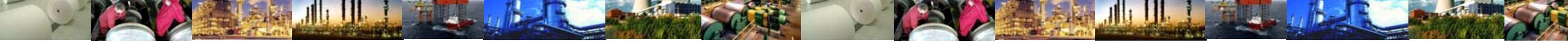

Invitation

We cordially invite you to the 80th workshop of the GOR working group *Practice of Mathematical Optimization* which is held at the ABB Corporate Research Center Germany. The topic of this workshop is

Optimization in
Manufacturing Execution Systems.

We look forward to your participation.

Josef Kallrath	*Guido Sand*
Head of the working group	Local organization, ABB

Speakers

Julien Briton
ILOG S.A., France

Prof. Dr. Sebastian Engell
Universität Dortmund, Germany

Dr. Marco Fahl
Honeywell GmbH, Germany

Dr. Eduardo Gallestey
ABB Ltd, Switzerland

Dr. Hermann Gold
Infineon Technologies AG, Germany

Prof. Dr. Ignacio Grossmann
Carnegie Mellon University, U.S.

Dr. Iiro Harjunkoski
ABB AG, Germany

Dr. Alexander Horch
ABB AG, Germany

Bazmi Husain
ABB AB, Sweden

Dr. Alex Meeraus
GAMS Development Corp., U.S.

Prof. Dr. Manfred Morari
ETH Zürich, Switzerland

Dr. Ansgar Münnemann
BASF AG, Germany

Jan Poland
ABB Ltd, Switzerland

Frans de Rooij
AIMMS, The Netherlands

Thomas Schulz
Rockwell Automation GmbH, Germany

Contact

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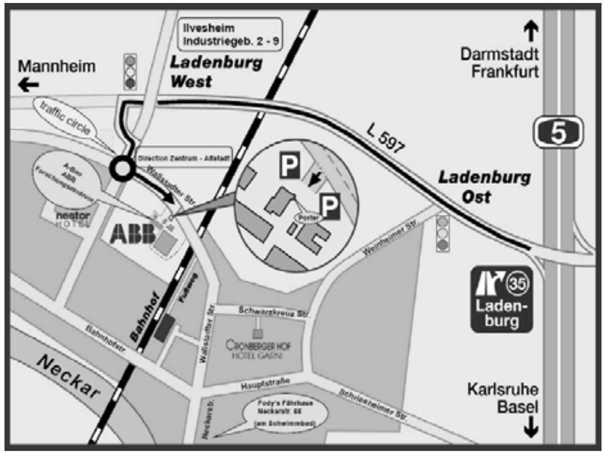
Venue

The more than 1900 year old city of Ladenburg is located close to Heidelberg and Mannheim. Its town-scape is dominated by well preserved Roman ruins and the green banks of the river Neckar.

ABB AG
Corporate Research Center Germany
Wallstadter Str. 59
68526 Ladenburg, Germany



GERMAN OPERATIONS RESEARCH SOCIETY
ABB CORPORATE RESEARCH CENTER GERMANY

INVITATION TO THE

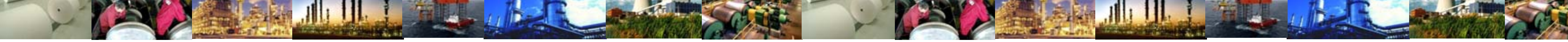
80TH WORKSHOP OF THE GOR WORKING GROUP

PRACTICE OF MATHEMATICAL OPTIMIZATION

3-4 APRIL 2008

Optimization in Manufacturing Execution Systems

GOR ABB



About the Working Group

The GOR working group **Practice of Mathematical Optimization** (Praxis der mathematischen Optimierung, https://gor.uni-paderborn.de/Members/AG06/) aims at the promotion of communication and exchange of ideas among practitioners, researchers and algorithm developers in the field of mathematical optimization.

Among the topics covered are reports on applications of mathematical optimization in industry, experience and evaluations of modeling languages, algorithms, and optimization software.

