Industrial Optimization
Report

COMPACT COURSE &
CHALLENGE WORKSHOP

February 17–20, 2014
IWR – Interdisciplinary Center for Scientific Computing
Heidelberg University
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The HCO

The Heidelberg Collaboratory for Industrial Optimization (HCO) is a public-private partnership initiative to identify and tackle future challenges of mathematical methods for industrial optimization.

At HCO, we want to bring together scientists from research & development in industry and economy, as well as scientists from Heidelberg University and beyond. This industry-on-campus initiative identifies future challenges in modeling, simulation, and optimization – key enabling technologies in Germany’s “Industry 4.0 strategy – and addresses them through a collaborative, application-oriented basic research program. Our interdisciplinary collaborations help to leverage the potential of innovative and state-of-the-art computational methods that secure technology leadership.

HCO is based at the Interdisciplinary Center for Scientific Computing (IWR) of Heidelberg University in Heidelberg, Germany. With over 25 years of experience in public-private cooperation, IWR is a valuable partner for industrial optimization projects and is proud of its strong long-term collaborations with industrial partners, among them global players such as BASF, Bayer, Daimler, Lufthansa, and Siemens.

More information is available at:
http://hgs.iwr.uni-heidelberg.de/industrialoptimization/
INDUSTRIAL OPTIMIZATION

Optimization plays a crucial role in the design and operation of industrial processes due to the desire to save valuable resources, to meet ambitious production goals, and to achieve the best possible profit margins. Often the processes under consideration are nonlinear and dynamic by nature, thus complex dynamic optimization or optimal control problems need to be formulated and solved. Recent years have seen rapid progress in this area, both algorithmically and in terms of solvable applications. However, this area still raises major challenges for scientific computing and interdisciplinary collaboration.

The aim of this workshop was to bring together scientists and decision makers from industry and academia to initiate joint projects on industrial optimization. The event commenced with a two-day course about topics from modeling, simulation, optimization and model validation. On the third day successful case studies from previous and present collaborations were presented. The fourth day served as forum for discussions about current and future challenges, which could lead to new projects within structured collaboration in an Industry-on-Campus initiative.

Target group for this workshop were scientists and decision makers from industry, university, and research institutions, as well as interested doctoral students, in particular from the Heidelberg Graduate School of Mathematical and Computational Methods for the Sciences (HGS MathComp).

Support is gratefully acknowledged:
• Heidelberg Graduate School of Mathematical and Computational Methods for the Sciences (HGS MathComp)
• Interdisciplinary Center for Scientific Computing (IWR), Heidelberg University
• Mathematics Center Heidelberg (MATCH)
• Committee for Mathematical Modeling, Simulation and Optimization (KoMSO)
LIST OF SPEAKERS

Angelika Altmann-Dieses, HS Karlsruhe
Dörte Beigel, IWR
Tanja Binder, IAV GmbH
Debora Clever, IWR
Christoph Garbe, IWR/HCI
Gottlob Gienger, ESA/ESOC
Manuel Gräber, TLK Braunschweig
Guido Kanschat, IWR
Robert Kircheis, IWR
Christian Kirches, IWR
Stefan Körkel, IWR
Robert Lee, BASF
Simon Lenz, IWR
Ilaria Malanchini, Bell Labs/Alcatel-Lucent
Stefan Menzel, Honda
Katja Mombaur, IWR
Jan Poland, ABB
Andreas Potschka, IWR
Volkmar Reinhardt, SEW Eurodrive
Thomas Richter, IWR
Johannes P. Schlöder, IWR
Volker Schulz, Universität Trier
Klemens Springer, University Linz
Stefan Valentin, Bell Labs/Alcatel-Lucent
Christoph Weiler, IWR
At the beginning of the workshop Prof. Hans Georg Bock welcomed all participants and introduced the work of both HCO and IWR. Hans Georg Bock is professor at IWR, managing director of IWR and HCO and has long-lasting experience in interdisciplinary collaboration with scientists from industry. Ninety-nine participants from six countries attended the HCO Workshop, twenty-six of which are members of industry.

The first day of the workshop was dedicated to a compact course on mathematical basics for optimization with differential equations.

