Gesellschaft für Operations Research e.V.

Joseph-Sommer-Straße 34, 41812 Erkelenz, Tel.: 02431 9026710, Fax: 02431 9026711

93rd Meeting of the GOR Working Group

Praxis der Mathematischen Optimierung
("Real World Optimization")

Mathematical Optimization in Industry

27–28 November, 2014
Physikzentrum, Bad Honnef, Germany
(www.pbh.de)

Organization

Josef Kallrath & Steffen Rebennack
GOR AG „Praxis der mathematischen Optimierung"

Mathematical Optimization in Industry

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 Operation 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 10-12 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.

This two-day event attempts to give an overview of the current state of the art of mathematical optimization techniques applied in industry. It is also an ideal opportunity to learn more about this GOR working group. Please contact Steffen Rebennack (steffen.rebennack@gmail.com) or myself if you are interested in contributing a presentation.

In presentations, each approx. 40 minutes, experts from practice, research institutions or software companies, will present selected problems and their corresponding solutions.

Presentations from the following speakers have been received:

Dr. Torben Barth (Fraport AG, Frankfurt, Germany)
Optimization in Airport Operations at the Example of Baggage Handling

Eckart Boege (Vattenfall Energy Trading GmbH, Hamburg, Germany)
A Benchmark Model for Investigating Real-World Dispatch Optimisation Problems

Dr. Michael Bussieck (GAMS GmbH, Braunschweig, Germany)
The Role and Impact of Algebraic Modeling Languages in and on Industrial Optimization

Dr. Hermann Gold (Infineon Technologies AG, Regensburg, Germany)
Mathematical Optimization in the Semiconductor Industry

Dr. Silke Jütte (University of Cologne, Germany)
Mathematical Optimization of a Crew Scheduling Problem in the Freight Railway Industry

Prof. Dr. Josef Kallrath (Weisenheim am Berg, Germany)
Mathematical Optimization in the Paper and Metals Industry

Uwe Pilgram (Uwe Pilgram ITC Management, Weisenheim, Germany)
Deploying Applications - Success Factor #1 in ICT Management

Prof. Dr. Steffen Rebennack (Colorado School of Mines, Golden, CO, USA)
Mathematical Optimization in the Energy Industry

Dr. Jens Schulz (BASF SE, Ludwigshafen, Germany)
Optimization in the Process Industry

Dr. Ingmar Steinzen (ORCONOMY GmbH, Paderborn,Germany)
Maximizing Yield and Customer Satisfaction in the Flight Simulator Scheduling Problem

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93. Meeting of the GOR Working Group
„Real World Mathematical Optimization“

Mathematical Optimization in Industry

Physikzentrum, Bad Honnef, November 27 & 28, 2014

Thursday, Nov 27 - 2014: 10:30 – 22:00

10:30-10:45 **Opening and Welcome Session** (J. Kallrath & S. Rebennack)

10:45-11:35 **Uwe Pilgram** (Uwe Pilgram ITC Management, Weisenheim, Germany)
Deploying Applications - Success Factor #1 in ICT Management

11:40-12:00 **Dr. Victor Gomer** (Physikzentrum Bad Honnef, Germany)
The History of the Physics Center

12:00-13:30 ---------- Lunch Break ----------

13:30-14:20 **Dr. Torben Barth** (Fraport AG, Frankfurt, Germany)
Optimization in Airport Operations at the Example of Baggage Handling

14:20-15:10 **Dr. Ingmar Steinzen** (ORCONOMY GmbH, Paderborn,Germany)
Maximizing Yield and Customer Satisfaction in the Flight Simulator Scheduling Problem

15:15-15:45 ---------- Coffee Break ----------

15:45-17:15 ----- Visit & Guided Tour: Stiftung Bundeskanzler-Adenauer-Haus --------

17:15-18:05 **Prof. Dr. Josef Kallrath** (GOR Arbeitsgruppe, Weisenheim am Berg)
Mathematical Optimization in the Paper and Metals Industry

18:10-18:20 **Internal Meeting** of the Working Group

18:30 - **Conference Dinner** – Buffet; get-together in the wine-cellar
Celebrating the 93rd meeting of our GOR Working Group

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Friday, Nov 28 - 2013: 09:30 – 16:30

09:30-10:20 **Dr. Michael Bussieck** (GAMS GmbH, Braunschweig, Germany)
The Role and Impact of Algebraic Modeling Languages in and on Industrial Optimization