It became a tradition of the group to have a spring workshop hosted by an industrial company, and an autumn workshop at the attractive conference center (PBH) of the German Physical Society at Bad Honnef (www.pbh.de). While the spring workshop usually has a focus on an application topic, the autumn workshop is more centered around a methodology.

In average, 40 to 50% are industrial participants, 20 to 30% are solution providers, and 20 to 30% are researchers from academic institutions. Previous workshops covered:

- Global Optimization (PBH)
- Stochastic Optimization in the Energy Industry (ProCom GmbH, Aachen)
- Metals Industry and Mathematics (PBH)
- Financial Optimization and Pricing Strategies (BASF AG, Ludwigshafen)
- Optimization under Uncertainty (PBH)
- Mathematical Optimization in Daily Life (Siemens AG, Munich)
- Optimization Services in Europe (PBH)
- Modeling Languages in Mathematical Optimization (PBH)
- Utility Industry and Mathematics (PBH)

Topic of this Workshop

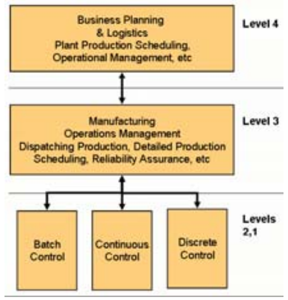
Manufacturing Execution Systems (MES) integrate automation functionalities of the Distributed Control System (DCS) layer with the Enterprise Resource Planning (ERP) layer.

The focus of this workshop is the **optimization in MES using mathematical methods** including

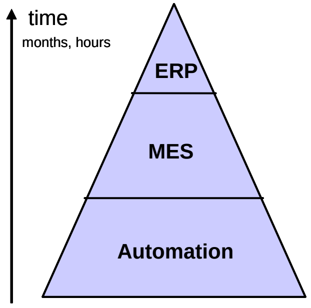
- Short-term production planning,
- Finite capacity scheduling,
- Maintenance planning,
- Asset optimization,
- Material management,
- Quality management,
- Energy optimization,
- Environmental aspects,
- Horizontal and vertical integration,
- ISA 95 standards,
- Modeling,
- Industry-specific solutions

with applications in **process industries** including

- Minerals and cement,
- Metals,
- Pulp and paper,
- Chemicals and pharmaceuticals,
- Oil and gas.



Source: Siemens, 2006



Source: Kletti, 2006

Date and Time

The workshop is scheduled for

April 3rd, 2008, 1.30 pm – April 4th, 2008, 4.00 pm.

Prior to its opening, an optional lunch at the workshop venue is offered.

Accommodation

Rooms have been reserved at **Leonardo Hotel Mannheim-Ladenburg** at a special rate (www.leonardo-hotel-mannheim-ladenburg.com). You can book your room using the keyword *ABB-GOR*. The special rate is valid until

March 3rd, 2008.

The hotel is in walking distance to the workshop venue.

Workshop Dinner

ABB invites the participants for dinner and informal discussions at the **Castle-Restaurant Strahlenburg** (www.strahlenburg-schriesheim.de). The Strahlenburg is 8 km to the west of the workshop venue (10 min driving time).

Registration

Up-to-date information and a registration form are available at **https://gor.uni-paderborn.de/Members/AG06/**

Please submit your registration as soon as possible, but not later than

March 3rd, 2008.

Please note: The number of participants is limited and the participation is subject to a registration fee (up to 160€, depending on participant status).

Optimization in Manufacturing Execution Systems

Integrated Manufacturing Planning, Batching, and Scheduling, with ILOG Plant PowerOps

Julien Briton
ILOG S.A.
1681 Route des Dolines, Les Taissounières HB2, FR-06560 Valbonne, France
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Manufacturing rough plans and detailed schedules must establish a compromise between antagonistic optimization criteria: meet as much as possible of the established and expected customer demand; deliver customer demands on time; reduce production costs (processing costs, resource usage costs, setup costs, cleaning costs); keep little value in inventories without risking starvation, etc. Usual practice is often very unsatisfactory in this respect. For example, rough plans are often built by averaging setup times and costs, even when variations are significant; production batch sizes are determined by economical considerations, with no respect to the distribution of demand due dates; detailed schedules are built and maintained under fixed resource availability and production-order-to-demand pegging assumptions. In many cases, globally sub-optimal results are obtained, due to the fact that at some step in the process an important optimization criterion and the associated constraints have been ignored.

