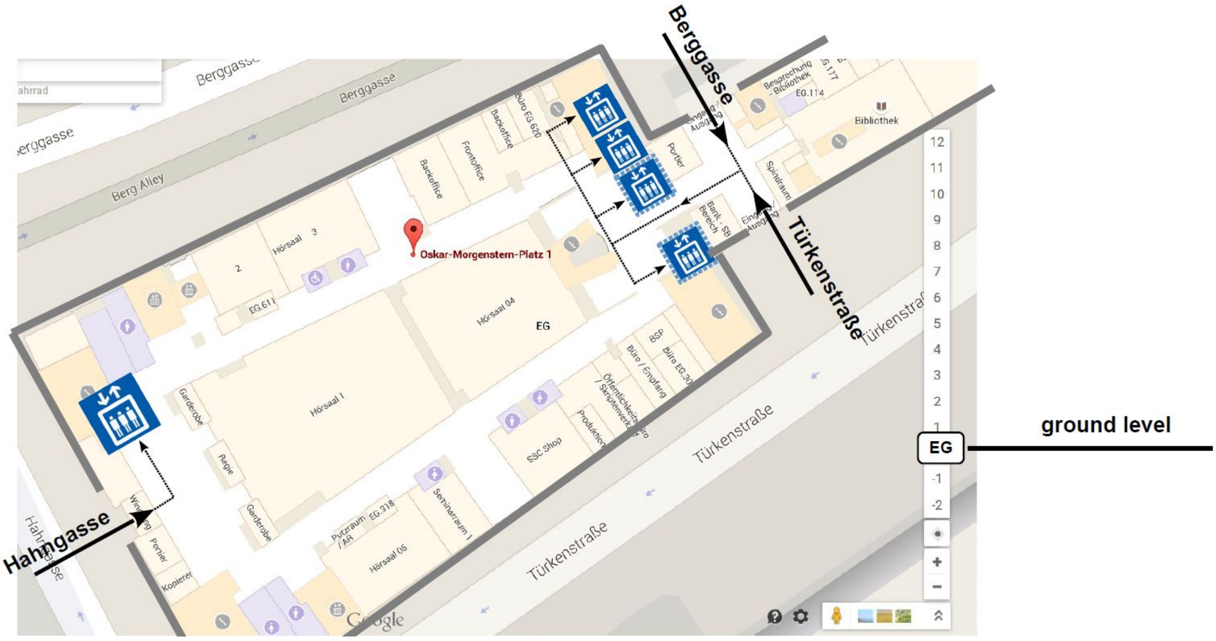
- close to public transportation: 5 minutes walk to metro line U4 (connecting e.g. to the City Air terminal, the opera, Schönbrunn castle) and 3 minutes walk to Tram D (passing along Ringstrasse and connecting two major train stations)
- within easy walking distance to the city center and most of the sights of Vienna
- right at the banks of the "Donaukanal" channel next to lots of pubs at the banks of the river/channel, a particularly pleasant place in summer.

The easiest way to get to the conference venue is by U4, exit "Roßauerlände". Alternatively, one can take tram D until exit "Schlickgasse".

The building Oskar-Morgenstern-Platz 1 can be entered through 3 different ways: (1) entrance "Berggasse" when arriving with U4, (2) entrance "Türkenstraße" (opposite) and (3) entrance "Hahngasse" when arriving with tram D.

The conference room "**Sky Lounge**" is located on the **12th floor** of the building. This floor can only be reached with two elevators at the entrance Berggasse/Türkenstraße.

Please find the floor plans of the conference venue Oskar-Morgenstern-Platz 1 on the next page.



Berggasse
Türkenstraße
Hahngasse
ground level
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Oskar-Morgenstern-Platz 1
Hörsaal 1
Hörsaal 04
Hörsaal 3
Hörsaal 05
Seminarraum 1
SSC Shop
Garderobe
Regie
Portier
Kopierer
Backoffice
Frontoffice
Spindraum
Bibliothek
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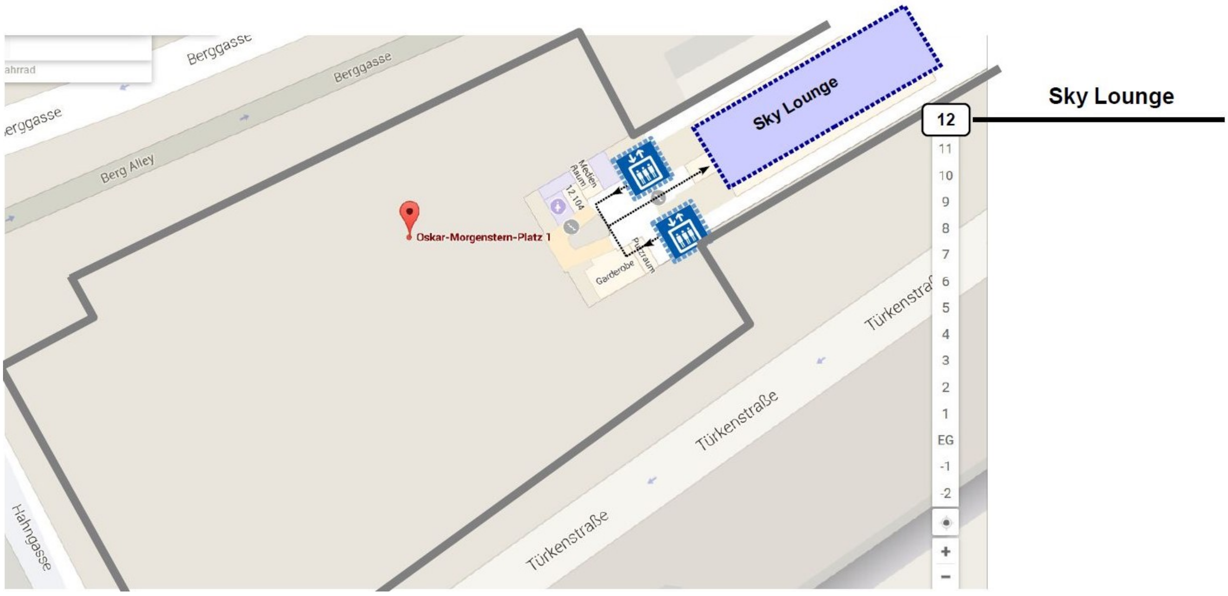

Sky Lounge
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Berggasse
Berg Alley
Oskar-Morgenstern-Platz 1
Medien Raum 12.104
Garderobe
Putzraum
Türkenstraße
Hahngasse
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General Information

Registration & Information Desk The Registration & Information Desk is situated in the Sky Lounge and is open on Tuesday, September 13, during the Welcome Reception (18:00-21:00), during the workshop each morning between 08:40 and 09:00 and during the coffee breaks indicated in the Conference Program.