**K. Mombaur, IWR: Overview on Optimization**

In the first lecture Prof. Katja Mombaur gave an Overview on Optimization. Katja Mombaur is professor for Scientific Computing at IWR and leads the research group “Optimization in Robotics and Biomechanics”. She presented the different types of optimization problems including continuous and discrete variables, unconstrained, equality- and inequality-constrained problems as well as linear, quadratic and non-linear programs. Moreover, she introduced optimization problems constrained by dynamic process models, which are described by differential equations. Finally, she gave a short overview on optimization algorithms including derivative-based and derivative-free approaches.

**C. Kirches, IWR: Linear Programming**

Dr. Christian Kirches gave the second lecture. Christian Kirches is head of the junior research group “Optimization of Uncertain Systems“ of the Heidelberg Graduate School of Mathematical and Computational Methods for the Sciences (HGS Math-Comp). His lecture was on Linear Programming and he presented the primal and dual simplex algorithm to solve this class of problems.
S. Körkel, IWR: Nonlinear Programming
After the coffee break Dr. Stefan Körkel gave a lecture on Nonlinear Programming. Stefan Körkel leads the junior research group “Optimum Experimental Design”, which is funded by BASF SE as well as HGS MathComp. In his lecture Stefan Körkel characterized optimality and presented optimality conditions for constrained nonlinear optimization problems. As solution approaches he explained Newton-type methods and Sequential Quadratic Programming. Finally, he presented the Gauss-Newton method to solve nonlinear least squares problems.

C. Kirches, IWR: Mixed Integer Nonlinear Programming
Subsequently, Dr. Christian Kirches gave a lecture on Mixed-Integer Nonlinear Programming. The transportation in gas networks is one example of this complex problem class. He presented the branch & bound solution approach, the outer approximation as well as several heuristics to reduce the computational complexity.

J. P. Schlöder, IWR: Overview on Modeling
After the lunch break the block on modeling and simulation started with a lecture by Dr. Johannes P. Schlöder giving an Overview on Modeling. Johannes P. Schlöder is senior scientist and academic director at IWR. He defined mathematical models as a description of systems using mathematical concepts and language (here: differential equations), aiming at studying effects of different components and making predictions about the system behavior. He derived exemplary models in form of ordinary differential equations for processes from chemical engineering and mechanics. The talk also sketched model properties required for use of the models in derivative-based optimization.

D. Beigel, IWR: ODE Simulation
Dr. Dörte Beigel gave the subsequent lecture on ODE Simulation. Dörte Beigel is postdoctoral scientist at IWR and works on adaptive methods for simulation and optimization. She started her lecture with conditions for existence and uniqueness of solutions of initial value problems in ODEs. Afterwards, she presented numerical methods for this class of problems. She focused on explicit Runge Kutta methods and implicit BDF methods and pointed out their suitability for the different types of IVPs.
K. Mombaur, IWR: Boundary Value Problems
The final lecture of the first day was on Boundary Value Problems given by Prof. Katja Mombaur. After presenting the problem formulation and examples she described theoretical solution aspects and the appearance of these problems in optimization tasks. As solution methods Katja Mombaur presented single shooting, multiple shooting and collocation. The multiple shooting algorithm combines the advantages of single shooting and collocation (usage of system knowledge, adaptive solution of differential equation).
The second day of the workshop was dedicated to a compact course on advanced topics for optimization with differential equations.

**D. Beigel, IWR: Derivatives**

Dr. Dörte Beigel gave the first lecture, which was dedicated to derivatives that play a crucial role in optimization. She presented different approaches to compute derivatives of functions and pointed out that Algorithmic Differentiation is most favorable. To compute derivatives of IVP solutions, also called sensitivities, Internal Numerical Differentiation is recommended. This approach relies on Algorithmic Differentiation techniques as well.

**D. Clever, IWR: Optimal Control**

Dr. Debora Clever gave the lecture on Optimal Control. Debora Clever is postdoctoral researcher at IWR and works on optimal control problems in the context of human and humanoid motion. She gave an overview on the underlying theory for solving optimal control problems, which are characterized by infinite dimensional control and state functions. She presented indirect and direct numerical approaches to solve these problems in practice and focused on the powerful Direct Multiple Shooting method.