New integrated planning, batching, and scheduling models, aimed at ensuring greater consistency between the planning, batching, and scheduling steps, and, as a result, at delivering better plans and schedules, must be developed. Focusing on such integrated models has three advantages: the approximations needed at each problem-solving step are made explicit and the related issues clearly identified; global problem-solving methods can be designed and implemented towards a unique well-defined objective; these methods can be evaluated with regard to the global planning and scheduling problem.

ILOG Plant PowerOps is an advanced planning and scheduling system built with these ideas is mind. It integrates planning models (solved with mathematical programming), batching models (solved with mathematic programming and heuristics), and scheduling models (solved with constraint programming and local search), together with a powerful graphical user interface allowing manual and computer-aided modifications of the overall plan. The integration framework of Plant PowerOps is flexible enough to allow the adaptation of the global problem-solving strategy to a specific case (e.g., adoption of a specific problem decomposition) or the replacement of one of its generic underlying mathematical model by an industry-specific or plant-specific model (e.g., a specific batching heuristic), thereby enabling industrial implementations that would not have been possible otherwise, and opening a wide avenue for experimental research in the manufacturing planning and scheduling domain.

Uncertainty-conscious production scheduling

Sebastian Engell, Guido Sand[1], Jochen Till[2]
Universität Dortmund, Lehrstuhl für Anlagensteuerungstechnik

Manufacturing execution systems perform a wide range of tasks among which production scheduling is probably the algorithmically and computationally most demanding one. On the MES layer of the automation hierarchy, decisions of what to produce when and with which resources have to be made in a very dynamic environment because the production goals, the resource availabilities and the production yields are subject to frequent changes and unforeseen deviations between predictions and reality. Moreover, the timespan in which adaptations of schedules have to be made is usually short.

Two-stage stochastic programming is a promising approach to the consideration of the uncertainties in the problem data in scheduling algorithms. In brief, the decision variables are divided into two sets, the here-and-now decisions that have to be fixed despite the presence of the uncertainties, and the recourse variables that can be adapted to the realization of previously unknown variables, e.g. to updates of the production demands. In an online setting, similar to the model-predictive approach to continuous control the look-ahead horizon can be shifted after a certain period of time such that a part of the recourse variables become here-and-now variables in the next step and new recourse variables are added. The most practical way to represent the uncertainties in scheduling problems is to define a set of (n) discrete scenarios of the future evolution of the uncertain parameters which may have different probabilities, and to minimize or to maximize the expected value of a cost function over all scenarios. This leads to large mixed-integer optimization problems with the here-and-now variables plus n copies of the recourse variables as degrees of freedom.

In the case of linear cost functions and constraints, the resulting MILP can either be solved by a brute-force (monolithic) approach or by rigorous decomposition techniques. For the latter, the DDSIP algorithm by Caroe and Schultz which is based upon a relaxation of the requirement that the here-and-now variables must be equal for all scenarios represents the state of the art. In our recent work, we have explored the potential of an alternative stage-decomposition approach were the here-and-now variables are optimized by evolutionary algorithms whereas the recourse variables are computed for each scenario separately using a standard MILP solver. Computational experiments confirmed that the numerical effort of this approach is in the same range as that of DDSIP or a monolithic formulation for small problems but grows only approximately linearly with the number of scenarios for larger problems. What is even more important is that the new approach is able to compute good feasible solutions in short computation times, making it attractive for online reactive applications.

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[2] Present affiliation: BASF Aktiengesellschaft, 67056 Ludwigshafen, Email: jochen.till@basf.com

Oil & Gas Supply Chain Optimization

Marco Fahl
Honeywell GmbH, Germany

In today's dynamic and complex business environments a key requirement for successful MES and Supply Chain Management systems is to provide an integrated solution that enables collaborative business processes within a company and across company boundaries.

