GOR

Gesellschaft für Operations Research e.V.

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

94th Meeting of the GOR Working Group

Praxis der Mathematischen Optimierung
(“Real World Optimization”)

Mathematical Optimization in the Process Industry

16–17 April, 2015
BASF SE, Ludwigshafen, Germany
(www.basf.com)

Organization

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

&

Anna Schreieck & Jens Schulz
BASF SE, Ludwigshafen, Germany

Mathematical Optimization in the Process Industry

BASF is the world's leading chemical company with more than 112,000 employees, six Verbund sites and 376 additional production sites worldwide we serve customers and partners in almost all countries of the world. In 2013, BASF posted sales of €74.0 billion and income before special items of approximately €7.2 billion. We combine economic success with environmental protection and social responsibility. Through research and innovation, we support our customers in nearly every industry in meeting the current and future needs of society.

The Verbund-system is all about intelligent interlinking of production plants, energy flows and infrastructure. The Verbund system creates efficient value chains 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. In that manner, we save on raw materials and energy, minimize emissions, cut logistics costs and exploit synergies. These solutions enable BASF to sustain competitiveness in every world region while making our customers more successful.

Optimization of such complex Verbund networks with many non-linearities is a big challenge.

The focus areas, where mathematical optimization already created benefits, range from production scheduling over supply, demand and distribution planning, inventory management to strategic network design. A big challenge in these areas is to handle uncertainties arising from demand forecasts, impacts of an economic crisis as well as from challenging raw material prices.

This two-days event will attempt to give an overview of the current state of the art of mathematical optimization in the process industry.

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94th Meeting of the GOR Working Group
„Real World Mathematical Optimization“

Mathematical Optimization in the Process Industry

BASF SE, Ludwigshafen, April 16 & 17, 2015

Thursday, April 16 - 2015: 09:30 – 21:00

09:30-09:45 **Opening and Welcome** (J. Kallrath & S. Rebennack, A. Schreieck & J. Schulz)

09:45-10:15 **Dr. Uwe Liebelt** (President, BASF SE, Germany)
Greetings, Welcome and Overview on BASF in Industry 4.0

10:15-11:00 **Prof. Dr. Christodoulos Floudas** (Texas A&M University, USA)
Framework for Mathematical Modeling and Global Optimization of Entire Petrochemical Planning Operations

11:00-11:15 ----------------------------- Coffee Break --------------------------------

11:15-12:00 **Dr. Hans Schlenker** (IBM Software Group, Germany)
Supply Chain Optimization under Uncertainty

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

13:00-13:45 **Prof. Dr. Stefan Minner** (TU München, Germany)
Integrated dynamic production and safety stock planning in the process industry

13:45-14:30 **Prof. Dr. Rolf Möhring** (TU Berlin, Germany)
Coping with Uncertainty in Project Scheduling: New Developments and Applications

14:30-14:45 ----------------------------- Coffee Break -------------------------------

14:45-15:30 **Prof. Dr. Stratos Pistikopoulos (**Imperial College London, UK, and Texas A&M, USA)
Model based Optimization & Optimal Control

15:45-16:15 ----- Going to Limburger Hof ----------

16:15-17:45 **Visit & Guided Tour:**
Excursion to the Agricultural Center Limburgerhof

18:00 - **Conference Dinner** at “Rehhütte, Limburger Hof”
Celebrating the 94th meeting of our GOR Working Group
----- Taking a Group Photograph for the Press -------

Friday, April 17 - 2014: 09:30 – 16:00

09:30-09:45 Welcomes to second day

09:45-10:30 **Prof. Dr. Moritz Fleischmann** (University of Mannheim, Germany)
Selling over an Uncertain Season: Scale and Timing of Inventory Availability

10:30-11:15 ~~**Ulrich Reincke** (SAS Institute, Germany~~) LATE CANCELLATION
~~*Timing Is Money: Getting the Drug Launch Sequence Right*~~

11:15-11:30 ------------------------------ Coffee Break ---------------------------------

11:30-12:15 **Dr. David Francas (**Camelot Management Consultants, Germany)
Global network design in process industries

12:15-13:30 ------------------------------ Lunch Break ----------------------------------

13:30-14:15 **Dr. Subanatarajan Subbiah** (ABB AG, Germany)
Power Optimization for Heating Processes