**J. P. Schlöder, IWR: Parameter Estimation**

The third lecture of the day was on Parameter Estimation, given by Dr. Johannes P. Schlöder. First, some examples to illustrate typical properties of parameter estimation problems in practice were given. Then he explained direct structure-exploiting methods to solve nonlinear constrained parameter estimation problems with differential equations and pointed out the superiority of Direct Multiple Shooting combined with Generalized Gauss-Newton methods.

**S. Körkel, IWR: Optimum Experimental Design**

Subsequently, Dr. Stefan Körkel gave a lecture on Optimum Experimental Design. Here, the goal is to define optimal experiments, which allow the most significant
identification (estimation) of the model parameters since only validated models can be used for optimal control of processes. Stefan Körkel presented a framework for sequential model validation and applied this approach to a chemical reaction process from BASF. It turned out that the optimum experimental design approach indeed outplays an experienced chemist.

**G. Kanschat, IWR: PDE Simulation**

After the lunch break Prof. Guido Kanschat held a lecture on PDE Simulation. Guido Kanschat is professor at IWR and head of the group “Mathematical Methods of Simulation”. In his talk he stressed that reliable numerical methods to solve PDEs are crucial, e.g. in the design of nuclear reactors, but as there exist numerous PDE classes special-tailored treatment by experts is needed. Guido Kanschat presented a case study for discontinuous Galerkin methods and gave an overview on methods to solve stationary PDEs. Finally, he described the ingredients of a PDE solver with the help of the software package deal.II.

**A. Potschka, IWR: PDE Optimization**

Dr. Andreas Potschka gave the subsequent lecture on PDE Optimization. Andreas Potschka is head of the junior research group “Model-Based Optimizing Control” at IWR. He started the talk with an elliptic PDE-constrained optimization problem to figure out the importance of function space theory to get efficient numerical methods. After discussing some theoretic issues and one-shot solution methods he presented an efficient numerical approach based on Direct Multiple Shooting to solve optimization problems in parabolic PDEs.

**C. Kirches, IWR: Real-Time Optimization**

The last lecture of the compact course was on Real-Time Optimization given by Dr. Christian Kirches. In optimal control of real-world processes closed loop feedback control is necessary to deal with process disturbances. With the help of examples from automotive engineering Christian Kirches presented efficient state-of-the-art numerical methods to solve the optimal control problems appearing in nonlinear model predictive control.
M. Gräber, TLK Braunschweig:
Optimal Power Management of Parallel Hybrid Electric Vehicles
Dr. Gräber reported about cooperation with IWR, topic was the heat power management of hybrid engines. The first aim was optimal control in order to minimize heat consumption. Computations were made with MUSCOD, which was coupled to a Modelica library. Using a simplified model with implicit switches, a NMPC strategy was implemented. Several optimization scenarios and strategies were presented reducing the fuel consumption up to 4.8 %. Challenges in this project are real-time optimization, the shift initialization and the treatment of shrinking horizons.

S. Lenz, IWR: Multiple Shooting Methods for Satellite Orbit Determination
Mr. Lenz cooperates with ESA/ESOC in the field of satellite orbit determination. He applies state-of-the-art methods for parameter estimation, namely a multiple shooting parameterization and a Gauss-Newton method. Tailored projection techniques have been developed that provide suitable multiple shooting initial guesses. The launch of the ARTEMIS satellite was considered as a challenging test case for orbit determination. The IWR software PARFIT (which realizes multiple shooting) turns out to be much more reliable than the ESOC software BAHN (which employs single shooting). Further test cases for which multiple shooting has turned out to be highly advantageous are highly elliptic orbits and reentry trajectories. As a conclusion, successful treatment of real-world problems requires both experts for the particular application and numerical mathematicians.

T. Richter, Applied Mathematics:
Simulation and Optimization of High Performance Ball Bearings
Prof. Richter reported about a cooperation with Rockwell-Collins regarding simulation and optimization of ball bearings used for satellite motion. Important issue is the modeling of the oil lubrication film where difficulties in anisotropy, extreme pressures, large deformations occur. The models comprise nonlinear material laws, modified Navier-Stokes equations, an energy equation and the elasticity equation. Key technique is the treatment of fluid-structure interaction as a 3D problem leading
to a huge system, which is solved adaptively using goal-oriented error estimation by dual weighted residuals. The results of the simulation are compared to experimental data. For the computations the software GASCOIGNE was used embedded in a production environment. The future optimization challenge is parameter estimation.