Badges are required to access the lunch area. However, we encourage all attendees to wear the badges at all sessions and events.

Coffee breaks Coffee, tea, beverages, fruits and snacks are served in the Sky Lounge during the coffee breaks indicated in the Conference Program.

Lunch will be provided at Gasthaus Rebhuhn from 12:30 to 13:30. Please bring your conference badge to lunch! Gasthaus Rebhuhn is located 250 metres walking distance from the conference site in Berggasse 24 (see map below).

Internet Access WiFi is either available through your eduroam account or by a guest account provided in your welcome folder.

Guidelines for Speakers

All sessions will be held in the Sky Lounge of the Faculty building of Business, Economics and Statistics, Oskar-Morgenstern-Platz 1. The room is equipped with a computer and a projector.

Please bring your presentation as pdf-file or ppt-file on a USB memory-stick and copy it on the computer **before** the session starts.

Please limit your presentation to the designated time span of **25 minutes**, to allow for 5 minutes of discussion after each presentation. The session chair is responsible for time keeping.

In each session, one staff member will be available to assist you with technical difficulties.

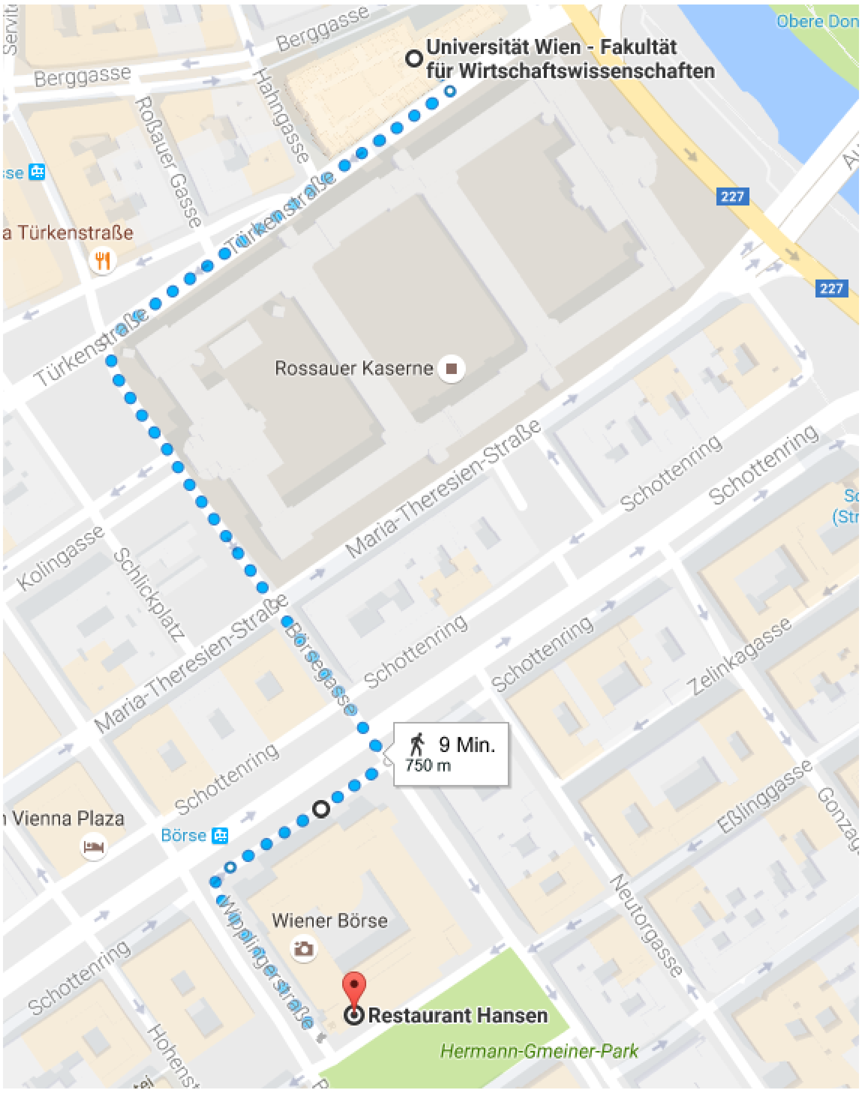
Social Events

Welcome Reception

We kindly invite you to participate at the Welcome Reception, which takes place on Tuesday, September 13, from 18:00 to 21:00 in the Sky Lounge at the University of Vienna, Oskar-Morgenstern-Platz 1, 12th floor.

Gala Dinner

The Conference Gala Dinner will take place on Wednesday, September 14, 19:00, at Restaurant Hansen. The restaurant is accommodated in the former Stock Exchange Building at the Vienna Ringstraße (Wipplingerstraße 34, 1010 Wien). It can be easily reached by foot from the conference venue, alternatively take the tramline D (direction "Alfred-Adler-Straße"; exit at station "Börse") to get to the restaurant.



Heuriger

By invitation of the Mayor and Governor of Vienna, participants will have a traditional Viennese dinner at the Heurigen “10er Marie” in Ottakring (Ottakringer Straße 222-224, 1060 Wien) on Thursday, September 15, 19:30. It can be reached by public transport from the conference venue by taking tramline D (direction “Alfred-Adler-Straße”) to station “Stadiongasse/Parlament” and changing there to tramline 2 (direction “Ottakringer Str./Erdbrustg.”) to station “Johannes-Krawarik-Gasse”.

Participants without a valid transport ticket for the Viennese Transport System may pick up two tickets for a single journey from a member of the organizing committee.

Scientific Program

Wednesday, September 14

1 Opening **09:00 – 10:00**
Sky Lounge

Oliver Fabel, *Dean of the Faculty of Business, Economics and Statistics*, University of Vienna
Otto Altenburger, *Head of the Department of Business Administration*, University of Vienna
Marc Reimann, *President of the Austrian Society of Operations Research (ÖGOR)*, University of Graz
Gustav Feichtinger, *Professor Emeritus*, Vienna University of Technology

2 Plenary **10:00 –11:00**
***Chair*: G. Feichtinger** **Sky Lounge**

Coffee break

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3 History Dependence in Optimal Control & Differential Games **11:30 –12:30**
***Chair*: G. Tragler** **Sky Lounge**

Lunch Break

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4 Plenary **13:45 –14:45**
***Chair*: H. Dawid** **Sky Lounge**

5 Applications of Optimal Control 1 **14:45 –15:45**
***Chair*: P.M. Kort** **Sky Lounge**

Coffe Break

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6 Optimal Control for Environmental Problems **16:15 –17:15**
***Chair*: F. Wirl** **Sky Lounge**

