Fraunhofer
ITWM

FRAUNHOFER INSTITUTE FOR INDUSTRIAL MATHEMATICS ITWM

20 YEARS ITWM

The numbers all add up.

ANNUAL REPORT 2015/16

Front page

From fifteen to 180 scientists in twenty years: The Institute for Industrial Mathematics has continually expanded since its founding in November 1995. The number of employees has increased significantly as well.

ANNUAL REPORT
2015/16

CONTENT

As can be already assumed from our cover photo, 2015 was a jubilee year for ITWM: We are able to look back on twenty successful and varied years during which we secured a fixed position in the scientific community and a reputation as a reliable partner for industry. We have continuously advanced our mission to develop, implement, and apply mathematical methods for the modeling, simulation, and optimization of products, processes, and services for the economy and society.

The ITWM strategy process for the period 2016 to 2020 served as a guide throughout the year for the design of our organizational, scientific, and economic development. The organizational structure and operating procedures, revenue sources and cost factors, skills and business sectors were critically illuminated and questioned not only by the management, but also in great part by the staff of the departments with much dedication, motivation, and spirit. In a strategy audit, external experts from the scientific and business communities evaluated our current focus and our plans for the future. The findings by the evaluation committee once again give us valuable information for the future direction of the institute. We are also very pleased that in the auditors' overall opinion, the institute is already seen as being quite unique in the world: "No other institute supports and enables technological innovation through the results of mathematical research in a comparable scope or with a comparable success."

An employee survey was conducted in all organizational units of the Fraunhofer-Gesellschaft in 2015. The participation was very high with more than 80 percent of the staff at ITWM and the results show a high degree of identification with the institute. Overall, ITWM received good to very good ratings above the benchmark and was in the TOP 10 in nearly every area Fraunhofer-wide. Especially positive feedback was recorded for questions about transparency and satisfaction with allowances and compensation, working conditions, fair promotions, leadership, and customer orientation. The potential for improvement was noted in the areas of career development and planning, cooperation (both internal and external), and in the balance between project work and freedom of action in research. In this context, the ongoing succession process at the institute includes a series of measures in the planning stage.

A special highlight was the decision by Fraunhofer management to establish the High Performance Center Simulation and Software-based Innovation on January 1, 2016. It was the successful culmination of a long-standing effort by the Fraunhofer institutions and many local research partners to create just such a performance center in Kaiserslautern. Rhineland-Palatinate and regional industries agreed to make a significant contribution to the funding of the center. As a major research location, the overall profile of Kaiserslautern benefits from the fact that this performance center combines regional priorities on simulation and software in cooperation with the business community.

Another success with extra regional impact was achieved by the Financial Mathematics department: The department responded to and won a tender announced the previous year by the Federal Ministry of Finance for a Risk-Opportunity Rating of sponsored pension plan products. As a result, the neutral non-profit Produktinformationsstelle Altersvorsorge (PIA) was established. Parallel to the transition of the former department head Prof. Dr. Ralf Korn to the position of scientific consultant to the PIA, the department welcomed Dr. Andreas Wagner as the new head.

The outstanding highlights in the Optimization department were the licensing of an interactive radiation therapy planning method and the start of a research and development partnership with Varian Medical Solutions based in Palo Alto. Varian, with a solid market share of 60 percent, is the global leader in radiation therapy and provides the ITWM planning tool to cancer patients worldwide. For its scientific contribution in association with the German Cancer Research Center and University Clinic in Heidelberg as well as Massachusetts General Hospital and Harvard Medical School in Boston, the research team of department head Prof. Dr. Karl-Heinz Küfer received the Donors' Association Prize at the Fraunhofer Annual Conference 2016.

PREFACE

The technological development of simulations for human-vehicle-environment interaction was further expanded in 2015 in the areas of dynamics and durability by the Mathematical Methods department. After commissioning the interactive driving simulator RODOS® and the successful market launch of the geo-referencing system, Virtual Measurement Campaign (VMC®), we are now putting the REDAR (Road & Environmental Data Acquisition Rover) measuring vehicle into service.

The highlight at the Competence Center for High Performance Computing was the successful participation in the EU's H2020 FET-HPC program. Already well known at the European level, the CC HPC now has four EU sponsored projects with the BeeGFS Filesystem and the GPI programming model. In addition, the CC HPC presented Xtreemview, an interactive software for the visualization of large data volumes to prevail in the internal Fraunhofer Innovator Program competition and ensured funding for 2016.