14:15-15:00 **Hubert Hadera** (ABB AG, Germany)
Electricity Demand-Side Management in Process Industries: how to bring together production scheduling and energy-cost optimization

15:00-15:15 ------------------------------ Coffee Break ---------------------------------

15:15-16:00 **Prof. Dr. Josef Kallrath** (BASF SE, Germany)
Mathematical Optimization at BASF – A Quarter Century and more …

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

Hints on the Location:

April 16, 2015: Lectures take place in Building B009 near gate 7: Lecture Hall in 3rd floor.
April 17, 2015: Lectures take place in Building F103 near gate 2: “Visitor Center”

The Speakers

Moritz Fleischmann is Professor of Logistics and Supply Chain Management at the University of Mannheim. He is also the Academic Director of the Essec-Mannheim Modular EMBA Program at Mannheim Business School. His research and teaching interests encompass various topics in the field of supply chain management. Current focal points include inventory management, service differentiation and revenue management, multi-channel distribution, in particular e-fulfillment, and closed-loop and sustainable supply chains. In these fields, Moritz has been working with companies such as BASF, IBM, Heineken, and Albert Heijn. His work has been published in leading international academic journals, including Production and Operations Management, Transportation Science, European Journal of Operational Research, and OR Spectrum. Moritz holds a PhD in General Management from Erasmus University Rotterdam, The Netherlands (2000) and a Masters degree in Business Mathematics from the University of Ulm, Germany (1996). Prior to joining the Mannheim faculty, he was an Associate Professor of Supply Chain Management at the Rotterdam School of Management, Erasmus University and a visitor at the Tuck School of Business and at INSEAD.

Brief Biography of Professor Christodoulos A. Floudas

Professor Christodoulos A. Floudas
Director, Texas A&M Energy Institute
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Dr. Floudas is the **Director of the Texas A&M Energy Institute, and the Erle Nye '59 Chair Professor for Engineering Excellence at the Artie McFerrin Department of Chemical Engineering at Texas A&M University.** Dr. Floudas served Princeton University for 29 years and is the Stephen C. Macaleer '63 Professor in Engineering and Applied Science, Emeritus, and Professor of Chemical and Biological Engineering, Emeritus at Princeton University.

Professor Floudas is a world-renowned authority in mathematical modeling and optimization of complex systems. His research interests lie at the interface of chemical engineering, applied mathematics, and operations research, with principal areas of focus including multi-scale systems engineering for energy and the environment, chemical process synthesis and design, process operations, discrete-continuous nonlinear optimization, local and global optimization, and computational chemistry and molecular biology.

Professor Floudas is the author of two graduate textbooks, *Nonlinear Mixed-Integer Optimization (Oxford University Press, 1995)*, and *Deterministic Global Optimization (Kluwer Academic Publishers, 2000).* He has co-edited ten monographs/books, has over 320 refereed publications, delivered over 330 invited lectures, seminars, and named lectureships. He is the recipient of numerous awards and honors for teaching and research that include the NSF Presidential Young Investigator Award, 1988; the Engineering Council Teaching Award, Princeton University, 1995; the Bodossaki Foundation Award in Applied Sciences, 1997; the Best Paper Award in Computers and Chemical Engineering, 1998; the Aspen Tech Excellence in Teaching Award, 1999; the 2001 AIChE Professional Progress Award for Outstanding Progress in Chemical Engineering; the 2006 AIChE Computing in Chemical Engineering Award; the 2007 Graduate Mentoring Award, Princeton University; Member of National Academy of Engineering, 2011; One thousand Global Experts, China 2012-2015; SIAM Fellow, 2013; TIAS Fellow and Eminent Scholar, 2013-14; AIChE Fellow, 2013; National Award and HELORS Gold Medal, 2013; Honorary Doctorate, Abo Akademi University, Finland, 2014; Thompson Reuters Highly Cited Researcher, 2014 (for 2002-2012, 11 years); Member of TAMEST (The Academy of Medicine, Engineering, and Sciences of Texas), 2015; the Constantin Caratheodory Prize, International Society of Global Optimization, 2015; Academy of Athens, Corresponding Member, 2015.

Dr. David Francas is a consultant and network design expert at Camelot Management Consultants. He received his doctoral degree in business administration from the University of Mannheim, focusing on logistics and operations research. He has more than 10 years of international consulting and industry experience with focus on improving supply chain management, logistics, and network strategies for clients in process and discrete industries. In addition to his professional work he is a lecturer for operations research and production & logistics at the Frankfurt School of Finance & Management.