**V. Schulz, Universität Trier:**

**Efficient Shape Optimization in Industrial Applications**

Prof. Schulz cooperates with DLR, Airbus and E.G.O. Oberderdingen with regards to PDE for efficient shape optimization. As an example he presented the Very efficient large aircraft (VELA). Methods are flow solvers and gradient based optimization within a primal-dual SQP approach. The PDE constrained optimization problem is treated with a one-shot-approach using adjoints. Derivatives are evaluated with shape calculus, in particular shape Hessians. This approach is much faster than parameterized shapes. As an application example the shape optimization of a hot plate was presented.

**K. Mombaur, IWR: Optimization in Orthopedics & Robotics**

Prof. Mombaur reported about her projects, e.g. in cooperation with KUKA and Össur, about mechanical modeling, multibody dynamics and optimal control. In the KOROIBOT project human and humanoid walking is investigated, subject of the ECHORD project are optimal paths. Another application is the development of prostheses, e.g. the ones of Oscar Pistorius, where questions of modeling, optimal running and functional electrical stimulation are treated. In the MOBOT project active mobility assistance robots for indoor environments are developed, e.g. for sit to stand motions. Exoskeleton wearable robots aim to enable paraplegic patients to walk.

**S. Menzel, Honda Research Institute Europe GmbH:**

**Efficient Shape Deformations for Simulation-based Design Optimization**

Dr. Menzel presented the research on representation methods for simulation-based design optimization carried out at HRI-EU. Shape morphing algorithms are combined with evolutionary optimization algorithms as metaheuristics for efficient stochastic search of the global optimum. Illustrative practical examples ranging from gas turbine design to automotive parts and motorsport design gave an insight
of the application in an industrial environment. In a recent collaborative research project with Bielefeld University the advantages of radial basis function based deformation methods had been evaluated and demonstrated. Current target of this collaboration is a direct integration of constraints in the shape morphing minimizing the number of invalid geometries during a fully automated design optimization.

S. Körkel, IWR: Industry on Campus at IWR – Cooperation with BASF
Dr. Körkel presented the cooperation of his research group with BASF. They develop methods for model validation and process optimization. Optimization based modeling comprises parameter estimation and optimum experimental design in an iterative way. Validated models allow the optimization of the process wrt. a performance index. The methods are applied to the model classes of ordinary, differential algebraic and partial differential equations. In the doctoral projects in the group aspects of applications and modeling, development of new efficient numerical methods and software development are important. Several real world application cases from BASF were sketched. Dr. Körkel presented the software VPLAN, a virtual laboratory for nonlinear dynamic processes and discussed several demands and strategies in software development.

R. Lee, BASF SE:
PDE Models for Heterogeneous Catalysis: Validation and Optimization
Dr. Lee is working on heterogeneous catalysis. He is applying mathematical methods and software developed at IWR Heidelberg. The model formulation comprises a description of the chemical reactor, Fick’s law, continuity equations, drift-diffusion, as well as a reaction scheme with appropriate reaction kinetics. Optimization of the process is the long-term goal of the work. The main optimizable quantity is the catalyst-filling profile. Dr. Lee showed the model equations and the optimization problem with an objective function in Euro (€). Optimization results yield an improvement of several percent. Further challenges are the incorporation of other transport terms and the introduction of new time scales. Dr. Lee emphasized that heterogeneous catalysis is an extremely important problem class for BASF.
KoMSO

Prof. Bock introduced KoMSO, the Committee for Mathematical Modeling, Simulation and Optimization. It serves as network within the “Mathematics for Innovations in Industry and Services” program established by the Federal Ministry of Education and Research (BMBF). The KoMSO Coordination Office is located at the Interdisciplinary Center for Scientific Computing (IWR) in Heidelberg and is led by Dr. Anja Milde. KoMSO is a strategic alliance that was founded in 2011 in response to the Strategietag Mathematik 2020 (Strategy Day for Mathematics), a component of the Strategy Dialogue for Mathematics. The latter was established by the German Federal Ministry of Education and Research during the Year of Mathematics 2008. KoMSO unites the triad of mathematical modeling, simulation and optimization as new field of technology in research and development to reinforce the innovational strength of Germany as a location of technology. Social prosperity relies on research and innovation. Consequently, previously undiscovered or only partially utilized potentials of MSO need to be detected and made visible.