Scientifically and economically, the year 2015 was a very successful one for the Transport Processes department. The strategy audit confirmed the department's excellent positioning and attests to outstanding prospects for the future. The department also used the strategy process to implement a new organizational alignment. Beginning in 2016, the former head Dr. Raimund Wegener and the former deputy Dr. Dietmar Hietel will alternate in the job of managing the department in two year terms.

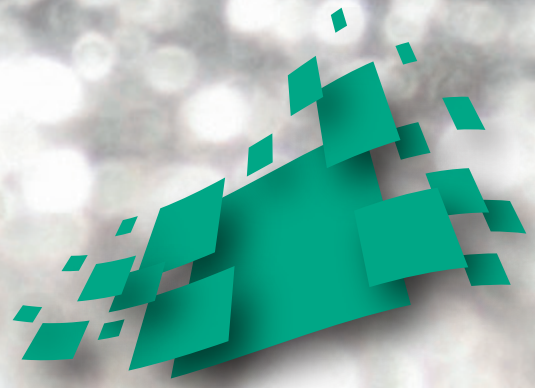
The Flow and Material Simulation department continued to achieve very positive results. Specifically, new collaborative ventures were initiated with regular customers like Procter & Gamble. The outstanding departmental cooperation with the spin-off company Math2Market is now expanded by a long-term agreement for development and applications in connection with the highly efficient micro-mechanical FE solver FeelMath.

The Image Processing department installed additional inspection systems in various production plants. In partnership with Hexagon Metrology and Hexagon Technology Center, the department develops fully automated solutions for the surface inspection and measurement of blisks (turbine rotors) in the "AMI4BLISK" project, which is part of the EU research program "Clean Sky for Aviation."

The System Analysis, Prognosis, and Control department has focused for many years on model-based design of controls and the validation of control algorithms. In many applications, the latter could only be achieved in the form of "model- or software-in-the-loop" simulations. However, since 2015, the department is operating a hardware-in-the-loop simulator with a sophisticated I/O interface.

I express my sincere gratitude to all the employees, fellows, and students for their productive scientific and economic efforts in a number of successful research areas and projects. A special note of appreciation applies to their enthusiastic response in our strategy planning effort. To our customers and project partners, I say "thank you" for your cooperation and trust and look forward to taking on new tasks and challenges with you in the future.

Prof. Dr. Dieter Prätzel-Wolters
Director of Fraunhofer ITWM



20 YEARS ITWM

The numbers all add up.

FRAUNHOFER ITWM

www.itwm.fraunhofer.de/en

20 YEARS ITWM – THE NUMBERS ALL ADD UP

1 *Interactions: Panel discussion with Dr. Klaus Weichel, Prof. Dr. Jürgen Schmidt, Dr. Marion Schulz-Reese, Prof. Dr. Jürgen E. Zöllner, and Prof. Dr. Dieter Prätzel-Wolters*

2 *Simulation of flexible components – demonstrated by Dr.-Ing. Joachim Linn*

Who could have imagined twenty years ago that mathematics would serve as a bridge between the virtual and real worlds - one so viable as to form the resilient foundation for a successful Fraunhofer Institute? Yet, the Fraunhofer Institute for Industrial Mathematics stands today with its problem-driven, model-based, and application-oriented work as a beacon in the scientific and business communities and enriches the reputation of Kaiserslautern as a center for research and innovation.

This was echoed by many of the guests from the government, business, and scientific communities who celebrated the 20th anniversary of the institute in November. A highlight at the celebration was the presentation of the Fraunhofer Sovereign to the institute's director Prof. Dr. Dieter Prätzel-Wolters; the coin is the second highest award of the Fraunhofer-Gesellschaft. Fraunhofer President Prof. Dr.-Ing. Reimund Neugebauer joined the festivities via video conferencing and praised Professor Prätzel-Wolters in his laudation for having rendered outstanding services to the institute and to the Fraunhofer-Gesellschaft. Specifically, he has served as Chairperson of the Science and Technology Council (WTR), a central advisory board of the Fraunhofer-Gesellschaft since 2006 and, as Chairperson of the most important WTR panel – the main commission. These roles are associated with his membership in executive committee and the Senate. "Anyone who knows Mr. Prätzel-Wolters also knows that he is a valuable advisor with profound expertise and a man of great vision. The Board appreciates, in particular, his advice in matters of research and human resource policies. Under his aegis, the WTR has become an extremely useful organ of the Fraunhofer-Gesellschaft; as a member of the Fraunhofer Future Foundation, Dieter Prätzel-Wolters also helped to promote the initial research in pioneering fields of technology," said the Fraunhofer President. Representing Prof. Neugebauer, Prof. Dr. Matthias Jarke, Chairperson of the Fraunhofer Group for Information and Communication Technology, presented the award.