19:00 Conference Dinner

Thursday, September 15

7 Applications of Optimal Control 2 **09:00 – 10:30**

***Chair*: V.M. Veliov** **Sky Lounge**

Coffee Break

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8 Product & Process Innovation **11:00 –12:30**

***Chair*: A.J. Novak** **Sky Lounge**

Lunch Break

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9 Plenary **13:45 –14:45**

***Chair*: K. Doerner** **Sky Lounge**

10 Vehicle Routing 1 **14:45 –15:45**

***Chair*: J.-J. Salazar-Gonzales** **Sky Lounge**

Coffee Break

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11 Production & Operations Management & Games **16:15 –17:45**

***Chair*: C. Stummer** **Sky Lounge**

19:30 Heuriger

Friday, September 16

12 Heuristics **09:00 – 10:30**

***Chair*: M. Gendreau** **Sky Lounge**

Coffee Break

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13 Logistics **11:00 –12:30**

***Chair*: T. Wakolbinger** **Sky Lounge**

Lunch Break

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14 Plenary **13:45 –14:45**

***Chair*: W. Gutjahr** **Sky Lounge**

Coffee Break

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15 Vehicle Routing 2 **15:15 –16:45**

***Chair*: K. Inderfurth** **Sky Lounge**

16 Closing **16:45 – 17:00**

Sky Lounge

Abstracts

Wednesday, September 14

1. Opening 09:00 – 10:00

Sky Lounge

Oliver Fabel, *Dean of the Faculty of Business, Economics and Statistics*, University of Vienna
Otto Altenburger, *Head of the Department of Business Administration*, University of Vienna
Marc Reimann, *President of the Austrian Society of Operations Research (ÖGOR)*, University of Graz
Gustav Feichtinger, *Professor Emeritus*, Vienna University of Technology

2. Plenary 10:00 –11:00

***Chair*: G. Feichtinger** **Sky Lounge**

Optimally Controling Richard Hartl

Peter M. Kort (1,2),

(1) Department of Econometrics and Operations Research & CentER, Tilburg University, Tilburg, The Netherlands (2) University of Antwerp, Department of Economics, Antwerp, Belgium

Richard and I wrote many papers together, A prime example is the paper I will present at this workshop held in the honor of Richard. I for sure believe this is one of the best papers we have ever written, which is not in the least because of the complete classification we were able to give of the different properties the unstable steady state can have.
In particular, the paper considers a capital accumulation model in which revenue is a convex-concave function of the capital stock. While for certain capital stock values increasing returns to scale are reasonable, usually this property does not hold in general. In particular for large capital stock values it becomes increasingly difficult and thus expensive to produce more and more because of limitations of resources or infrastructure, lack of trained personnel in the region etc. We give a complete classification under which parameter constellations a saddle point equilibrium is optimal, when it is optimal to close down by choosing zero investment and when history dependent equilibria occur. In the last scenario we distinguish between different types of the unstable equilibrium, which can each have their own implication for the firms investment policy.

3. History Dependence in Optimal Control & Differential Games 11:30 –12:30

***Chair*: G. Tragler** **Sky Lounge**

Markov-Perfect Equilibria of Differential Games with Multiple Stable Steady States

Herbert Dawid (1), Michel Keoula (1), Peter M. Kort (2,3),

(1) Bielefeld University, Germany (2) Department of Econometrics and Operations Research & CentER, Tilburg University, Tilburg, The Netherlands (3) University of Antwerp, Department of Economics, Antwerp, Belgium

This paper presents a numerical method for the characterization of Markov-perfect equilibria of symmetric differential games exhibiting coexisting stable steady states. The method relying on the calculation of local value functions through collocation in overlapping parts of the state space, is applicable for games with multiple state variables. It is applied to analyze a piecewise deterministic game capturing the dynamic competition between two oligopolistic firms, which are active in an established market and invest in R&D. Both R&D investment and an evolving public knowledge stock positively influence a breakthrough probability, where the breakthrough generates the option to introduce an innovative product on the market. Additionally, firms engage in activities influencing the appeal of the established and new product to consumers. Markov-perfect equilibrium profiles are numerically determined for different parameter settings and it is shown that for certain constellations the new product is introduced with probability one if the initial strength of the established market is below a threshold, which depends on the initial level of public knowledge. In case the initial strength of the established market is above this threshold, the R&D effort of both firms quickly goes to zero and with a high probability the new product is never introduced. Furthermore, it is shown that after the introduction of the new product the innovator engages in activities weakening the established market, although it is still producing positive quantities of that product.

Thresholds, Limit Cycles, and Indeterminacy in Competitive Economies Due to a Dynamic Externality

Franz Wirl (1),

(1) University of Vienna, Faculty of Business, Economics and Statistics, Vienna, Austria

This paper addresses complex dynamic patterns of intertemporal competitive equilibria due to a dynamic externality using a general framework instead of a particular example. Starting point is the dynamic externality framework in Wirl (1997), which assumed that at least one eigenvalue is positive (thus ruling out indeterminacy) and focused on limit cycles. The set up is that of a rational expectations, intertemporal competitive equilibrium of an economy in which competitive agents accumulate a private stock (e.g., capital, human or physical) and the individual actions lead to a dynamic externality (positive or negative). In contrast to Wirl (1997), the emphasis in this paper is on thresholds and indeterminacy. The objective is to uncover the mechanics, i.e., the arithmetical conditions, of such non-standard outcomes like indeteminacy, thresholds coupled with multiple equilibria, and limit cycles and to explain them in economic terms. This objective is complementary to the related literature providing examples such as by Antoci with different

co-authors. However, the focus is on the role of the dynamic externality since the power of (capital) stock spillovers is known and documented in many examples.

4. Plenary 13:45 –14:45

***Chair*: H. Dawid** **Sky Lounge**

My Research with Richard Hartl and My Current Work on Stackelberg Games and Applications

Suresh P. Sethi (1),

(1) Naveen Jindal School of Management, University of Texas at Dallas, Richardson, USA

In view of this conference honoring Richard Hartl, I will begin this talk by briefly describing his postdoctoral work and his later work with me. I will then shift to my current research on dynamic Stackelberg games and their applications to management of supply and marketing channels.

5. Applications of Optimal Control 1 14:45 –15:45

***Chair*: P.M. Kort** **Sky Lounge**

How does Industry Competition Affect Firm Risk?

