
86th Meeting of the GOR Working Group

Praxis der Mathematischen Optimierung
("Real World Optimization")

The Impact of OR onto Industry and Society

INFORM GmbH, Aachen, April 07 & 08, 2011
(<http://www.inform-software.com/>)

Organization

Josef Kallrath & Alexander Lavrov
GOR AG „Praxis der mathematischen Optimierung“

&

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INFORM GmbH, Aachen

The Impact of OR onto Industry and Society

Operations Research (OR) and especially Mathematical Optimisation is becoming an important differentiator in various industries and society. Because companies offer similar products, have comparable technology and compete on a global scale, high performance business processes are among the last differentiators. As UPS mentioned: "In God we trust, everything else we measure and improve", underpinning the importance of Operations Research and mathematical optimization as an enabler for creating that competitive edge. In these times of economic downturn Operations Research is even more important. It gives guidance to management on where to invest and where to scale down, making the operation more agile.

This meeting will give an overview about the state-of-the-art technologies illustrated by real-world applications. In a series of 12 talks, each approximately 40 minutes, experts from practice, research institutions or software companies, will present selected problems and the corresponding solutions and illustrate what has been achieved during the last 40 years, what have been the key factors for success, and what is the vision for the future. Among the speakers are distinguished individuals who shaped OR and optimization not only in Germany, and we have representatives of those companies who won the GOR company award. Confirmations for their talks have been received from the following speakers:

- Dr. Michael Bussieck (GAMS GmbH, Cologne, Germany)
GAMS - Striving for Innovation and Compatibility
- Dr. Ulrich Dorndorf (INFORM GmbH, Aachen, Germany)
Scheduling automated Triple cross-over Stacking Cranes in a Container Yard
- Dr. Michael Drexler (Johannes Gutenberg University Mainz, Mainz & Fraunhofer Centre for Applied Research on Supply Chain Services SCS, Nürnberg, Germany)
Commercial Vehicle Routing Software -- A Comprehensive Study of the German Market
- Prof. Dr. Martin Grötschel (ZIB, TU Berlin & Matheon, Berlin, Germany)
Mathematics, Operations Research, and Modern Industry
- Dr. Tore Grünert (GTS Systems and Consulting GmbH, Herzogenrath, Germany)
Planning Routes for Pickup and Delivery of Disabled Persons
- Dr. Jörg Herbers (INFORM GmbH, Aachen, Germany)
Iterated Branch-and-Price for Flexible Rostering of Airport Ground Staff
- Dr. Andreas Meyer (INFORM GmbH, Aachen, Germany)
Real-time Decision Making to Prevent Internet Banking Fraud
- Prof. Dr. Marco Lübbecke (Universität Aachen, Germany):
Would the World be different without Branch-and-Price?
- Prof. Dr. Josef Kallrath (BASF SE, Ludwigshafen, Germany)
The Impact of Algebraic Modeling Languages on the Optimization Community – Polyhedral Modeling and Solution Approaches –
- Prof. Dr. Tom Rutherford (ETH Zürich, Zürich, Switzerland)
Roads, Housing Prices and Compensating Wage Differentials in Zurich
- Prof. Dr. Hans-Jürgen Zimmermann (INFORM GmbH, Aachen, Germany):
INFORM: Institute for Operations Research and Management, INFORM GmbH