10:20-10:50 ---------- Coffee Break ----------

10:50-11:40 **Dr. Silke Jütte** (University of Cologne, Germany)
Mathematical Optimization of a Crew Scheduling Problem in the Freight Railway Industry

11:40-12:30 **Dr. Jens Schulz** (BASF SE, Ludwigshafen, Germany)
Optimization in the Process Industry

12:30-13:45 ---------- Lunch Break ----------

13:45-14:30 **Eckart Boege** (Vattenfall Energy Trading GmbH, Hamburg, Germany)
A Benchmark Model for Investigating Real-World Dispatch Optimization Problems

14:30-15:00 ---------- Coffee Break ----------

15:00-15:40 **Prof. Dr. Steffen Rebennack** (Colorado School of Mines, USA)
Mathematical Optimization in the Energy Industry

15:40-16:30 **Dr. Hermann Gold** (Infineon Technologies AG, Regensburg, Germany)
Mathematical Optimization in the Semiconductor Industry

16:30 **Final Discussion – End of the Workshop – Coffee Break**

The Speakers

Torben Barth is an internal Senior Consultant at Fraport. He is responsible for the development of optimization solutions and quantitative analyses at Frankfurt Airport. The main focus of his work is on the field of decision support solutions in baggage handling. He obtained his Ph.D. at the Management Engineering department of the Technical University of Denmark (DTU) in 2014.

Eckart Boege studied mathematics at Friedrich-Schiller-University Jena. His diploma thesis considered the lot-sizing problem taking into account transportation costs (supervisor Prof. Dr. Armin Scholl, chair of management science, University of Jena).

He started his professional career at a management consultancy in Düsseldorf. Joining Vattenfall in 2009, Eckart Boege initially worked in the field of power/gas logistics and reserve management. After an assignment as Forecasting Analyst in Amsterdam, he moved to the Analysis department of Vattenfall Asset Optimisation and Trading, where he now heads the Operations Research group.

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.

Hermann Gold is a Senior Staff Engineer at Infineon Technologies AG, where he is working on planning and scheduling problems in semiconductor manufacturing. He studied computer science at the University of Erlangen and received a doctorate degree from the Faculty of Mathematics at the University of Würzburg. His special research interest is in the combination of queueing theory and optimization.

Silke Jütte is a research analyst at the department of Supply Chain Management and Management Science at the University of Cologne, where she obtained her Ph.D. in 2012. During her time in Cologne, she has been in charge of a multiannual research project designing crew schedules for the railway industry. Prior to working in Cologne, she has been a process engineer at Deutsche Post Consult GmbH in Bonn.

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 polylithic modeling and solution approaches to solve large-scale or difficult optimization problems, for instance, by decomposition techniques such as column generation, or hybrid methods.

Uwe Pilgram Ausbildung: Jahrgang 1942. Studium der Volkswirtschaftslehre Uni Tübingen – Schwerpunktewaren Wirtschaftsstatistik, Ökonometrie, Produktionswirtschaft. Berufliches: Projekte zur Entwicklung von System-Software und Anwendungssoftware, Leitung von Entwicklungs- und Rechenzentren, Produktmarketing fr Serviceprodukte, Strategische Neuausrichtung und Businessreengineering von ICT Organisationen, Forschung zum Thema "Industrialized Management of Services" mit der Universitt St. Gallen.

Steffen Rebennack is Assistant Professor at the Colorado School of Mines, USA. He obtained his PhD at the University of Florida. His research interests are in dimension-reduction techniques for large-scale optimization problems, particularly with applications in power systems, stochastic optimization and global optimization. He is the vice-president of the Real World Optimization Working Group of the German Operations Research Society.

Jens Schulz obtained his PhD in mathematics at TU Berlin (Germany) in 2012 and is now working as mathematician in the group of Operations Research at BASF SE. At BASF, he is solving large-scale real-world problems using a broad spectrum of scientific methods from statistics to mathematical optimization. His interests in applied mathematics range from production scheduling over tactical supply, production and demand network optimization to strategic distribution network design problems.

Ingmar Steinzen is Managing Director at ORCONOMY GmbH – an innovative solution provider for high-quality custom application using optimization. Prior to joining ORCONOMY, Dr. Steinzen worked as Analytic Specialist for McKinsey & Company. He received his PhD in Operations Research from Paderborn University, Germany. His main fields of expertise include supply chain optimization, scheduling, production planning and vehicle routing.

Optimization in Airport Operations at the Example of Baggage Handling

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The presentation will provide an overview of the different optimization problems in airport operations. The state of the art in research and industry will be discussed for the different problems.