KoMSO is dedicated to gradually implement the objectives of the Strategy Day for Mathematics 2020:
• Facilitation and Coordination of regional and national Networks
• Promotion of Further and New Development of MSO Methods and their Application
• Proposing and Implementing of Events regarding Key Issues to identify new Challenges for Research and Development
• Determining Guiding Principles for Research Key Topics
• Consultation for Research Aid Programs
• Quality Evaluation and Management of MSO
• Promoting Young Scientists
• Promoting Scientific Environments of MSO
• Promoting Industrial Application
• Information Exchange
• Introducing Success Stories

KoMSO is also part of the European Service Network of Mathematics for Industry and Innovation (EU-MATHS-IN), an initiative to facilitate mathematics for industry in Europe.
C. Weiler, IWR: Optimum Experimental Design for Gaussian Disorder Modeled Organic Semiconductor Devices

Mr. Weiler talked about the modeling, simulation and optimization-based model validation of charge transport in organic semiconductors. Steady state models are described as van Roosbroeck systems with the generalized Einstein relation and the extended Gaussian disorder model for the organic mobility function. To achieve robust simulation, Mr. Weiler has developed a new stabilization term for the extended Gummel method, the switching from Gummel to Newton and a contraction based damping strategy. Moreover, Mr. Weiler has applied internal numerical differentiation for efficient evaluation of the derivatives of the states wrt. parameters and experimental design controls. The talk ended with the presentation of optimum experimental design results for organic semiconductor materials.

R. Kircheis, IWR: Microbial Enhanced Oil Recovery

In cooperation with BASF and Wintershall, Mr. Kircheis is developing a validated model for microbial enhanced oil recovery. In the presentation he showed the PDE model equations and explained the sand pack experiments, which are carried out at the industrial partners. Mr. Kircheis is developing numerical methods for simulation and parameter estimation. He showed first computational results for water flooding and bacteria concentration.

C. Kirches, IWR: Mixed-Integer Real-Time Optimization for Predictive Cruise Control of Heavy Duty Trucks

Dr. Kirches is cooperating with Daimler’s division for heavy duty trucks. Aim is the development of an intelligent cruise control system in a real-time capable implementation. Based on an ODE truck model, Dr. Kirches presented a mixed integer optimal control problem resp. a mixed integer NMPC problem. To cope with the combinatorial explosion of this problem, Dr. Kirches suggests using partial outer convexification in combination with relaxation techniques. As a toy example, he presented the application of the approach to the moose test setting. Here, vanishing constraints and, thus, a violation of the constraint qualification pose specific numerical difficulties. As a result, optimization yields savings of 3 – 5% fuel.
J. Poland, ABB Corporate Research Switzerland: What is Missing to Make Stochastic Optimization an Established Industrial Practice?
In this talk, the straightforward application of randomized sample based dynamic optimization to control problems with uncertainty was investigated. Using a battery control problem with stochastic load as a working example, it was observed that the probability distribution of the optimal decisions might depend on the optimization setup (cost functions, horizon length) in a counter-intuitive way. Moreover, sample complexity is a critical issue. In order to overcome these difficulties, further development of advanced computational tools will be necessary to facilitate broad and successful application of stochastic optimization.

S. Valentin and I. Malanchini, Bell Labs, Alcatel-Lucent: When Dantzig, Shannon, and Jobs Meet: Selected Optimization Challenges in Wireless Communications
Dr. Valentin and Dr. Malanchini presented challenges in the optimization of cellular networks. Current research areas are the context-aware and anticipatory allocation of wireless channel resources, the optimization of mobile media streaming, and the pooling of cellular base stations in the „cloud“. Behind these topics are time-variant combinatorial optimization problems, e.g., subband allocation or user association, which have to be solved in real time. These problems are treated by integer programming with relaxation to convex problems. Future challenges will be: transceiver design for thousands of antennas, pro-active resource allocation based on user tracking, and coordinating resource allocation over a large number of cells. Dr. Valentin claimed that there would be “No iPhone without optimization”.