Eugenie Blass & Josef Kallrath & Alexander Lavrov & Hans-Jürgen Zimmermann

86. Sitzung der GOR Arbeitsgruppe
Praxis der Mathematischen Optimierung

The Impact of OR onto Industry and Society

INFORM GmbH, Aachen, April 07 & 08, 2011

Thursday, April 07 - 2011 : 10:00 – 21:30

- 10:00-10:10 **Opening and Welcome Session** (H.-J. Zimmermann,
J. Kallrath & A. Lavrov)
- 10:10-10:30 **Prof. Dr. Hans-Jürgen Zimmermann** – INFORM GmbH, Aachen
INFORM: Institute for Operations Research and Management, INFORM GmbH
- 10:30-11:20 **Prof. Dr. Martin Grötschel** – ZIB Berlin, Berlin, Germany
Mathematics, Operations Research, and Modern Industry
- 11:20-11:40 ----- Coffee Break -----
- 11:40-12:30 **Dr. Ulrich Dorndorf** – INFORM GmbH, Aachen, Germany
Scheduling automated Triple cross-over Stacking Cranes in a Container Yard
- 12:40-14:00 ----- Lunch Break -----
- 14:00-14:50 **Prof. Dr. Marco Lübbecke** – RWTH Universität Aachen, Aachen
Would the World be different without Branch-and-Price?
- 14:55-15:45 **Dr. Jörg Herbers** – INFORM GmbH, Aachen, Germany
Iterated Branch-and-Price for Flexible Rostering of Airport Ground Staff
- 15:45-16:10 ----- Coffee Break -----
- 16:10-17:00 **Dr. Michael Drexl** – Johannes Gutenberg University Mainz, Mainz &
Fraunhofer Centre for Applied Research on Supply Chain Services SCS,
Nürnberg, Germany
*Commercial Vehicle Routing Software -- A Comprehensive Study of the
German Market*
- 18:00-18:45 **Guided Tour (Domführung) through Aachen Cathedral**
- 19:00-20:00 **City Tour by Bus** (RWTH, Super C, Lousberg, Casino, Frankenberger
Viertel, Westwall) and Bus Transfer to INFORM GmbH
- 20:00-21:30 **Get-Together at INFORM GmbH** – Buffet; Pascalstr. 35
Celebrating the 86th Meeting of our GOR Working Group

Friday, April 08 - 2011 : 09:30 – 16:15

09:30-10:20 **Dr. Andreas Meyer** – INFORM GmbH, Aachen, Germany
Iterated Real-time Decision Making to Prevent Internet Banking Fraud

10:25-11:15 **Prof. Dr. Tom Rutherford** – ETH Zürich, Zürich, Switzerland
Roads, Housing Prices and Compensating Wage Differentials in Zurich

11:15-11:40 ----- Coffee Break -----

11:40-12:30 **Prof. Dr. Josef Kallrath** – BASF SE, Ludwigshafen, Germany
*The Impact of Algebraic Modeling languages onto the Optimization Community
– Polyhedral Modeling and Solution Approaches –*

12:40-14:00 ----- Lunch Break -----

14:00-14:50 **Dr. Michael Bussieck** – GAMS GmbH, Cologne, Germany
GAMS - Striving for Innovation and Compatibility

14:50-15:10 ----- Coffee Break -----

15:10-16:00 **Dr. Tore Grünert** – GTS Systems and Consulting GmbH, Herzogenrath
Planning Routes for Pickup and Delivery of Disabled Persons

16:00-16:15 **Final Discussion – End of the Workshop**

The Speakers

Michael R. Bussieck is a Senior Research Analyst at GAMS Software GmbH. From 1999 to 2004 he worked at the GAMS Development headquarters in Washington DC, USA. He received his Ph.D. from Technical University Braunschweig, Germany.

Ulrich Dorndorf is the Chief Technical Officer of INFORM. Working with INFORM since 1992, he has since been active in a large number of optimisation software projects in logistics, airport operations, and production planning and control. He received his Ph.D. from the Technical University of Darmstadt.

Michael Drexler is with the department Networks at the Fraunhofer Centre for Applied Research on Supply Chain Services SCS in Nuremberg, Germany. He works in the field of applied operational research in logistics and transport and is currently engaged in a project on synchronization in vehicle routing at the Chair of Business Administration, especially Logistics Management, at Johannes Gutenberg University in Mainz.

Martin Grötschel is professor of mathematics at TU Berlin and vice president of the Zuse Institute Berlin. His main areas of research are discrete mathematics, optimization, and operations research with a special focus on the design of practically efficient algorithms for hard combinatorial optimization problems appearing in the real world. He and his research team have cooperated closely and extensively with scientists in other disciplines and practitioners from industry. The application areas include telecommunications, chip design, energy distribution, production planning and control, logistics and public transport. He has received various honors and distinctions.

Tore Grünert is General Manager at GTS Systems and Consulting GmbH, a company specialised in consulting and software for optimisation, logistics and supply chain management. He studied electrical engineering at the Technical University Darmstadt and received a master's and doctorate degree from RWTH Aachen University. In 1999 he co-founded GTS Systems and Consulting GmbH and has been General Manager of the company since 2005.

Jörg Herbers studied computer science at RWTH Aachen. In 2005, he finalized his PhD on airport ground staff scheduling for which he was awarded the PhD award of German Operations Research Society GOR. Working for INFORM since 2000, he has since been active in various projects on optimization of personnel planning, combining process optimization with the application of Operations Research techniques. Since 2008, he has been heading a development team that aims at applying mathematical programming to flexible staff rostering problems.