With increasing complexity of the business processes to be supported, more and more specialized point solutions need to be integrated (real-time information systems, accounting systems, laboratory information systems, to name a few).

A crucial factor for the efficiency of this type of solutions is typically a set of Advanced Planning & Scheduling (APS) applications that combine information from various sources and drive decision-making based on production targets and feedback from production execution.

This presentation is outlining key aspects and challenges related to APS solutions in the context of Supply Chain Optimization and MES Systems for the Oil & Gas industry incl. examples from industrial projects with a special focus on (liquefied) natural gas production and distribution.

Advanced Process Control and Optimization in the Modern Industry

Eduardo Gallestey
ABB Ltd, Switzerland

Implementation of advanced process control and scheduling systems throughout a plant operation can reduce costs, optimize investment and create a substantial added value. Advanced optimization techniques supported by dedicated mathematical models and seamless integration with the plant data warehouse allow for economic process optimization (process setpoints and coordination thereof, energy management, production planning, energy supply contract optimization, etc) of the plant as a whole.

One of the techniques ABB is using for this sake is Mixed Logical Dynamical systems. The presentation will show how theoretical results have been implemented in an industrial framework for robustness and easy of use.

Furthermore, two recent applications will be discussed. First, process optimization of a TiO2 plant is considered. In this case, batch and continuous processes were coordinated to achieve energy savings, reactanc usage and reduce process bottlenecks. In the second example, the optimal operation of the water supply system of the city of Basel will be presented, where pumping stations are controlled in real time to meet consumption demands, transport constraints and minimize the energy costs.

Overview of Planning and Scheduling for Enterprise-wide Optimization of Process Industries

Ignacio Grossmann, Muge Erdirik-Dogan and Ramkumar Karuppiah
Department of Chemical Engineering
Carnegie Mellon University
Pittsburgh, PA 15213

Enterprise-wide optimization (EWO) is a new emerging area that lies at the interface of chemical engineering and operations research, and has become a major goal in the process industries due to the increasing pressures for remaining competitive in the global marketplace. EWO involves optimizing the operations of supply, manufacturing and distribution activities of a company to reduce costs and inventories. A major focus in EWO is the optimal operation of manufacturing facilities, which often requires the use of nonlinear process models. Major operational items include planning, scheduling, real-time optimization and control. This paper provides an overview of major challenges in the development of linear/nonlinear optimization models and algorithms for the optimization of entire supply chains that are involved in EWO problems. We specifically review two major challenges: (a) modeling of planning and scheduling, (b) multiscale optimization, and consider two major applications in batch scheduling and crude oil scheduling. We conclude with a brief discussion on future directions.

Production Optimization – requirements for sustainable success

Alexander Horch
ABB AG, Germany

Optimization problems arise in many industrial problems in most industries nowadays. Both the (r)evolution of the information technologies, computing power as well as the ever increasing industrial requirements on production quality, cost reduction and larger product variety lead to increasingly more difficult and complex optimization problems.

On the other hand, mathematical optimization methods have been developed to cover increasingly complex problems while becoming more and more efficient.

Another trend that goes hand in hand with these in modern process industry is tighter integration of different systems. This is made possible by modern software technologies and architectures like service oriented architecture (SOA), OPC UA etc. and the widespread use and application of standards such as ISA S95 and others. Also, the use of XML, a general-purpose markup language[3], whose primary purpose is to facilitate the sharing of structured data across different information systems, has boosted successful integration architectures in the process automation world.

As both of the described trends, the one in optimization and the other in system integration pose their own and difficult challenges, a necessity today is to combine both of them. In modern production facilities, advanced functionality is required to well integrate with the available system landscape in the plant.

The reasons for this are well-known: few plant engineers are responsible for an increasingly complex production plant subject to stronger and more difficult boundary conditions than in the past. Therefore, advanced solutions need to fit the available automation technology and need to be flexible enough to be changed easily, also by non-expert staff, whenever plant or production changes require this.

The talk discusses these requirements and how they are can be met in industrial projects. One important issue is the need for interdisciplinary teams where experts from both optimization, computer engineering and other fields collaborate closely with each other.