K. Springer, Johannes Kepler University of Linz: Selected Optimization Topics for the Design and Operation of Multibody Systems
DI Springer presented work on multibody system dynamics where the tasks are time optimal path-planning and optimal control combined with geometric path planning and the generation of point-to-point trajectories. As an example he presented the avoidance of vibrations for lightweight robots. Further tasks are inverse kinematics,
geometric topology optimization for kinematics and dynamics, and the design of revolute resp. prismatic subsystems. Among the mathematical methods to solve these problems are dynamic programming, model based optimal control and stochastic optimization. Challenges are the minimization of computational complexity and the use of combined optimization instead of sequential optimization.

**V. Reinhardt, SEW Eurodrive: Selected Optimization Topics for the Design and Operation of Electric Drives**

Dr. Reinhardt works on the computation and design of electric motors and implications of this design for other components of electric drives, which comprise gear, frequency inverter and the corresponding software. Optimization tasks are design, model calibration, operation and control. An automated design process was presented for an induction machine. Model calibration and geometry optimization are applied for power-loss torque maximization resulting in mechanical power increase. Challenges are e.g. the incorporation of both mechanics and thermal behavior, and multi-physics.

**T. Binder, IAV GmbH: Optimization Tasks in Automotive Industry**

The engine control unit (ECU) is the brain of the vehicle. Its control tasks are mainly tackled by closed loop control using fixed-point arithmetic. It controls e.g. fuel supply and mixture formation by adaptively correcting injection valve differences. An important task is failure detection, where no false positive should occur. The design of an imperfect classification criterion with discriminatory power and automatic exclusion is an optimization problem, which can be tackled by machine learning methods. Another objective in calibrating ECUs is consumption reduction for the combustion engine. For simulation of hybrid electrical vehicles, the challenging class of differential equations with continuous and discrete controls and switches, e.g. hybrid mathematical models, are employed. Dr. Binder stated that her company applies and develops mathematical methods because a function developer’s man-year is cheaper than a superior but more expensive engine component.
G. Gienger, ESA/ESOC: Gaia Global Microarcsecond Astrometry: An Extremely Large Parameter Estimation Problem
The ESA satellite Gaia was launched in Dec 2013. It performs angular measurements of unprecedented accuracy for one billion stars in our galaxy. The astrometric core solution is a simultaneous least-squares estimation of about half a billion parameters, including the astrometric parameters. By now, it is based on traditional normal equations method. Dr. Gienger proposed to take advantage of orthogonalization methods for the Gaia astrometric core solution to avoid the known numerical limitations of the normal equations method.

C. Garbe, IWR/HCI: Industrial Image Processing — Optimization of Visual Information
Dr. Garbe presented part of his work in light field imaging for industrial inspection. He heads an independent research group at the Heidelberg Collaboratory for Image Processing (HCI) where he cooperates e.g. with Bosch, Sony, Zeiss, Mercedes-Benz, Intel, Volume Graphics and Edevis. The different aspects of illumination, image acquisition, image processing and analysis can be naturally united under the umbrella of light field imaging. Concepts of computational photography have to be applied in order to extract object geometry or structures from scenes. Completely different aspects of a scene, such as motion or structure, can be extracted using different dimensions of the light field, but employing similar algorithms. Different approaches for optimization are used for accurately estimating parameters of the scene given noise and systematic errors due to specular reflections, which need to be suppressed. Light field imaging a very powerful tool for a wide range of industrial and scientific applications.