At the example of baggage handling at Frankfurt Airport specific solution approaches will be presented. The talk gives an introduction into the baggage handling processes and the related optimization problems. Fraport invested in decision support solutions for the different baggage handling processes in the last years. This work helped to improve decision making and supported the dispatcher significantly.

The internal OR team was started in 2007 as part of the IT department. The main task is to support all business areas from Fraport. The support covers among others the development of optimization solutions for operational problem, quantitative analyses and the support of the introduction of external IT solutions in the field of decision support.

A Benchmark Model for Investigating Real-World Dispatch Optimisation Problems

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As market conditions for energy utilities have become tough, top-class dispatch optimisation has become even more important. However, especially in complex asset portfolios and diverse markets the added value of different optimization strategies and methodologies is far from obvious. Thorough investigations are needed to identify and assess actual improvement potential. Results from scientific research can be a starting point, but their significance for real asset portfolios is rather limited. Mostly they are based on small and overs-simplified models.

In the Analysis department of Vattenfall Asset Optimisation and Trading (AOT) we therefore developed a dispatch optimisation benchmark model for our in-house research efforts. This model is designed to reflect the core properties of a complex asset portfolio while being as simple as possible to facilitate traceability of results and reasonable calculation times. Investigations based on this model have already led to the implementation of new methodologies in our dispatch planning and confirmed business cases for major changes in our actual dispatch optimisation model.

The Role of Algebraic Modeling Languages in Industrial Optimization

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Algebraic Modeling Languages (AML) are one of the success stories in Operations Research. GAMS is one of the prominent AMLs and in this talk we show fundamental principles, recent and ongoing developments, and our view of the future of AMLs. We will review some application examples done by our clients in academia and industry, in which optimization is an important element. These projects give an insight into the complexity of tasks and the variety of environments in developing and deploying optimization applications. The seamless integration for optimization applications into existing environments is essential for industrial applications. In our examples we will also review the impact on the application and sometime the entire organization when optimization comes into the picture.

Optimal Resource Allocation in Semiconductor Manufacturing

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In this talk we discuss the optimal resource allocation in semiconductor manufacturing. Ideas arising from classical activity analysis are applied in stochastic processing networks as they appear in semiconductor manufacturing. They are elaborated with respect to their meaning in questions of planning and operating a fab. It is shown how optimization goals can be adapted to satisfy the specific requirements of applications in planning and automatic control in the context of machine resource pools with dedicated and descretionary traffic. In particular the worthiness of John Rawls' difference principle applied at the level of enterprise planning and the issues to be dealed with when conveying this idealistic approach to actual manufacturing are explained. Related solution approaches are presented.

Mathematical Optimization of a Crew Scheduling Problem in the Freight Railway Industry

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The freight railway crew scheduling problem consists of generating crew duties to operate trains of a weekly schedule at minimal cost, while meeting all work regulations and operational requirements. Typically, a freight railway operation uses thousands of trains and requires thousands of crew members to be assigned to these trains. Due to the large size of the problem, even moderate percentage savings in crew cost translate into large monetary savings. However, freight railway operations are complex, and the crew scheduling problem is large and difficult to solve.

We describe the development and successful implementation of a crew scheduling software at DB Schenker, the largest European railway freight carrier. The software is based on a column generation solution technique. Computational results demonstrate that high quality solutions can be obtained at reasonable runtimes even for large problem instances.

Mathematical Optimization in the Paper and Metals Industry

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The pulp and paper industry plays an important role worldwide. There are in the order of 3000 paper mills, which produced a total of 394 million tons of paper and paperboard, in 2010. Europe (including Russia) has approximately 900 paper mills, while Germany has about 180. The largest producer in the world is the Finnish UPM group with an annual tonnage of 12.7 million tonnes, followed by Stora Enso with 11.8 million tons and by International Paper with 9.7 million tonnes per year. In Portugal the pulp and paper industry contributes over 4% of the GDP and 5% of the active employees. As it is subject of both local and global environmental discussions, effective planning and cutting stock techniques lies at the very heart of the operational performance of its manufacturing organizations.

Exact solution approaches and heuristics have been used for decades to support cutting stock decisions in the paper industry. In the standard cutting stock problem, the input data consist of a set of item sizes and demands, and of a set of master rolls of given widths; the simplest case consists of only one type of master rolls. The task is to decide on how many master rolls are cut to a certain pattern in order to minimize the total number of master rolls used.