Hubert Hadera is a researcher at ABB Corporate Research Germany, Process and Production Optimization Research Group. At the same time he is a PhD candidate in Chemical Engineering with Prof. Sebastian Engell at TU Dortmund. He holds a Master's degree in Production Engineering and Management (TU Rzeszow, Poland) and another in Energy Systems and Policies (University of Iceland). Within his research work he acted as visiting researcher and collaborator with: Prof. Ignacio Grossmann at Carnegie Mellon University (USA), ThyssenKrupp AST (Italy), ABB Industrial Solutions (Finland), University of Linkoping (Sweden), Aalto Univeristy (Finland). His research interest include solving real industrial optimization problems with emphasis on MILP and decomposition strategies.

Josef Kallrath obtained his PhD in astrophysics from Bonn University (Germany) in 1989. He is is with BASF's Scientific Computing group at BASF in Ludwigshafen since 1989, 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 100 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.

Stefan Minner is a Full Professor for Logistics and Supply Chain Management at TUM School of Management, Technische Universitt Mnchen. Before, he held positions at the Universities of Paderborn, Mannheim, and Vienna and obtained his Ph.D. and habilitation at the Otto-von-Guericke University of Magdeburg. His primary research interests are logistics network design, transportation optimization, and inventory management. Recent projects include logistics for the automotive industry, retail operations, and last-mile city logistics. Stefan Minner serves on several editorial boards of logistics and operations research journals. He was the president of the International Society for Inventory Research (ISIR) and is currently a member of the advisory board of the German Logistics association (BVL) and a member the Research Committee of the European Logistics Association (ELA).

Rolf Möhring obtained his M.S. (1973) and PhD (1975) in Mathematics at the RWTH Aachen and is since 1987 Professor for Applied Mathematics and Computer Science at Berlin University of Technology, where he heads the research group“Combinatorial Optimization and Graph Algorithms” (COGA). He has held earlier positions as associate and assistant professor at the University of Bonn, the University of Hildesheim, and the RWTH Aachen. His research focusses on graph algorithms, combinatorial optimization, scheduling, and industrial applications. Möhring has been scientist in charge at the DFG Research Center Matheon, responsible for the application area “Networks”. He has been member of the editorial board of leading scientific journals, has served as chair of the German Operations Research Society GMÖOR as well as of the Mathematical Programming Society (MPS). In 2005, Möhring was awarded the Scientific Award of the German Operations Research Society GOR, and in 2010 he received the EURO Gold Medal of the European Association of Operational Research Societies.

Stratos Pistikopoulos has been a Professor of chemical engineering at Imperial College London, where he was a Director of its Centre for Process Systems Engineering between 2002 and 2009. He holds a PhD from Carnegie Mellon University and was with Shell Chemicals in Amsterdam before joining Imperial in 1991. He has authored/co-authored over 350 major research publications in the areas of modelling, control and optimization of process, energy and systems engineering applications, 10 books and 2 patents. A Fellow of the Institution of Chemical Engineers, Editor of Computers & Chemical Engineering, Co-Editor of the Book Series in Computer Aided Chemical Engineering (Elsevier) and Process Systems Engineering (Wiley-VCH), on the Editorial Boards of Industrial & Engineering Chemistry Research (2011-2013), the Journal of Global Optimization and the Journal of Computational Management Science, Professor Pistikopoulos has been a co-founder/non-executive director of Process Systems Enterprise (PSE) Ltd and a founder/director of Parametric Optimization Solutions (ParOS) Ltd. In 2007, Prof. Pistikopoulos was a co-recipient of the prestigious MacRobert Award from the Royal Academy of Engineering; in 2008, he received an Advanced Investigator Award from the European Research Council; in 2009, he delivered the Bayer Lecture in Process Systems Engineering at Carnegie Mellon University, USA, and in 2014, the 21st Professor Roger Sargent Lecture ate Imperial College London; in 2014, he was the recipient of the title of Doctor Honoris Causa, the highest honorary distinction of the University Politehnica of Bucharest. In 2012, he received the Computing in Chemical Engineering Award of the Computing and Systems Technology (CAST) Division of the American Institute of Chemical Engineers (AIChE) and in 2013, he was elected Fellow of the Royal Academy of Engineering in the UK. He is due to join the McFerrin Department of Chemical Engineering at Texas A&M later this year/early 2015 having accepted an endowed chair there.