Another challenge in a quickly changing industrial world is to develop solutions that cover a large area of applications since – given the requirements outlined above – solutions that only work for one single application will not motivate the increased effort required for such undertakings any more.

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[3] A markup language combines text and extra information about the text. The extra information, for example about the text's structure or presentation, is expressed using markup, which is intermingled with the primary text. The best-known markup language in modern use is HTML (HyperText Markup Language).

The Challenge of Increasing Complexity in Production Optimization

Iiro Harjunkoski, Guido Sand
ABB AG, Germany

Today's industries are more than ever enforced to lower their operational costs, largely due to a harder global competition. One related target is to ensure that the overall result of earlier isolated optimization tasks is "globally optimal", i.e. the decisions done on different levels or in different process sections do not negate, or counteract, each other. This has created a trend and more importantly a need of increased information sharing between various decision-support systems. Inevitably, information sharing leads to more complex optimization systems as the models need to cover larger problem entities in order to merge previously separate optimization targets. Also, aspects earlier not considered may have to be included. Another complexity increase arises from the communication need between the tasks. The earlier isolated problems (e.g. machine-specific production planning) become networked, which means that not all goals can be derived from local facts alone, but at least some must be handled globally.

Apart from the cultural change and integration challenges, it is very important to ensure that optimization methodologies can cope with the new demands. As no single strategy suffices to cover all industrial problem solutions – even within one plant – a system of optimization systems needs to be designed by combination of methods, partitioning of problems and modeling collaboration. Some strategies of combining solution methods will be shown, followed by project examples carried out at ABB Corporate Research. Finally, future challenges and opportunities are discussed.

Requirements On Sustainable MES Solutions And Technologies In Process Industry

Ansgar Münnemann
BASF AG, Germany

The MES automation layer can be defined as a combination of software tools to manage the following tasks: performance and capacity analysis, ressourcen management, coordination of information, reporting and documentation in the domains of production, maintenance, quality assurance and logistics. Therefore you find tools with different methodical approaches from chemical engineering, signal processing, automation techniques and computer sience, which results in a system landscape, where almost any MES project is an integration project, adopting different technologies, methods and semantics. So often the cost-benefit ratio is increased by the integration task and the lifecycle consideration of the integration solution.

Sustainable MES solutions require the introduction of standard technologies and semantics for the MES automation layer. Different MES products should provide open interfaces for dynamic data and master data (resp. configuration data) based on standard technologies and semantics. To avoid the development of inconsistent domain sepcific standards, the standardization has to be done as a stepwise abstraction resp. detailing with a common meta-model, which is able to describe the inner model and the model to model dependencies. Interface technologies for MES have to be designed in such a way, that the transmitting of all that semantic information is possible.

Unattended operation of Water Supply and Optimization of Pump Schedules

Jan Poland
ABB Ltd, Switzerland

Having anytime access to fresh tap water is a fundamental benefit to all of us living in technologically developed societies. A large part of the tap water is produced by pumping ground water to the water supply system. In a system with multiple pumps available, the decision when to use which pump can have an important impact on both the water quality and the costs of producing the water, in particular the energy costs.

In this talk, we present an automatic control strategy for a water supply plant in the city of Basel. The strategy works on a model of the topology of pumps and pipes, constraints and water quality implications, energy and other costs, and production targets. Using predictive control with a Mixed Logical Dynamical (MLD) model, optimal decisions are computed. In this way, operation and maintenance costs of the water supply plant could significantly be reduced.

Optimizing manufacturing processes and planning with AIMMS

Frans de Rooij
AIMMS, The Netherlands
frans.de.rooij@aimms.comThomas Schulz

There is often a large gap between theoretical optimization concepts and the operational practices in manufacturing. AIMMS is a modeling system that can bridge this gap, making optimization technologies easy to use and deploy in an operational context.

To use optimization technologies that accurately model a real-life situation, AIMMS offers an integrated model development environment that links seamlessly to many mathematical solvers for linear, integer and nonlinear problems. Many advanced modeling concepts are available, such as automatic generation of Stochastic Programs. The resulting mathematical programs are often very large, but Benders decomposition is available to solve these programs more efficiently.