The Rhineland-Palatinate Science Minister Vera Reiß offered congratulations on behalf of the Minister President Malu Dreyer: "The Fraunhofer ITWM has become an indispensable pillar of Germany's image as a center of education and research over the past 20 years. As a key technology, mathematics contributes innovative solutions to the pressing societal challenges of our time – from energy efficient businesses to consumer protection. The institute provides a substantial contribution to the training of highly qualified experts and works closely with the small and medium size enterprises in the region. It is also an engine of knowledge transfer and key to the innovation strategy of Rhineland-Palatinate."

A short video showed the institute from its beginnings in the mid-1980s in the Technomathe WG of the department of Mathematics at TU Kaiserslautern. This was followed by two rounds of talks; Dr. Marion Schulz-Reese, administrative director at ITWM, welcomed representatives from government and the community and then discussed with them the interrelationships between science and the society. The panel included the Lord Mayor of Kaiserslautern Dr. Klaus Weichel, President of TU Kaiserslautern, Prof. Dr. Helmut Schmidt, former Science Minister of Rhineland-Palatinate, Prof. Dr. E. Jürgen Zöllner, and the director of the institute.

Prof. Dr. Helmut Neunzert, the founder of ITWM, moderated the second round where, together with ITWM researchers and partners from science presented selected representative projects of the institute such as a simulation of cables, the optimization of radiation therapy planning, a battery simulation, and a flow calculation. In his concluding remarks, Professor Dieter Prätzel-Wolters thanked everyone for many years of trust and the ITWM staff for their dedication. He then gave an overview of other current projects, which included the establishment of the Performance Center for Simulation and Software-based Innovation. Suitable real estate nearby the institute has already been acquired.

Short video: "Die Rechnung ging auf" and more information about the history of the institute is provided at: http://www.itwm.fraunhofer.de/im-profil/fraunhofer-itwm-20-jahre

3 *Musical accompaniment at the buffet*

4 *After the award presentation: Minister Vera Reiß, Prof. Dr. Prätzel-Wolters, Prof. Dr. Matthias Jahrke, and Dr. Marion Schulz-Reese*

The Fraunhofer Sovereign

King Ludwig I of Bavaria had the sovereigns minted in remembrance of Joseph von Fraunhofer and Georg von Reichenbach, who jointly developed optical precision instruments. The Fraunhofer-Gesellschaft minted a limited edition of the Fraunhofer coin in 1986 and, ever since, honors people who have rendered outstanding services to the Fraunhofer-Gesellschaft with a presentation.

SUCCESSFUL AUDIT FOLLOWS INTENSIVE STRATEGY DEBATE

1 *After the successful audit: The strategy process institute managers with auditors*

2 *Prof. Dr. Ralf Korn, former head of the Financial Mathematics department and initiator of PIA with PIA director Dr. Melissa Ruby*

ITWM had only one day to present the findings of the one-year strategy process to the auditors: Dr. Wolfgang Burget (Liebherr), Prof. Dr. Heinz Engl (University of Vienna), Prof. Dr. Nicolas Gauger (TU Kaiserslautern), Prof. Dr. Albert Gilg (Siemens), Prof. Dr. Peter Maaß (Bremen University), Dr.-Ing. Kurt Pötter (BMW), and Dr. Mattias Schmidt (Procter & Gamble) – but the day concluded with extremely gratifying results. The experts were of the opinion that the institute is an exceptional success and argued in favor of maintaining its basic structure. Their recommendations included support to interdepartmental crucibles of innovation and enhanced cooperation with other Fraunhofer Institutes to develop further market potential. The experts also expressly supported the concept of the High Performance Center Simulation and Software-based Innovation.

NON-PROFIT "PRODUKTINFORMATIONSSTELLE ALTERSVORSORGE" (PIA) ESTABLISHED

The aim of the subsidized private pension plans is to provide financial security for the time following the active working years so that the customer is able to maintain their accustomed living standards. Starting in January 2017, an information sheet must be provided for each of the pension plan products offered to enable product comparisons by the consumer before signing a contract. The Fraunhofer-Gesellschaft established the non-profit "Produktinformationsstelle Altersvorsorge" (PIA) in October 2015 on behalf of the Federal Ministry of Finance (BMF) to perform a neutral evaluation of these pension products. The PIA received a grant from BMF for five years – with an option for an additional five years – to perform the tasks of the pension plan information center. As an independent scientific institute, Fraunhofer ITWM provides support to the PIA in improving the transparency and comparability of the pension plan products. The Financial Mathematics department of Fraunhofer ITWM has extensive expertise in using financial mathematics and statistical methods to develop innovative products and processes for the financial sector and government authorities.