Engelbert J. Dockner (1), Jøril Mæland (2), Kristian R. Miltersen (3),

(1) Department of Finance, Accounting and Statistics, Vienna University of Economics and Business, Vienna, Austria (2) Department of Finance and Management Science, Norwegian School of Economics and Business Administration, Bergen, Norway (3) Department of Finance, Copenhagen Business School, Frederiksberg, Denmark

Traditional research on competition in oligopolistics industries has documented that firms producing differentiated products prefer price to quantity competition (i.e. their profits are higher) if products are complements, and quantity to price competition if products are substitutes. This result is quite robust and carries over to dynamic competition. Our paper does not look at the profitability of price versus quantity competition but at the risk implications of these two types of strategic interactions. Using a simple duopoly model with stochastic and linear demand and an infinite horizon we find that price competition always results in higher firm risk compared to quantity competition, i.e. the betas for firms competing in prices are higher than those competing in quantities. This result is a consequence of the strategic complementarities present in oligopolistic competition. Strategic complements (price competition) result in higher price variations and hence higher firm risks.

Multiplicity of balanced growth paths in an endogenous growth model with elastic labor supply

Gerhard Sorger (1),

(1) University of Vienna, Vienna, Austria

We consider the neoclassical one-sector growth model in continuous time with elastic labor supply and a learning-by-doing externality. It is shown that this model can have a continuum of balanced growth paths. Some of these balanced growth paths can be locally unique (determinate) whereas others can be indeterminate.

6. Optimal Control for Environmental Problems 16:15 –17:15

***Chair*: F. Wirl** **Sky Lounge**

Can the optimal harvesting of biological resources have periods of recovery?

Vladimir M. Veliov (1),

(1) ORCOS, Institute of Statistics and Mathematical Methods in Economics, Vienna University of Technology, Vienna, Austria

This talk is based on two joint papers with A. Belykov, in which we investigate the optimal mode of industrial fishing. We address the following qualitative question of huge practical importance: can a periodic mode of fishing (that includes recovery periods) be superior in the long run compared with fishing with (asymptotically) constant intensity. Models that do not take into account the heterogeneity of fish (with respect to age, size or gene) suggest that the answer of the above question is negative. We base our investigation on a model that takes into account the heterogeneity of fish with respect to age only.

Two alternative optimality criteria involving the net revenue are considered: averaged and discounted.

We show that proper (asymptotically) periodic optimal solutions may appear, provided that the fishing is selective, as it usually is in practice. The analysis involves a “properness test” for the averaged problem and some relations between the averaged and the discounted problem. Reliable computations are also involved. In case of non-selective harvesting, the optimal harvesting is asymptotically constant. The proofs of the last fact for the two problems make a substantial use of two results by Richard F. Hartl from 1987 and 1993.

Economic Growth with Recycling and the Environmental Kuznets Curve

Fouad El Ouardighi (1), Konstantin Kogan (2), Raouf Boucekkine (3),

(1) ESSEC Business School, Cergy Pontoise, France (2) Bar-Ilan University, Ramat-Gan, Israel (3) Aix-Marseille University, Marseille, France

In this paper, we investigate how the relationship between economic growth and pollution is affected by the source of pollution, that is, either production or consumption. We are interested in polluting waste that cannot be naturally absorbed, but for which recycling efforts are made to avoid massive pollution accumulation with harmful consequences in the long run. We distinguish the cases where recycling efforts are capital-improving or capital-neutral. Based on both environmental and social welfare perspectives, we determine how the interaction between growth and polluting waste accumulation is affected by the source of pollution, i.e., either consumption or production, on the one hand, and by the fact that recycling acts or not as an income generator, i.e., either capital-improving or capital-neutral recycling efforts.

Thursday, September 15

7. Applications of Optimal Control 2 — 09:00 – 10:30

***Chair*: V.M. Veliov** — **Sky Lounge**

Bifurcation-phenomena in an optimal control model with one to infinitely many states

Dieter Grass (1),

(1) Vienna University of Technology, Vienna, Austria

We start with a highly stylized model that rewards ”moderation–finding the right balance between sliding down either of two ”slippery slopes. Thus, it is assumed that a decision maker represents a single position (opinion, view, etc.), where a moderate, middle position is preferred. The slightest deviation from this middle position will tend to be amplified if one does not exert effort to avoid it.

Optimal solutions are computed as a function of two key parameters: (1) the cost of resisting the underlying uncontrolled dynamics and (2) the discount rate. This model is simple enough to derive analytical expressions for bifurcation lines separating regions where it is optimal to fight to stay balanced, to give in to the attraction of the ”left or the ”right, or to decide based on one’s initial state.

In a first step this model is extended by introducing a second position. These two positions can affect each other and we analyze the optimal solutions in dependence on the strength of these interactions. Obviously the different solution structures and bifurcation-phenomena of the one position model will be transferred to the two position model.

This step from one to two positions lets us anticipate what will happen if three, four, ... positions are considered. Consequently we end up with a continuum of positions. In its simplest formulation we assume that these positions interact via ”positional diffusion. This stepwise approach allows us to gain insights into bifurcation-phenomena of optimal control problems with spatial diffusion and its numerical treatment.

Time-optimal control of the deployment of a tethered satellite

Alois Steindl (1),

(1) Vienna University of Technology, Vienna, Austria

Tethered satellites are a promising technology for space missions: A satellite is connected to a space station on a Keplerian orbit by a long and light-weight cable (tether). A demanding task during the mission is the deployment of the satellite from the main station to a distant position; also the retrieval of the satellite back to the main station has to be carried out very carefully, otherwise expensive damage could occur.

Since the tether is usually much lighter than the satellite, the weight of the tether is commonly neglected and the tether is assumed to be straight. In this talk we address the time-optimal deloyment for a simply discretized tether configuration with a small mass and in-plane transversal oscillations by a tension force at the tether outlet.

Optimal Control of a Stochastic Epidemiological SIS-Model

Raimund Kovacevic (1),

(1) Vienna University of Technology, Vienna, Austria

SIS-models form a class of simple prototypical epidemiological models. They assume that individuals can be infected multiple times throughout their lives with no immunity after each infection. We use a stochastic SIS-model and assume that the recovery rate can be influenced by a decision maker. Using costs that are quadratic in the control and linear in the number of infected. Based on this setup, we formulate two versions of stochastic control problem under different assumptions about the available information. In the first case the state of the system is fully observable, and the decision maker can use the Hamilton-Jacobi-Bellman equation for solving the optimization problem. In the second case we assume that the states cannot be observed and feedback control is not an option. The decision maker hast to search for an open-loop solution. In both cases, the special form of the dynamic violates standard assumptions at the boundaries. We show existence and uniqueness of solutions in this setup and derive suitable optimality conditions. Moreover we analyze the effect of information in a numerical example.