To deploy these optimization models operationally, AIMMS offers the capability to construct a graphical user interface around the model, and this can be linked to ERP and MES systems to exchange data. One could also choose to use the AIMMS model as a component, functioning as an “optimization engine” behind an existing applications through standard interfaces.

We will illustrate the use of AIMMS in manufacturing with two cases from industry, in process optimization and in production planning.

The first case is the process model that Shell has developed to optimize Fluid Catalytic Cracking Units. This model accurately predicts the economic impact of changes in operating conditions and can optimize the process performance on a continuous on-line basis.

The second case is the AIMMS-based production planning solution developed by Outperform, an AIMMS Service Partner. This solution has been implemented at various clients in the food processing industry, such as Baltic Beverages Holding (BBH), a joint venture of the brewers Carlsberg and Scottish & Newcastle, and Remia, a Dutch producer of margarine and sauces. The solution enables them to plan their manufacturing and storage facilities, resolving the many detailed and conflicting requirements on a monthly, weekly and even daily basis.

Non-anticipative Scheduling in Semiconductor Manufacturing Systems involving Setups

Hermann Gold, Infineon Technologies AG

Abstract:

We investigate the problem of setup optimization in semiconductor manufacturing. Considerable setup requirements typically occur for ion implantation steps in this type of manufacturing. The setup requirements are hierarchical with two levels. At the upper level machines have to be set up for specific dopants, for instance Boron, Phosphorus, Arsenide etc. At the lower level recipes for specific dopants have to be loaded and machines have to be tuned according to the requirements for ion dosis and energy of the recipe in consideration.

The two setup types of this hierarchy have different setup time characteristics. Setups at the upper level are more or less deterministic since they mainly consist of a clean step of constant length neutralizing the process chamber. The setup at the lower level is highly variable in duration and these time durations are sigificantly smaller than the setup times on the upper level on average.

In response to these different setup characteristics setup optimization is done in two steps. The second step which optimizes setup times at the lower level is mainly a matter of regression analysis whereas setup optimization on the first level is essentially a combinatorial optimization problem which is focussed in the following.

We are given m job classes arriving according to Poisson arrival streams to a multi server system with n servers. In general the arrival traffic is dedicated traffic, i.e. some given job class can not be allocated to anyone machine of the multi server system upon discretion. However the servers and job classes communicate in a certain sense so to establish a resource pool in the best case. Beyond this job class classification the job classes are divided into F setup families. Each familiy f contains k_f job classes and is related to a given dopant setup.

The goal of optimization is to setup machines in such a way that fair queueing is realized for the different families present in the system. This means that the capacity allocated to some family f is ideally a $N_f/((N_1 + N_2 + \ + N_F$ portion of the overall resource pool capacity (Principle of Discriminatory Processor Sharing), where N_f is the number of jobs of family f present in the queue. However a minimum service rate is guaranteed to each family present (Principle of Generalized Processor Sharing). The resulting set of numbers of machines to be set up for families $1, \ldots, F$ is denoted as optimal composition. The actual choice of individual machines to be setup for families $1, \ldots, F$ is still a combinatorial optimization problem. The collection of possible setup combinations coincides with the collection of all rankings of the set of N players in cooperative games under precedence constraints. A heuristic is used to solve this problem in the on-line dispatcher. Combinatorial optimization is applied to indicate preferrable additive job-to-machine qualifications as well as superfluous ones with respect to first moments of the arrival stream distributions. Neither in on-line scheduling nor in the latter assumptions on indivdual arrival times are made. Therefore the type of scheduling is called non-anticipative. The combinatorial optimization tool is also used to control the loss accepted by using a heuristic for dispatching. Practical experience has shown that this loss is small between 0.4 % and 1 % of the capacity.

From queueing theory it is known that the optimal control for a multi-class queue with setups is of threshold type. This is taken into regard by allowing setup changes only for high priority jobs except for idling machines. One criteria for a job to become a high priority job is having exceeded a certain waiting time threshold.