We present various examples related to 1D-role or 2D-format production solved by exact methods such as column generation or wider polylithic modeling and solution approaches.

As an example from the metals industry we present the following example. A set of circles, rectangles, and convex polygons are to be cut from rectangular design plates to be produced or from a set of stocked rectangles of known geometric dimensions. The objective is to minimize the area of the design rectangles subject to lower and upper bounds of their widths and lengths. The objects are free of any orientation restrictions.

If all nested objects fit into one design or stocked plate the problem is formulated and solved as a nonconvex nonlinear programming problem. If the number of objects cannot be cut from one plate, additional integer variables are needed to represent the allocation problem leading to a nonconvex mixed integer nonlinear optimization problem.

As an extention of this problem, we present the case in which we cut a set of given ellipses from minimal area rectangles.

Keywords: Global Optimization, mixed integer programming, cutting stock, packing, shape constraints, non-overlap constraints, design problem, assignment

Deploying Applications - Success Factor #1 in ICT Management

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The acceptance of ICT by users mainly depends generating benefit at user's business processes. Unfortunately this benefit is earned when the application is used in day by day tasks of the business people. This long after development has delivered the new application and IT Operations has deployed it on the infrastructure. The users often stays orphaned and untrained and has to run long and cumbersome learning curves. The role of the user and his needs and responsibilities when using the application to raise the planned benefit is often underestimated or even ignored. With this presentation we try to show some aspects which should be taken care of when deploying complex applications. Especially applications which contain elaborated optimization algorithms like LP/NLP need carefully prepared deployment and well trained users for successful employment.

Mathematical Optimization in the Energy Industry

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The energy sector is very rich on challenging optimization problems. In this talk, we classify these power systems optimization problems into three categories.

One category is the time frame of the optimization model, spanning from minute-to-minute optimization problems to expansion planning problems with an optimization horizon of several decades. Latest developments on power plant operation and renewable generation impose a power system characteristics which demand a very fine granularity, leading to multi-scale models.

A second category is the optimization class. Linear programming and mixed-integer linear programming are widely used, but the most challenging practical problems are highly non-convex optimization problems. Examples are transportation problems in gas or electricity networks. These non-convexities are imposed by physical laws and cannot be easily ignored. In addition, these problems tend to be of very large-scale. Current off-the-shelf global optimization solvers can only solve toy problems, several orders of magnitude smaller than practical problems.

The third category concerns the uncertainty of input data. Many important practical optimization problems in the energy industry are challenged by significant uncertainties in the data, *e.g.*, due to renewable generation or uncertain rainfall, demand, gas or emission prices. There are many unsolved problems in this category as well.

Optimization in the Process Industry

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BASF's success is to operate in a Verbund system which is all about intelligent interlinking of production plants, energy flows and infrastructure. By the Verbund system efficient value chains are created that extend from basic chemicals right through to high-value-added products such as coatings and crop protection agents. In addition, the by-products of one plant can be used as the starting materials of another. In this system, chemical processes consume less energy, produce higher product yields and conserve resources. Hence, savings due to synergies on raw materials and energy, and cutting of logistics costs can be accomplished. The size and interdependencies within these networks result in challenging optimization problems.

Success stories from the BASF internal OR group will be presented where the power of mathematical solutions has been proven within BASF. In Integrated Site planning, feed selection, plant operation, make-or-buy decisions, transfers and exports for maximum profit are to be optimized. For sales-and-operations planning, decision support tools enable the planners to optimally balance raw material procurement, production schedules and stock levels to service customers at minimum cost while ensuring their service requirements. Optimization of global value-chains creates transparency on volume and costs in case of upcoming shortages, and allows the optimization of product portfolio mix and margin development. Measurable results of tailored mathematical solutions are shown on topics like cost savings, increased output rate, shortened development or production time, improved utilization of production facilities, increasing processes efficiency, and increased profit.

Maximizing yield and customer satisfaction in the flight simulator scheduling problem

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In this talk, we discuss the flight simulator scheduling problem. The challenge is to find a set of trainings that satisfy demand, complex training restrictions and remaining cockpit simulator capacities. The objectives are to maximize yield and as well customer satisfaction. Training restrictions comprise hard and soft constraints. Soft constraints represent customer preferences that are met whenever commercially reasonable. We propose a column generation approach that solves real-world scheduling problems within several minutes. In co-operation with Lufthansa Flight Training we developed a seamlessly integrated IT-solution. An advanced user interface in combination with a powerful optimization core ensures the quality and acceptance of the solution.