8. Product & Process Innovation 11:00 –12:30

***Chair*: A.J. Novak** **Sky Lounge**

An Analytical Model of the Relationship Between Product Quality and Advertising

Regis Chenavaz (1), Sajjad Jasimuddin (1),

(1) Kedge Business School, Aix-Marseille School of Economics, CNRS & EHESS Domaine de Luminy, Marseille, France

The existing literature debates if the products of better quality are heavily advertised. This article resolves this contradiction by answering the question of when better quality leads to more advertising in a dynamic context. It provides a novel articulation of prior empirical research, modeling the advertising-quality relationship in an optimal control setting. On the supply-side, a firm carries out advertising to inform about a product and product innovation policies that improves product quality. On the demand-side, consumers are sensitive to product price, product quality, and advertising expenditure. The paper identifies the conditions that will dictate when the advertising-quality relationship will be positive or negative. The argument is that advertising increases with quality (i.e., positive relationships) if the demand effects (quality and advertising effects on demand) outweigh the supply effect (quality effect on cost). Alternatively, advertising decreases with quality (i.e., negative relationships) if the demand effects are lower than the supply effect. Consequently, despite consumer awareness of quality, a firm may advertise a product of lower quality more to maximize profit.

Managing Process Innovation for Remanufacturing in a Closed-loop Supply Chain

Marc Reimann (1), Yu Xiong (1), Yu Zhou (1),

(1) University of Graz, Graz, Austria (2) Newcastle Business School, Northumbria University, Newcastle, United Kingdom (3) Chongqing University, Chongqing, China

Remanufacturing is an opportunity to deliver all-round sustainability benefits when products are designed accordingly. In this paper, we focus on the link between remanufacturing and the opportunity to lower the unit remanufacturing cost via process innovation. Specifically, we analyze how this opportunity is utilized in a supply chain consisting of a supplier and a manufacturer. Only the supplier may undertake process innovation, while the remanufacturing as such could be done by either the supplier or the manufacturer. Our analytical results characterise the relationship between the optimal process innovation level and the optimal remanufacturing strategy. It turns out that the manufacturer may remanufacture used units even if the supplier makes no investment in process innovation. We also find that while the traditional manufacturing process accepts incremental improvement, remanufacturing in general requires radical innovation. Further, inefficiency resulting from the decentralisation of decisions in the closed-loop supply chain may cause overinvestment in process innovation for remanufacturing. Through our numerical analysis we find that this overinvestment always reduces the environmental impact in terms of virgin material consumption, even if the innovation does not have a per-unit impact on virgin material usage. Finally, our numerical analysis shows that supplier remanufacturing could be a dominant strategy from the perspective of the manufacturer.

On the Monotonicity of the State Trajectories in Autonomous Control Models

Andrea Seidl (1), Jonathan P. Caulkins (2), Gustav Feichtinger (3), Dieter Grass (3), Richard F. Hartl (1), Peter M. Kort (4),

(1) Department of Business Administration, University of Vienna, Vienna, Austria (2) Carnegie Mellon University, Pittsburgh, USA (3) Institute of Statistics and Mathematical Methods in Economics, Vienna University of Technology, Vienna, Austria (4) Tilburg University, Tilburg, The Netherlands

In Hartl (1987) it is shown that for autonomous control problems the state trajectory must always be monotonic. The present talk analyzes the importance of the proof and the underlying ideas for history-dependent solutions and multi-stage models. We discuss assumptions and restrictions in models with regime switching that allow solution paths to be non-monotonic. We analyze what happens if we omit these restrictions.

9. Plenary — 13:45 –14:45

***Chair*: K. Doerner** — **Sky Lounge**

Dynamic Vehicle Routing: State-of-the-Art and Some Research Perspectives

Michel Gendreau (1),

(1) MAGI and CIRRELT, Ecole Polytechnique de Montreal, Montreal, Canada

The term "Dynamic Vehicle Routing Problems" (DVRP) refers to the large class of vehicle routing problems in which problem data is not completely available when the solution process is initiated and where solution determination (i.e., computation) and solution execution by the vehicles are (at least, partially) concurrent. This class of problems covers, in particular, routing problems in which customer demands arrive over a long period of time during which the vehicles are already under way to serve some requests. A typical example of this situation occurs in the area of express courier services.

While classical, static Vehicle Routing Problems have now been studied for more than 55 years, the interest for DVRPs started in the late 1970's and has been steadily growing since then, largely due to the emergence of technological innovations, such as cellular phones, on-board computers, global positioning systems, etc. This has led to the development of various models and solution approaches that are able to solve effectively dynamic problems in a large variety of settings.

In this talk, we will first review the main concepts relevant to the definition, analysis, and solution of DVRP's. Among other things, we will explain the differences and similarities between DVRP's and Stochastic Vehicle Routing Problems. We will then survey the most important application areas and the main solution methods that have been proposed for DVRPs. The last part of the talk will be devoted to a discussion of the research avenues that the recent developments in Big Data technologies are opening.

10. Vehicle Routing 1 — 14:45 –15:45

***Chair*: J.-J. Salazar-Gonzales** — **Sky Lounge**

Anticipation in Dynamic Vehicle Routing

Dirk C. Mattfeld (1),

(1) TU Braunschweig, Braunschweig, Germany

Vehicle routing has received a tremendous attention in recent years. This attention is driven by todays customer expectations with respect to fast and reliable service. The more operational details are incorporated in the problem formulation, the less likely all these details will persist in the implementation of a static optimization. Therefore a dynamic and stochastic problem formulation suggests itself. Typical sources of uncertainty in vehicle routing are stochastic customer requests, stochastic demand of customers as well as stochastic service- and travel times. All these figures may change over time while vehicles are already on the road. Thus, operational planning has to either incorporate possible stochastic changes before the implementation of a plan or subsequent decisions have to be taken while vehicles actually operate. Today's sensor and communication techniques deliver real time mass data for subsequent decision making. Deferring decisions to the latest possible point in time comes along with the highest possible gain of information, but may lose out on advantages to be achieved by taking the right decisions early. Anticipation of future system states can be seen as a key feature for a successful treatment of dynamic stochastic vehicle routing problems. The Markov decision process is a suitable instrument for modeling state spaces and transitions within these spaces. Optimization is still present in this modeling approach, but does step back behind the view of state transitions forming trajectories from the known initial state to possible finite states. The stochastic simulation of trajectories produces objective function values for possible future states. These values can be learnt offline and can support online decision making.
While already in operation, one may take decisions by relying solely on the offline information provided. Additionally, one may perform short online look-ahead simulations in order to adjust as elaborately as possible to the actual situation faced. Online look-ahead suffers from the relatively small number of simulations to be carried out at the time when a decision is demanded. Thus, offline as well as online approaches have their virtues. Offline approaches are restricted to a coarse grained state representation but depict the global decision space. Online approaches model the actual decision situation is detail but are restricted to a narrow scope of possible future outcomes. This contribution pioneers an integration of offline and online approximate dynamic programming techniques for a vehicle routing problem with stochastic customer requests.