Josef Kallrath obtained his PhD in astrophysics from Bonn University (Germany) in 1989. He is a professor at the University of (Gainesville, FL, www.astro.ufl.edu/~kallrath), and solves real-world problems in industry using a broad spectrum of methods in scientific computing, from modeling physical systems to supporting decisions processes by mathematical optimization. He has written review articles on the subject, about 70 research papers in astronomy and applied mathematics, and several books on mixed integer optimization, as well as one on eclipsing binary stars.

He leads the Real World Optimization Working Group of the German Operations Research Society. His current research interests are polyhedral modeling and solution approaches to solve large-scale or difficult optimization problems, for instance, by decomposition techniques such as column generation, or hybrid methods.

Marco Lübbecke is a professor and chair of operations research at RWTH Aachen University. Before moving to Aachen in 2010 he was a visiting professor for discrete optimization at TU Darmstadt, and assistant professor for combinatorial optimization and graph algorithms at TU Berlin's institute of mathematics. He is also a member of the DFG research MATHEON in Berlin. He received his Ph.D. in mathematics from TU Braunschweig in 2001, and finished his habilitation in 2007 at TU Berlin. Marco's research interests are in integer programming, combinatorial optimization, and algorithms. A particular focus is on decomposition approaches to large-scale real-world problems. It is not the exception but the rule that his results find their way into industrial practice as well. As can be seen from his publication, refereeing, organizational, and conference activities, he understands his work as truly interdisciplinary between algorithmic discrete mathematics, theoretical computer science, and operations research.

Andreas Meyer studied computer science at Saarland University and Darmstadt University of Technology, Germany. He started his professional career in 1997 as product manager in an IT Security company. Being in charge of the development of software and hardware products to secure internet banking as Director for Research and Development since 2003, he became two years later Vice President for Sales and Marketing with world-wide responsibility. Whilst working as an executive, Darmstadt University of Technology awarded him a PhD in computer science for his thesis in Public Key Cryptography. In 2008 he joined INFORM GmbH as a member of the executive board where he is responsible for INFORM's Risk & Fraud Division.

Thomas F. Rutherford, Ph.D., Stanford University, 1987, is Professor of Energy Economics at the Swiss Federal Institute of Technology in Zurich where is co-director of the Center for Energy Policy and Economics. His research specialty involves the formulation and analysis of large-scale economic equilibrium models. He has made contributions to applied general-equilibrium analysis in which his applied work ranges from an analysis of the effect of trade and economic growth to the economic effects of carbon emissions restrictions in response to global warming.

H.-J. Zimmermann worked 10 years in industry before he accepted a professorship for Operations Research and Production Management at the University of Illinois in Urbana (USA). In 1967 he returned to Germany and became chairman of the department of Operations Research at the RWTH Aachen, where he stayed until his emeritation in 1999.

He founded INFORM in 1969, ELITE (European Laboratory for Intelligent Techniques Engineering) and MIT (Management of Intelligent Techniques GMBH) in 1991. He was president of DGU, Founding President of DGOR, IFSA EURO, and EEMA. He received several honorary doctorates and a number of other international prizes, has published more than 260 articles and 35 books, and is now still active in Inform and MIT.

GAMS - Striving for Innovation and Compatibility

Michael R. Bussieck
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The GAMS system has been around commercially for about 25 years. One of the reasons for its continued success is our dedication to 100% backward compatibility of the core language elements from day one. Many GAMS applications have seen changes in solver technology and have been moved from mainframe, to workstation, to PC and back. On the other hand, backward compatibility can be a restraint for embracing innovations especially when they require adjustments in the GAMS language.

We will explore the interplay of these conflicting objectives by looking at some of our recent projects that make emerging technology available in the GAMS system without compromising our conservative approach to syntax modifications.

Scheduling automated triple cross-over stacking cranes in a container yard

Ulrich Dorndorf

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This talk describes an approach for scheduling triple cross-over rail-mounted stacking cranes in an automated container storage block. Containers are handed over asynchronously at the transfer areas at both block front ends. The problem is characterised by frequent long crane moves that make job assignment and crane routing particularly challenging, as a tight synchronisation between the cranes is required. The main objective is to maximise the productivity of the crane system under peak load while preventing delays in the transport of import and export containers from and to the transfer areas.

The method solves an online optimisation problem by constructing a new crane schedule for a certain planning horizon whenever a new job arrives or a job is completed. Extensive simulation studies for evaluating the scheduling strategy show that the method performs significantly better than commonly used heuristics, leading to a productivity gain of more than 20 percent.