A. Altmann-Dieses, University of Applied Sciences Karlsruhe: Transferring Mathematical Innovations to User-Oriented Products and Services – Challenges in Applying MSO-Tools to Solar Air-Conditioning
Prof. Altmann-Dieses demanded professionalism of mathematical innovations to make them available to users, by implementing them in professional software packages. She argued that university structures are not feasible for this so far. As a case study she presented the application of VPLAN to solar air-conditioning. Users are, on the one hand, bachelor and master students in engineering at HS Karlsruhe
working on models, e.g., for solar gain and cooling loads, the adsorption chiller, a stratified storage tank, collectors, blower convectors and room air, and designing a test plant at HS Karlsruhe. The students have to build validated models using the mathematical methods for parameter estimation and optimum experimental design with VPLAN and thereafter apply model-based optimization of plant design. These students can be considered prototypical users of the methods in academia being non-mathematicians. On the other hand, the students should be seen as multipliers to bring these methods to large companies and to SMEs. University software has a huge potential but requires high activation energy. Prof. Altmann-Dieses suggested that aspects as GUI, handbook, interfaces to common software packages, internet forums, technical support and consulting are important but cannot be provided by academia – a fact which constitutes an obstacle for broad use. She considers the reasons for this low professionalism in the structures of academia and the academic award system, where the focus lies on solution approaches but not on professionalism and commercialization. She claimed that the transfer of mathematical innovations by transfer institutions with public funding and the creation of incentives for this is a must for the future and a moral obligation.
PANEL DISCUSSION: CHALLENGES OF INDUSTRIAL OPTIMIZATION

To close this 4-day compact course and challenge workshop, the event was followed by a panel discussion moderated by Dörte Beigel, focusing on the challenges of industrial optimization. In this discussion, A. Badinski (BASF), H. G. Bock (IWR), M. Ehinger (Rockwell Collins), C. Garbe (IWR/HCI), G. Gienger (ESA/ESOC), and R. Rannacher (IWR) debated these issues with the audience. The following challenges were identified:

Demands from Industry:
- Regarding structural aspects, industrial project management is different from that of academia. For company-internal communication as well as for communication between industry and academia, too much mathematical detail can be prohibitive.
- On the other hand, positive experience from successful past collaborations tends to create mutual “trust in advance” between partners from academia and industry.
- Personal discussions are more useful for industrial partners than reading books. Therefore, communication on a regular basis is welcome.
- There exists a need for intensified industry-academia cooperation in terms of determining specific problems, finding the right tools, continuous involvement in model building, model validation, optimization, and solution transfer in order to produce a success story.
- In many companies researchers see the need to introduce new scientific methods. But there is a reported lack of introducing and promoting such new technologies in R&D departments.
- Management boards need to be convinced of the high potential gained by using new scientific methods both by their in-house researchers and scientists from academia, for example with the help of success stories.
- Industry and academia agree that success stories are an important scientific marketing instrument.

Potential Contributions from the HCO:
- Latest research results have not yet spread far into industry. On the other hand, there are hidden demands in industry that need to be addressed and solved.
• Even when state-of-the-art solutions exist, present-day challenges also require platforms for intensified regular communication (workshops!), mutual transfer of knowledge (vocational trainings!) and exchange of ideas.
• There is a need for stronger collaboration in mid- and long-term research between industry and academia as well as a need for solutions in economically reasonable time frames.
• HCO has the potential to bring industry and academia together, i.e. in a public-private partnership.
• Experience of a related collaboratory, the HCI, has shown that collaboration between several industrial partners can lead to a win-win situation for all partners. This may also open windows of opportunities for additional funding.
• Companies need strategic units and expertise, resp., to allocate appropriate methodologies and human resources to a project. Here, the HCO could offer assistance as crystallization point in close cooperation with the respective company.
• HCO offers a number of incentives for industrial partners: to use the graduate school as location for special training, to obtain funding, e.g., through the excellence initiative or the BMBF, or to involve KoMSO for networking and scientific marketing.
• The sensitive issue of publishing vs. intellectual property rights needs special attention.
• H. G. Bock suggests to repeat similar workshops and to join forces in form of a newsletter that informs about strategic meetings, new plans and further steps.

Tentative Organizational Structure of the HCO and Prerequisites:
• Consortium: invite additional industry partners from global players and SMEs to join the HCO for mid- or long-term collaboration.
• Business model: there are public funding possibilities (EU, DFG, BMBF), but substantial investment by industrial partners is a precondition.
• Governance: unanimous decisions help to avoid confrontation of immediate competitors.
• Staff structure: there is a need for permanent staff for sustainable expertise and knowledge.
• Location: the new building (Mathematikon) offers space for the HCO and its direct industrial collaborators.
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