A Multi-Compartment Vehicle Routing Problem with Loading and Unloading Costs

Alexander Hübner (1), Manuel Ostermeier (1), Heinrich Kuhn (1),

(1) Catholic University Eichstätt-Ingolstadt

In this presentation, a capacitated vehicle routing problem (VRP) is discussed that occurs in the context of grocery distribution. Different temperature-specific product segments (e.g., frozen, ambient) are transported from a retail warehouse to outlets. The different product segments can be transported together when multi-compartment vehicles are used. These trucks are technically able to have different

temperature zones on the same truck by separating the capacity of a vehicle flexibly into a limited number of compartments. The number of compartments and joint delivery of product segments impact loading, transportation and unloading costs.
For this problem, a model formulation that integrates loading and unloading costs into the VRP, as well as, a large neighborhood search algorithm for its solution are presented. It is tested using a case study with a retailer, benchmark data and simulated data. Results are also compared to existing approaches. In line with the performed analyses for the model presented, it is shown that the differentiation between divergent loading and unloading cost factors and the introduction of multi-compartment vehicles yield a significant savings potential for retailers. Integration of loading and unloading costs also changes the tours.

11. Production & Operations Management & Games 16:15 –17:45

Chair: C. Stummer **Sky Lounge**

Heuristic approach for the split-demand one-commodity pickup-and-delivery travelling salesman problem

Hipolito Hernandez-Perez (1), Juan-Jose Salazar-Gonzales (1), Beatriz Santos-Hernandez (1),

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This article addresses the problem of designing routes of minimum cost for a capacitated vehicle moving a commodity between a set of customers, allowing two characteristics uncommon in the pickup-and delivery literature. One characteristic is that a customer is allowed to be visited several times. The other characteristic is that a customer may be used as intermediate location to temporarily collect and deliver product. The article describes a math-heuristic approach that iteratively applies an initial phase and a refinement phase. The initial phase represents each customer by a set of nodes – each one associated with a potential visit –, decomposes each customer demand into partial demands associated with its nodes, and solves a one-commodity pickup-and-delivery travelling salesman problem with a variable neighbourhood search. The refinement phase is a branch-and-cut procedure to optimize some partial routes of a given solution. Exhaustive computational results on benchmark instances demonstrate the good performance of the approaches when solving instances with up to 500 customers.

A Mathematical Method, Model and Software for Optimal Construction of Telemedicine Networks' Structures in Medical Institutions

Gagik Kirakossian (1), Arthur Ghulyan (1), R. Kirakossian (1),

(1) State Engineering University of Armenia, Armenia

Complex and effective problem solving of integration of medical institutions' telemedicine networks with different structures is feasible taking into account communication means and economic factors like financial investments and proposed health services. A two-step dynamic mathematical model for optimal construction of telemedicine networks is developed which on first step identifies means of communication, the size of investment and the list of services of medical institutions' integrated telemedicine network and during the second step the optimal configuration is suggested. The model is developed based on separable

programming approach and the software solution is constructed based on cloud technologies and tested using the diabetes' telemedicine networks.

Direct algorithms for the fair division of indivisible items - An exhaustive computational study

D. Marc Kilgour (1), Rudolf Vetschera (1),

(1) Wilfrid Laurier University, Canada (2) University of Vienna, Austria

We consider procedures for fairly dividing a set of indivisible items between two players (identified as One and Two), who have individual and possibly different rankings of the items. Because of the difficulty of ascertaining individuals' utilities, and to avoid interpersonal comparisons, such problems are frequently analyzed using only ordinal information about the players' preferences. To do so requires algorithms that propose a fair allocation of items based only on the individual rankings, rather than the players' cardinal utilities for the items. Recently, several new algorithms have been proposed for this purpose. In the AL algorithm (Brams et al., 2014), some items are placed in a "contested pile" to be allocated subsequently, outside the main algorithm. Vetschera et al. (2013,2014) propose some analysis of the AL algorithm and its variants. In contrast, the new algorithms allocate all items directly, in one pass over the preference rankings of players. In this paper, we focus on three algorithms, the SA algorithm (Brams et al., 2015) and the SD and ISD algorithms (Brams et al., 2016). All of these algorithms share with AL the property of balance they assign equal numbers of items to the two players (and assume that the total number of items to be allocated is even). An important difference between the SA algorithm and the SD and ISD algorithms is the way in which they deal with the envy-freeness of allocations. An allocation is envy-free if it can be guaranteed (using only ordinal rankings, and thus for any possible assignment of cardinal utilities) that neither player will prefer the subset of items allocated to the opponent to her or his own subset. Thus, if an allocation is not envy-free, at least one player envies her or his opponent. Unfortunately, envy-free allocations do not exist for all possible profiles, or pairs of rankings of the items. SD and ISD algorithm generate only envy-free allocations; if no such allocation exists, the algorithm stops. In contrast, if there are no envy-free allocations, SA generates complete allocations that are not envy-free. To allow for a broader comparison, we also study extensions of SD and ISD that produce complete allocations if it happens that no envy-free allocations exist.

One question addressed in our computational study is how frequently this situation occurs. As well, we ask whether envy-free allocations generated by SA are the same as those generated by the other algorithms. Another possible property of allocations is the maximin property. An allocation is maximin if the rank of the least preferred item received by either player is as high (desirable) as possible. For example, an allocation is not maximin if it allocates to some player her seventh choice item and if there exists some other allocation in which every item received by both players is no worse than sixth-choice. SD and ISD produce only maximin allocations, while allocations generated by SA do not neces-sarily have this property. Another research question is how often the non-maximin allocations generated by SA also fail to be envy-free. Additionally, we consider the robustness of algorithms with respect to strategic play. We analyze whether sincere play (i.e., providing one's true ranking of items) constitutes a Nash equilibrium, and how often either one player, or both, has an incentive to provide a distorted ranking as input to the algorithm. Analyzing this property raises two conceptual problems: If only ordinal information on preferences is considered, it is in many cases not possible to compare an allocation with another that might be obtained via strategic reporting, which might lead to over-estimation of robustness against strategic manipulation.