Commercial Vehicle Routing Software— A Comprehensive Study of the German Market

Michael Drexl

Chair of Business Administration, especially Logistics Management

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Vehicle routing is one of the great success stories of Operational Research. There is hardly a field of OR that has had a larger impact in practice. This is reflected by the sheer number of available software packages for solving VRPs. This talk presents the results of an extensive study on commercial vehicle routing software for the German market. In the study, software and consulting companies offering pertinent software using OR methods for automated computation of route plans were asked to fill in a detailed questionnaire. In particular, information on the OR models and algorithms used in the software was gathered.

One objective of the study was to identify which modelling and algorithmic features are required nowadays by logistics practitioners, and which scientific models and algorithms have found their way into practice to which extent. The study compares the state of the art in practice with current scientific work on vehicle routing. Thus, important application areas and practical requirements on vehicle routing models and algorithms could be identified, and logistics practitioners can use the study to learn more about the benefits of modern OR techniques.

Mathematics, Operations Research, and Modern Industry

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This lecture discusses the relationship of mathematics and operations research with modern industry. It describes the contributions of these fields to the industrial creation of value and their key position in the handling of complex systems, in other words, their role as a production factor and amplifier for innovations.

The lecture outlines the mathematics based "application driven approach" to solve industrial problems and illuminates the associated combination of mathematical modeling, simulation, and optimization by means of numerous examples of projects with industry covering a wide range of real applications.

Planning Routes for Pickup and Delivery of Disabled Persons

Tore Grünert

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In Germany there are numerous non-profit companies specialised in the employment of disabled people. Many of these companies have a significant staff size, employing up to more than 500 people. Since most of their employees are not able to go to work on their own, they need help with transportation. In this talk we will describe the problem in detail and discuss the special requirements with respect to timing, capacity requirements and compatibility. These are implemented in the commercial vehicle routing and scheduling system TransIT that is used by several companies for transportation planning.

Iterated Branch-and-Price for Flexible Rostering of Airport Ground Staff

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In recent years, airport ground handling has been one of the forerunner industries in employing flexible planning staff planning methods. Assigning shifts and days off to handling agents is a task that is governed by a multitude of constraints and a diversity of objectives. We present a solution approach that is able to solve a large spectrum of employee rostering problems. We will show how a heuristic branch-and-price scheme is used to allow for scaling between running time and solution quality. The method is able to avoid the tailing-off problem that is often encountered in large-scale branch-and-price programs. Additionally, it allows for incorporating constraints that can be difficult to represent in a resource-constrained shortest path model that is usually used as a basis for the pricing problem. We will present computational results on a number of real-world scenarios that show the effectiveness and efficiency of the approach.

The Impact of Algebraic Modeling languages onto the Optimization Community - Polyolithic Modeling and Solution Approaches -

Josef Kallrath

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AMLs have played and still play an important role in the mathematical optimization community and optimization used in industry. In the 1950ies and 1960 Assembler and Fortran coded LP models were mostly replaced by IBM's matrix generators MPS establishing the standard of industrial model formulations. At that time there was no market for AMLs. But there was no real support for NLP problems. This was the niche for AMLs as they enabled the user to formulate NLP problems, and they supported automatic differentiation, i.e., they symbolically generated the first and second derivative information. After a while, they also became superior in implementing LP models and succeeded MPS. Nowadays, academic research models (developed by scientists) are used to developing and testing solvers, or constructing efficient model reformulations. Domain expert models (developed by analysts) are used within consultancy projects, or feasibility studies. And finally, AMLs often host the models for black box model users doing their operational planning. The AMLs ensure the robustness, stability, and data checks needed in industrially stable software. Furthermore, AMLs accelerate the development and improvement of solvers ranging from Linear Programming to Mixed Integer Nonlinear Programming and even Global Optimization techniques. If a user has an NLP problem implemented in an AML using a local solver to compute its local optimum, it is only a matter of minutes to switch to a global solver such as **BARON** or **LindoGlobal**. Thus, there is a significantly reduced development risk for the user. But also the solver developers can count on a much larger market when their solver is embedded into an AML. The solver technology, in some sense, is now a commodity which allows the users to switch, for instance, from one MILP solver to another one, or play and collect experience with the free Coin-OR solvers. The implementation of polyolithic solution approaches described in Kallrath (2011) discussed in detail in this lecture, is possible without huge development efforts. And last but not least, AMLs reduce the project time, make maintenance easier and increasing the lifetime of optimization software.