Ulrich Reincke studied mathematics at the Universities Kaiserslautern and economics at the Johns Hopkins University and George Washington University in Washington DC. He has been working for the Worldbank, the Frankfurt Stock Exchange and SAS Institute. In his current position as a Principal Analytic Solution Architect at the SAS Center of Excellence in Heidelberg he has frequent Consulting engagements in manufacturing, covering the Areas of Optimization, Forecasting, Quality Control, DOE and Statistics.

Dr. Schlenker is an IBM Technical Sales Specialist for IBM ILOG Decision Optimization products and solutions. He joined ILOG in 2005, and since 2009, worked in different roles in services and sales for IBM. He sold and delivered projects and solutions for many companies in various industries including automotive, industrial production, logistics, banking, insurance, and energy. Overall, he has more than 15 years of experience in algorithm development, IT architectures, optimization modeling, and solution design. Dr. Schlenker taught classes at several universities. He holds a Masters degree in computer science from Ludwig Maximilians University, Munich, and a Ph.D. degree in industrial engineering/ computer science from Technische Universitaet, Berlin.

Subanatarajan Subbiah obtained his masters in automation and robotics specializing in process automation from TU Dortmund (Germany) in 2006. Further in 2012 he obtained his PhD in Chemical Engineering from TU Dortmund (Germany) with special interest on solving production scheduling problems in process and chemical industries. His research interests include process control and model-based approaches to solve discrete and continuous optimization problems. Since 2013 he works with the ABB Corporate Research Center in Ladenburg (Germany) in the field of production optimization, data analytics and currently exploring data-based approaches towards prognostics and health management of assets.

Power Optimization for Heating Processes

Reinhard Bauer and Subanatarajan Subbiah (speaker)
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With the new DCT880 ABB offers a thyristor power controller for heating applications. Integrated power optimization algorithms save cost by reducing the peak power demand of the application. This is done fully automatically without affecting the production process or schedule. The key ingredient is an optimization suite that directly runs on the DCT880 without need of further supervisory equipment like additional PLCs. From a more technical perspective, the optimization algorithm is a micro-time energy scheduling solution: It shifts the periods in which energy is consumed by amounts small enough such that the heating process is not affected. However, by cleverly applying those changes, the peak power demand can be reduced greatly in many settings.

More concrete, we are given a set of consumers along with their operating power. Each consumer is either fully switched on or turned off. The consumers are operated in fixed time cycles. For each consumer it is known how long it is to be switched on in the next time-cycle. The core objective is to balance the combined power consumption of all consumers throughout the cycle-time.

In the talk we introduce the underlying mathematical optimization problem, show obstacles that arise from industrial requirements and how to overcome those obstacles. We further present some connections to computational geometry along with the according solution strategies.

Selling over an Uncertain Season: Scale and Timing of Inventory Availability

Jochen Schlapp, Moritz Fleischmann (speaker)
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Chair of Logistics and Supply Chain Management
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Unknown customer demand patterns are a significant challenge for many firms. This is particularly true for seasonal products which oftentimes do not only suffer from an uncertain demand scale, but also from an uncertain demand timing. To ensure a products profitability in such adverse market environments, firms have to coordinate a products inventory scale with the inventory timing. Motivated by this commonly observed challenge, we address the following question: for a seasonal product, when and how much inventory should a firm stock to best satisfy uncertain customer demand over an uncertain selling season? Our analysis reveals that for an efficient inventory strategy, the firm has to actively manage a tradeoff between the products market potential and the products costly market time. We also find that the timing uncertainty has more severe repercussions on a products profitability than an unknown demand scale. We discuss important managerial implications arising from these findings.

Framework for Mathematical Modeling and Global Optimization of Entire Petrochemical Planning Operations

Professor Christodoulos A. Floudas
Erle Nye '59 Chair Professor for Engineering Excellence
Director, Texas A&M Energy Institute
And
Artie McFerrin Department of Chemical Engineering
Texas A&M University

Abstract

The petrochemical industry has succeeded by creating markets and supplying them with suitable products such as gasoline, diesel, jet fuel, naphtha, light naphtha, and top oil that used to create goods such as plastics, cosmetics, lubricants, and paints in the last twenty years. The tighter competition, strict environmental regulations, and lower-margin profits driving provide an impetus for new technologies to improve their planning operations.