To overcome this problem, we consider one allocation to be preferred to another if it leads to a higher Borda score for a player. A second issue is that the algorithms do not necessarily produce a unique allocation. All algorithms branch for some preference profiles, producing multiple allocations. We therefore consider as relevant all allocations that might be obtained with an algorithm for a given preference profile, and consider both dominance and expected Borda score as criteria for their comparison. It is clear that the application of Borda comparisons makes it more likely that strategic play will lead to an improvement for a player. We study the extent of incentives for strategic play in both settings. Our main research tool is an exhaustive computational study, in which we analyze all possible pairs of preference profiles of 4, 6, 8, and 10 items. (There are 10! = 3,628,800 preference profiles for 10 items). This comprehensive simulation also al-lows us to study the impact of problem characteristics on the properties of alloca-tions. One particularly interesting property that we uncover is symmetry: A pair of profiles is symmetric if whenever there is an item ranked ith by One and jth by Two, then there is another item ranked ith by Two and jth by One. In symmetric problems, each player faces an opponent whose preferences differ from the player's own preferences in the same way. Simulation results indicate that the algorithms we study are overall quite efficient in finding the "Needle in the haystack", i.e. allocation which have the desired proper-ties. For problems with 10 items, less than 0.5% of all allocations have the properties of Envy Freeness, Max-Min and Borda Max-Min, and the algorithms find between 75% and 88% of them. Algorithms which explicitly consider envy freeness perform slightly better in this respect. However, for larger problems, they seem to be more vulnerable to strategic play.

Friday, September 16

12. Heuristics — 09:00 – 10:30

***Chair*: M. Gendreau** — **Sky Lounge**

Automated Generation of Construction Heuristics for the Capacitated Lot-Sizing Problem

Christian Almeder (1),

(1) Chair for Supply Chain Management, European University Viadrina Frankfurt (Oder), Germany

The capacitated lot-sizing problem (CLSP) is a core production planning problem allowing to determine production quantities satisfying dynamic deterministic demand for a finite planning horizon under capacity restrictions. The problem is a NP-hard optimization problem and researchers have developed various solution approaches over the last decades. Although simple construction heuristics provide less solution quality than more sophisticated metaheuristics or MIP-based solution approaches, they are attractive for real world applications due to their simplicity and computational speed. In this work we propose to use genetic programming to automate the generation of new construction heuristics which perform better than existing ones. This approach might allow to tackle also more sophisticated lot-sizing problems and in particular providing fast solution methods for stochastic lot-sizing problems.

Automatically generating high-performance heuristics from flexible algorithm frameworks

Thomas Stützle (1),

(1) Universite Libre de Bruxelles, Belgium

The design of algorithms for computationally hard problems is time-consuming and difficult for a number of reasons such as the complexity of such problems, the large number of degrees of freedom in algorithm design and the setting of numerical parameters, and the difficulties of algorithm analysis due to heuristic biases and stochasticity. In recent years, automatic algorithm configuration methods have been developed to effectively search large and diverse parameter spaces; these methods have been shown to be able to identify superior algorithm designs and to find performance improving parameter settings.

In this talk, we will shortly introduce the main rationale for an automatic configuration of algorithms and highlight its advantages. In the main part of the talk we will show how from flexible algorithm frameworks high-performing heuristics can be obtained. In particular, we focus on the automatic design of hybrid stochastic local search algorithms and show that even for problems that have received very high attention in the literature new state-of-the-art algorithms can be obtained automatically, that is, without manual algorithm tuning. We will conclude arguing that automatic algorithm configuration has the potential to transform the way algorithms for difficult problems are designed and developed in the future.

Linear-time Split Algorithm and Applications

Thibaut Vidal (1),

(1) PUC-Rio - Pontifical Catholic University of Rio de Janeiro, Brazil

The Split algorithm is a key ingredient of route-first cluster-second heuristics and modern genetic algorithms for vehicle routing problems. The classic algorithm is assimilated to the search for a shortest path in an acyclic directed graph, and performed in $O(n^2)$, where n is the number of delivery points. This complexity becomes $O(Bn)$ when the number of customers per route is bounded by a constant B. In this presentation, we introduce a very simple and efficient labeling algorithm in $O(n)$ for the same task. We extend the method to deal with a limited fleet and soft capacity constraints, and exploit this enhanced efficiency to deal with side attributes, such as intermediate facilities or recharging stations for electric vehicles.

13. Logistics 11:00 –12:30

***Chair*: T. Wakolbinger** **Sky Lounge**

Log yard logistics

Maria Anna Huka (1), Manfred Gronalt (1),

(1) University of Natural Resources and Life Sciences, Vienna

For a sawmill, a particleboard production, an OSB producer, a fiberboard production site and a biomass plant the log yard is the first step of production. Therefore, optimizing the logistics here is a key essential for these industries. To improve log yard operations various approaches are available.

First, a facility layout problem can be solved, which includes determining the inventory levels, identifying the best place for the material charge, defining fixed driveways, and investigating given boundary conditions such as safety regulations, weather conditions, and geographical specifications.

Second, the log bin assignment can be examined at the log yard. Hence, not only the inventory levels and their transshipping rates are needed information but also the distances within the log yard need to be known. Also, seasonality and supply disruption need to be considered to develop a robust assignment plan.

Last, the vehicle movement on the log yard can be optimized. Given several vehicles with different sized shovels and claws and varying weight capacities the handling times and abilities differ within the fleet. Also, different delivery types, such as truck and train delivery, exist on the log yard. Furthermore, not only loaded runs but also empty runs can be optimized. Solving a shift model for all the vehicles and assigning main duties for each vehicle optimize the man and machine power. We are developing an integrated approach which aims at covering all the above mentioned issues.

We can present several real life applications within this field of study. We optimized the facility layout plan of a combined particleboard and OSB producer with a biomass plant on site using a MIP model and a fiberboard production site, solved the log bin assignment problem of a sawmill with a MIP model and heuristics, and optimized the vehicle movements and shift model for another sawmill with a simulation model.

On optimally placing charging stations in an electric car sharing network

Georg Brandstätter (1), Markus Leitner (1), Ivana Ljubić (2), Mario Ruthmair (1),

(1) Department of Statistics and Operations Research, University of Vienna (2) Information Systems, Decision Sciences and Statistics Department, ESSEC Business School, Paris

In recent years, car sharing has received increasing attention as a flexible, yet affordable mode of transportation within cities. Because of their high efficiency in urban settings, as well as their environmental friendliness, electric vehicles are excellent candidates for use within such systems where customers often rent cars only for short journeys.

However, despite advances in battery technology, the range of electric vehicles is still low when compared to that of conventionally powered vehicles. Moreover, recharging them takes longer than refueling cars with internal combustion engines. Therefore, a network of charging stations must be built within the system's operational area where cars can be parked and recharged between trips. Since constructing these stations is not only costly, but also requires a large amount of public space, the location and size of these stations must be carefully chosen in order to ensure that the system can operate efficiently.

We present several integer linear programming formulations, as well as heuristic methods, for solving the problem of optimally placing charging stations within a car sharing system's operational area and finding their optimal size. Using a set of expected trips as an estimation for customer demand, our objective is to maximize the profit of those trips that can be satisfied by the constructed stations. To improve flexibility, customers can pick up a car at any sufficiently close station, as well as return it to any station near their destination (subject to the availability of a car and free charging slot, respectively). A limit on the number of stations and charging slots that can be built is imposed by a budget constraint.