Based on the Greek term *monolithos* (stone consisting of one single block) Kallrath (2009) introduced the corresponding term *polyolithic* for modeling and solution approaches in which mixed integer or non-convex nonlinear optimization problems are solved by a tailor-made methods involving several models and/or algorithmic components. A *monolithic model* is just one model with data, a set of variables and a set of constraints and one solve statement calling a solver, e.g., **CPLEX**, **Gurobi**, or **Xpress**. In contrast, a *polyolithic model* contains a set of models which are somehow connected in their data flow of input and output data, i.e., the solution of one model is input to another one. This can be exploited to initialize certain

variables, or to provide bounds on them. Examples of polyolithic models are decomposition approaches, column generation as in Gilmore & Gomory (1961)] and Branch&Price [see, for instance, Barnhart et al. (1998)] or hybrid techniques [see, for instance, Pochet and Wolsey (2006)] in which constructive heuristics and local search improvement methods are coupled with exact MIP algorithms to produce feasible points and tight lower and upper bounds. Thus, we observe that the sub-models of polyolithic models are often connected in such a way that they represent a tailor-made algorithm.

Tailor-made polyolithic solution approaches with thousands or millions of solve statement to be executed put an extreme challenge on algebraic modeling languages. Hot-start techniques avoiding that the whole matrix is re-generated become essential.

In this talk we present illustrative examples from the paper and metals industries, scheduling in the process industry, and planning of hydro-thermal plants in the energy industry. Lexicographic goal programming, a useful approach in multi-criteria planning problems, is another example of a polyolithic modeling.

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Would the World be different without Branch-and-Price?

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Branch-and-price or branch-price-and-cut algorithms build on the fact that a certain problem structure is known and can be algorithmically exploited. It is still an endeavor to implement and tune a full fledged branch-and-price code even though powerful frameworks are available. The question is justified whether the same results could not be achieved with the very powerful “traditional” and mature branch-and-cut approach of every state-of-the-art mixed integer programming solver. In this talk we argue that certain problems, in particular in the realm of transportation and logistics would not have been solved without this technique, and we give a few examples of successful applications. We close with a glimpse of what branch-and-price algorithms may offer for future challenging applications.

Real-time Decision Making to Prevent Internet Banking Fraud

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Banks around the world fear a huge loss of reputation and a reduced customer confidence in their Internet channel through very clever and increasingly successful Internet banking attacks. We present the typical countermeasures of major banks across Europe and analyse why, in some respects, they usually fail. We introduce a new software based approach to that real world challenge: An intelligent real-time decision making tool. We explain the solution architecture and the underlying technology which includes Fuzzy Logic. Furthermore, we show to what other challenges a bank could apply the software to assure investment security. Besides, we will point out that major financial institutions across Europe have recently approved both the new approach and the implementation presented in this talk.

Roads, Housing Prices and Compensating Wage Differentials in Zurich

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Economics can play a role in analyzing the sustainability in urban development patterns. We study the interplay between transportation infrastructure, congestion, and the spatial structure of urban economies. Our model is a spatial equilibrium model of housing and labor markets which takes explicit account of the structure of roadways and equilibrium commuting times. The model embeds a spatially disaggregate Alonso-Muth-Mills economic model of housing and labor markets within a model of individually-rational route choice on the congested traffic network Wardrop (1952). A central assumption is that households choose residence and employment locations which arbitrage differences the subjective appeal of various locations within the urban area. This Consumers trade off locations to work and live on the basis of (i) housing prices, (ii) wages, and (iii) commuting time.

The economic aspects of the model follow the standard assumptions of the Walrasian-Arrow-Debreu paradigm. Consumers earn money by working, and they allocate their income to housing and consumption. The model has a medium-term perspective by modeling equilibrium sorting of households on a metropolitan road network. This modeling framework exploits the complementarity formulation of the Wardropian traffic equilibrium model proposed by Ferris et al. (1998). A multicommodity representation of the traffic network is compact and efficient, as it does not require implicit or explicit enumeration of all paths between origin-destination pairs in the network which can be cleanly integrated with a complementarity model of economic decisions.

In contrast to pure transport models prices and demand for transport, employment and housing are endogenized. The model has two interacting components: a model which describes the routes and traffic flow given where people live and work, and a sorting model which describes where people choose to live and work.

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The "Institute for Operations Research and Management, Inform GmbH" was founded in 1969 with the aim to show the potential of Operations Research by developing and applying OR solutions in practise. In the meantime INFORM has grown to appr. 400 employees and applies OR in six divisions. Materials Management, Logistics in Terminals, Airport Logistics, Production Management, Risk and Fraud (Fuzzy Technology), and Logistics in Industry and Healthcare. Customers of INFORM are all over the world. INFORM has received a number of national and international prizes, amongst them the first "Company Award (Unternehmenspreis)" of GOR.