The entire petrochemical operations consist of refinery and chemical production operations. The refinery operations can be divided into three components including crude oil blending and processing, production unit operations, and product blending and distribution[1-2]. The entire petrochemical planning operations involve crude blending and distillation, production processing, production mode selection, flow connections between production units, and pooling and blending operations to satisfy quality requirements of production units, intermediates, and final products. Mathematical modeling of production, pooling and blending operations introduces bilinear, quadratic, polynomial, signomial, exponential, and higher order terms. On the other hand, the selection of parallel production units and production modes introduces binary variables. Hence, the entire problem is a large-scale non-convex mixed integer nonlinear optimization (MINLP) problem.

Commercial software such as RPMS (Refinery and Petrochemical Modeling System),[3] PIMS (Process Industry Modeling System),[4] and GRTMPS (Haverly Systems)[5] have been developed for optimization of entire petrochemical planning operations. However, they use non-rigorous models and approximate algorithms, which often lead to inaccuracies and generate solutions with suboptimal profitability or sacrificing product quality. Moreover, global optimality is not guaranteed. Nonlinear models and specialized algorithms [6-9] have also been developed, but have been restricted to refinery planning problems. A comprehensive review on refinery planning can be found in [1].

In this presentation, we propose a novel mathematical modeling and global optimization framework to address the entire petrochemical planning problem. In our proposed framework, we first develop detailed models to predict product yields and properties in production units including crude distillation units, coking units, hydrocracking units, catalytic cracking units, reforming units, ethylene-cracking units and other processing units. The yield and property prediction models for crude distillation units are developed using swing cut theory based on crude assay data. Models for the remaining processing units are developed by postulating surrogate approximations for the yield and property predictions and globally solving a non-linear parameter estimation problem for each unit, which includes all of the postulated equations and mass balance equations. These models involve bilinear, quadratic, polynomial,

and exponential terms. The property indices in pooling and blending units are linearly additive and calculated on weight or volume basis, which introduces bilinear and trilinear terms. We also introduce binary variables to denote the selection of several parallel units and operation modes in some production units. The entire planning model is a large-scale non-convex mixed integer nonlinear optimization (MINLP) model. To solve this large-scale MINLP model, we propose an optimization-based procedure to obtain the tightest lower and upper bounds for variables especially the variables involving nonlinear terms. Then, we incorporate those tightest lower and upper bounds into the commercial solver ANTIGONE[10] to obtain ε-global optimality. Finally, we have developed a user-friendly platform allowing the user to modify the planning model by updating model parameters when new data is available, product demands and specifications, and cost parameters. Several large-scale industrial examples are solved to illustrate the effectiveness of our proposed modeling and global optimization approach. The computational results show that all examples can be solved to global optimality within 30 minutes. Most importantly, we achieve at least 30% significant profit increase compared to the reported profit.

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Global network design in process industries

David Francas
Camelot Management Consultants

Many companies aim at optimizing their global distribution networks and logistics strategies. Based on industry cases from the healthcare industry, we provide an overview on trends and challenges in network design. In addition, we will look at project organization and approaches and the practical experience with different modeling approaches for network design.

Electricity Demand-Side Management in Process Industries: how to bring together production scheduling and energy-cost optimization

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Energy is becoming a critical resource for industry. Progressing volatility of energy availability and pricing creates new market channels to encourage large-scale electricity consumers for active load management. The industrial Demand-side Management (iDSM) has been recognized as a promising concept that incentivizes active shaping of the industrial load in response to energy market conditions in order to achieve bilateral benefits, i.e. the industrial plant reduces the energy bill while the energy supplier reduces peak generation hours and increases grids reliability.

One of the supporting technologies to realize the iDSM strategy is energy-aware scheduling and planning of daily operations by the industrial consumers. The traditional strategy in industry is to schedule the production first, satisfying all production specific rules, and from the production schedule to predict the demand for energy. Then, energy purchase and sale optimization models find the best available energy portfolio. This is not necessarily a system-optimal solution. Most reported methods in the scientific literature combine total scheduling problem with all energy-related information into a single monolithic problem. This ensures finding the system-optimal solution.