We also compare the performance of these formulations on a set of benchmark instances, which consists of both artificial instances and ones based on real-world data.

The Golf Tourist Problem

Fabien Tricoire (1), Sophie N. Parragh (1), Margaretha Gansterer (1),

(1) Department of Business Administration, University of Vienna, Vienna, Austria

Tourism and travel with the purpose to do sports is gaining in popularity and the golf tourism market is considered to be one of the largest. Motivated by this phenomenon we model and solve the golf tourist problem which generalizes the orienteering problem with time windows. It aims at providing decision support for the traveling golfer by concurrently optimizing two objective functions: travel cost on the one hand and attractiveness of the generated travel plans on the other hand. Travel costs consist of flight cost, hotel cost, car rental cost, green fees as well as petrol cost for traveling between the selected golf courses. Attractiveness is measured by the total par scores of the visited golf courses. We assume that the traveling golfer provides a selection of regions in Europe that he or she is equally inclined to visit on his or her next trip. A feasible travel plan selects one region, contains only golf courses of this region and starts and ends at the respective airport. We solve the golf tourist problem to optimality by means of a recent bi-objective branch-and-bound algorithm and by means of the ϵ-constraint method. Furthermore, we devise a decomposition approach that solves each regional problem separately and then combines the obtained Pareto sets. The proposed methods are applied to several real world instances with up to nine regions and between 57 and 227 golf courses per region. Our results show that the decomposition approach is significantly more efficient than the holistic approach. They also show that the bi-objective branch-and-bound algorithm performs better than the ϵ-constraint scheme.

14. Plenary 13:45 –14:45

***Chair*: W. Gutjahr** **Sky Lounge**

Vehicle routing problems arising in innovative B2C delivery models

Martin Savelsbergh (1),

(1) H. Milton Stewart School of Industrial & Systems Engineering, Georgia Institute of Technology, Atlanta, USA

E-commerce, especially Business-to-Consumer, is poised to grow significantly in the next few years. As a consequence, innovative delivery models are being explored which give rise to interesting new variants of the vehicle routing problem. We will discuss two of them: the vehicle routing problem with roaming delivery locations (VRPRDL) and the vehicle routing problem with occasional drivers (VRPOD). For the VRPRDL, we present a branch-and-price algorithm that can solve instance of up to 120 customers with up to 5 delivery locations, and for the VRPOD, we present an efficient and effective heuristic for a dynamic variant in which online orders and occasional drivers arrive throughout the planning horizon.

15. Vehicle Routing 2 15:15 –16:45

***Chair*: K. Inderfurth** **Sky Lounge**

Product Assignments to Distribution Centers in Retail Logistics Networks

Heinrich Kuhn (1), Andreas Holzapfel (1), Michael Sternbeck (1),

(1) Catholic University Eichstaett-Ingolstadt, Germany

We examine the problem of assigning SKUs to different types of distribution centers (DC), e.g., central, regional, and local DCs. We present an MIP model that reflects the interdependencies between inbound and outbound transportation, inventory management, picking and instore logistics while minimizing total logistics costs. A novel solution approach is developed and applied to a real life case of a market leading European grocery retail chain operating approx. 1000 stores. In the case study approx. 8000 SKUs sourced from 320 suppliers have to be assigned to three different types of DCs.

Hybrid Electric Fleet Routing with City Center Restrictions

Gerhard Hiermann (1), Richard F. Hartl (2), Jakob Puchinger (1,3,4), Thibaut Vidal (5),

(1) Mobility Department, AIT Austrian Institute of Technology, Vienna, Austria (2) Department of Business Administration, University of Vienna, Austria (3) Laboratoire Genie Industriel, CentraleSupelec, Universite Paris-Saclay, France (4) Institut de Recherche Technologique SystemX, Palaiseau, France (5) PUC-Rio - Pontifical Catholic University of Rio de Janeiro, Brazil

Recent developments in electric powered vehicles and their growing importance in urban mobility lead to an increased interest into specialized vehicle routing optimization for such vehicles. We present a solution method to tackle the combined problem considering Internal Combustion Engine Vehicle (ICEV) and Battery Electric Vehicles (BEV). In addition we consider potential access restrictions to city-centers for certain car-types.

We consider a vehicle routing problem with the following features: demand and time windows at customers, an energy resource for BEVs and different cost metrics based on the engine used to travel between pairs of nodes. Time-window bounds are modelled as hard constraints and waiting times prior to serving customers are not penalized. The energy resource can be replenished using optional recharging stations. As part of the problem, the amount of energy recharged is not fixed. The recharging time is a linear function of the amount of energy replenished. We consider a heterogeneous fleet consisting of ICEVs and BEVs. For each vehicle class, different types with varying acquisition cost, consumption rates, loading capacity and energy capacity are available. The number of vehicles per type is not limited. To tackle this problem we propose an optimization algorithm using a systematic evaluation, where the set of decision variables is separated into different layers: 1) assignment and sequencing, 2) visits of recharging stations, and 3) optimization of charging levels. Solving the layer 1) requires to solve repetitively the other two layers of decisions for several candidate routes, represented as visited to customers. These two additional layers of decisions are solved using labelling and dynamic programming techniques.

We define a city center as an area with limited number of entry and exit points where the use of conventional, fossil fuelled engines is restricted or prohibited. Such areas can be found in various medium and large cities. By restricting the use of fossil fuelled engines, the use of battery electric engines is encouraged, which considerably reduces local pollutant emissions. However, this might lead to increased costs in form of detours or additional vehicles required due to additional, time consuming recharging operations. A large set of computational experiments are currently being performed in order to analyse the competitiveness of the proposed algorithms. In addition, further experiments to study the impact of city center restrictions are conducted. The detailed results and possible implications on future research in the area of electric vehicle routing will be discussed at the workshop.

20 years of vehicle routing in Vienna – The many challenges of the VRP solved by Richard F. Hartl

Karl Doerner (1), Alexander Kiefer (1), David Wolfinger (1),

(1) Department of Business Administration, University of Vienna, Vienna, Austria

The vehicle routing problem was formulated more than 50 years ago and has attracted great attention since then, not least due to its high practical relevance and its computational complexity. Throughout the years, various generalizations and solution techniques were proposed. The purpose of this survey is to describe the developments in this particular field. Starting with a basic model, several generalizations to the classical vehicle routing problem are explained by gradually extending the initial model. A special focus lies on the contributions to this field of study by Richard F. Hartl and his colleagues at the University of Vienna, particularly with regard to developed solution methods.

16. Closing 16:45 – 17:00

Sky Lounge

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