In this presentation we show such strategy for a real-world batch process of a stainless-steel using general precedence continuous-time scheduling formulation and energy-cost optimization of a multiple time-sensitive electricity sources. In addition we consider a load commitment problem where the plant is obliged to pay certain penalties for deviation from pre-agreed load curve. A strategy to solve the challenging problem of electricity consumption accounting in continuous-time models is explained. The resulting large-scale MILP problem is solved using tailored bi-level heuristic.

The monolithic strategy requires noticeable efforts to integrate both scheduling and energy planning into one model, and solve it effectively. Therefore, for industrial practice it would be beneficial to consider the scheduling and energy-cost optimization as functionally separated problems. In this presentation we show that in some conditions it is possible to use variations of the Mean Value Cross Decomposition for solving the total problem as separated MILP models. The two optimizers can be modified such that they are a part of the sub-problem of the Benders decomposition (energy-cost optimizer) and a part of the sub-problem of the Dantzig-Wolfe decomposition (energy-aware scheduler). The models exchange two signals: dual information of the complicating constraint from the energy-cost optimizer, and the production schedulers load curve. Such functional decomposition strategy is investigated in an industrial case study on the continuous process of Thermo-mechanical Pulping.

Mathematical Optimization at BASF
- A Quarter Century and More... -

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Since the advent of computer, and PCs especially, in the 1970 and 1980, there was a positive climate towards mathematical methods at BASF. Mathematics and mathematical tools were used by various individuals or subgroups in departments to support analytics, the evaluation of experiments, or the description of reaction by differential equations – Mathematics was never strictly centralized at BASF.

The chemical industry is full of problems requiring a mathematical modeling *and* optimization background, *e.g.*, modeling of chemical reactions (parameter estimation in systems of stiff nonlinear ordinary or partial differential equations), the analysis of experimental data in pharmacokinetics, simulations on an atomistic or molecular level in material sciences or the optimal control of biotechnological reactors.

In 1990, the group *Systems for Chemistry* was founded focussing on problems as the ones mentioned above and as new fields of activities at BASF mixed integer mixed integer optimization and later on operations research in the more general sense were added, *e.g.*, blending problems, production planning and scheduling problems, supply network problems. These problems lead to linear programs, mixed-integer problems both linear and nonlinear which brings us also into the field of deterministic global optimization.

Nowadays, mathematical optimization is used in the area of supply chain management (SCM) for a wide range of strategic, tactical, and operational topics encountered at BASF, *e.g.*, to design the structure and size of its rail car fleet.

At BASF we have always followed the idea that in-house groups always keep the ability of solving difficult problems on their own although we also collaborate with research institutions where possible, in order to keep up-to-date with leading edge developments in academia. This independence and competence is important a) for keeping in reasonable contact and collaboration with research institutions in the area of mathematical optimization, but also b) to be able to assess the offerings of such institutions. Finally, there are c) also projects which are confidential and which cannot be communicated to the outside world. An additional advantages of this strategy is that the group as an internal unit can perfectly match its methodological knowledge with the specific application experience of our clients.

Consistent with this basic self-understanding of the group I have, for instance, developed polylithic modeling and solution approaches useful to solve very difficult or large scale problems, or to compute optimal breakpoint systems to approximate nonlinear terms with a pre-given tolerance in otherwise mixed integer linear problems. When confidentiality aspects allow this, we also publish our solutions.

Integrated dynamic production and safety stock planning in the process industry

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We introduce an integrated Mixed Integer Programming approach to simultaneous production and safety stock optimization under service level constraints. Approaches for different non-stationary demand distributions and availability and fill-rate service level constraints are presented based on linearization approximations. The capability and computational performance of the approach is illustrated for different capacitated multi-item lot-sizing and scheduling problems as well as a real case application from the process industry. We further highlight the improvements achievable by an integrated optimization compared to a sequential approach and the value of dynamic safety stocks. The approach is further extended to multi-stage supply chains using the guaranteed service framework.

Coping with Uncertainty in Project Scheduling: New Developments and Applications

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Combinatorial optimizers have recently become more aware about the influence of uncertainty and randomness in solving combinatorial optimization problems. Deterministic models for project scheduling and control suffer from the fact that they assume complete information and neglect random influences that occur during project execution. A typical consequence is the underestimation of the expected project duration and cost frequently observed in practice.

To cope with these phenomena, we consider scheduling models with random processing times. Scheduling is then done by policies which consist of an an online process of decisions that are based on the observed past and the a priori knowledge of the distribution of processing times.

I will first report on some major results for this model, including risk measures for the makespan distribution and approximation algorithms for policies in machine scheduling.

I will then then continue with an application to turnaround scheduling. This concerns large-scale maintenance in industrial plants and requires the shutdown of entire production units for disassembly, comprehensive inspection and renewal. It is an important process that causes high out-of-service cost. Therefore a good schedule for a shutdown and and an analysis of possible associated risks are crucial for the manufacturer.

We have developed algorithms for this task that work in two phases. The first phase supports the manager in finding a good makespan for the shutdown. It computes an approximate project time cost tradeoff curve together with a stochastic evaluation of the risk for meeting a particular makespan t. Our risk measures are the expected tardiness at time t and the probability of completing the shutdown within time t. In the second, detailed planning phase, we solve the actual scheduling optimization problem for the makespan t chosen in the first phase heuristically and compute a detailed schedule that respects all side constraints. Again, we complement this by computing upper bounds for the same two risk measures, but now for the detailed schedule.

Model based Optimization & Control

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Model based multi-Parametric programming provides a complete map of solutions of an optimization problem as a function of, unknown but bounded, parameters in the model, in a computationally efficient manner, without exhaustively enumerating the entire parameter space. In a Model-based Predictive Control (MPC) framework, multi-parametric programming can be used to obtain the governing control laws - the optimal control variables as an explicit function of the state variables. The main advantage of this approach is that it reduces repetitive on-line control and optimization to simple function evaluations, which can be implemented on simple computational hardware, such as a microchip, thereby opening avenues for many applications in chemical, energy, automotive, and biomedical equipment, devices and systems.

In this presentation, we will first provide a historical progress report of the key developments in multi-parametric programming and control. We will then describe PAROC, a prototype software system which allows for the representation, modelling and solution of integrated design, scheduling and control problems. Its main features include: (i) a high-fidelity dynamic model representation, also involving global sensitivity analysis, parameter estimation and mixed integer dynamic optimization capabilities; (ii) a suite/toolbox of model approximation methods; (iii) a host of multi-parametric programming solvers for mixed continuous/integer problems; (iv) a state-space modelling representation capability for scheduling and control problems; and (v) an advanced control toolkit for multi-parametric/explicit MPC and moving horizon reactive scheduling problems. Algorithms that enable the integration capabilities of the systems for design, scheduling and control are presented along with applications in sustainable energy systems, smart manufacturing and personalized healthcare engineering.

Timing Is Money: How optimization can help to get the Drug Launch Sequence Right

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Pharmaceutical companies are plagued by patent expirations and weakened product pipelines. Consequently, when a new product is approved and ultimately introduced, it is more vital than ever to properly execute product launch and generate maximum revenues in each market. However, each product launch is subject to national pricing regulations, making the prices of new drugs themselves dependent on reference prices in other countries where the drug has already been launched. This difficult global pricing environment demands the ability to respond swiftly (and smartly) to changing government requirements. A myriad of price referencing rules complicates the already difficult business and mathematical challenges of achieving optimal launch sequences and prices across all markets.

This presentation provides an overview of the Launch Sequence Optimization approach taking international pricing rules as constraints. It shows how launch scheduling optimization improves the companies baseline.

Supply Chain Optimzation under Uncertainty

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We all know that "Prediction is difficult, especially if it's about the future" (Niels Bohr). In order to plan production and other parts of a supply chain, a lot of data has to be predicted: future sales, prices, costs, or currency exchange rates, sometimes even availability of future technology. Supply chain and production optimization often suffers from uncertainty in predicting such data.

As part of its Decision Optimization solution portfolio, IBM offers a new approach to mitigate this problem: the Uncertainty Toolkit. It adds explicit handling of uncertainty to existing, deterministic optimization applications. The toolkit implements a variety of state-of-the-art approaches. For the OR expert, it provides a wizard that helps select the right approach for a given optimization problem. Based on the expert's input, it modifies the existing optimization application and even produces a reformulation of the model. This approach enables a large community of experts to add handling of uncertainty to their optimization applications.

This presentation introduces the foundations and the benefits of the Uncertainty Toolkit, and describes how it is currently applied to supply chain planning and other optimization problems.