To support PIA, the FM department conducts research, develops capital market models, and determines the opportunity-risk classes for the subsidized pension plan products offered. The institute developed a software called ALMSim, an Asset-Liability-Management (ALM) tool for this purpose. ALM is a risk management technique and, consequently, an important element of corporate management.

1

HIGH PERFORMANCE CENTER FOR "SIMULATION AND SOFTWARE-BASED INNOVATION"

As a center of education and research, Kaiserslautern has earned an excellent reputation in the area of simulation and software technology, which is reflected in the numerous joint ventures with business enterprises. A major part of the Fraunhofer strategy for sustainable development of the location is to bundle the regional research priorities even more. This is the thought behind the establishment of the high performance centers. These centers present an excellent platform for a subject-focused collaboration by the local Fraunhofer Institutes with universities and other non-university research institutions.

1 *Fraunhofer President Reimund Neugebauer at the opening of the new High Performance Center in Kaiserslautern*

As of January 2016, the extensive exchange among the three Fraunhofer Institutes in Kaiserslautern with the two universities and the excellent relationships to the regional economy has been formalized by the creation of the high performance center. As the name implies, "Simulation and Software-based Innovation" documents the scientific focus that has emerged in Kaiserslautern over the past two decades. The high regard for simulation and software skills by the business community can be seen in the list of industry partners. These include: BASF, Daimler, John Deere, Liebherr, Procter & Gamble, Robert Bosch, Schmitz Cargobull, and Volvo Construction Equipment Germany. From a scientific perspective, the application-oriented research of the three Fraunhofer Institutes: for Experimental Software Engineering IESE, for Industrial Mathematics ITWM, and for Physical Measurement Systems IPM (Material Characterization and Testing department) is strengthened by approximately 30 Chairs of the TU Kaiserslautern and the Kaiserslautern University of Applied Sciences. In addition, there is close cooperation with, for example, the German Research Center for Artificial Intelligence DFKI, the Institute for Composite Materials IVW, and the Max Planck Institute for Software Systems.

Computer simulations and software programs today are an essential tool for the design and optimization of products and processes. The requirements based development of software and simulations for technical processes will be a major challenge for mathematics and the information technologies throughout the next decade. The performance center will address these issues in cooperation with the universities, research institutes, and industry partners.

In the first two years, the performance center receives start-up financing in the total amount of five million euros from Land Rhineland-Palatinate. During the same period, the industry partners contribute another five million euros, and the Fraunhofer Institutes one million euros. The responsibility for coordinating the activities of the performance center is assigned to the director of Fraunhofer ITWM, Prof. Dr. Dieter Prätzel-Wolters.

DR. MARION SCHULZ-REESE
HEAD OF ADMINISTRATION

INSTITUTE PROFILE

Computer simulations are an indispensable tool in the design and optimization of products and production processes, services, communication processes and work processes. Real models are replaced by virtual models. Mathematics plays a fundamental role in the creation of this virtual world. Mathematical models cut horizontally across a landscape of vertically arranged scientific disciplines and technological applications. This transverse character of mathematics makes it a "generic technology"; as a basis for bridging into the simulation world, however, it also becomes the key technology for computer simulations which have found their way into nearly all areas of economic life. Increasingly more small and medium-sized companies utilize simulation for cost reduction. It is specifically these companies that the Fraunhofer ITWM supports with consultation and computing power. They profit in the market through the use of simulation as identification for innovation and quality assurance of their products.

Of course, we also work together with large companies, especially in the motor vehicle sector, in machine construction, the textile industry, in microelectronics, with banks and the computer industry. Consultation in R&D questions, support in the use of high-performance computer technology and provision of custom-tailored software solutions are integral building blocks of our work.

Along with the implementation of this technology in application projects and its further development in research projects, the close collaboration with the Department of Mathematics at the University of Kaiserslautern is also a point of emphasis for the Fraunhofer ITWM. The classical disciplines of applied mathematics such as numerics, optimization, stochastics and statistics as well as differential equations are cornerstones.

The specific competencies of the ITWM are

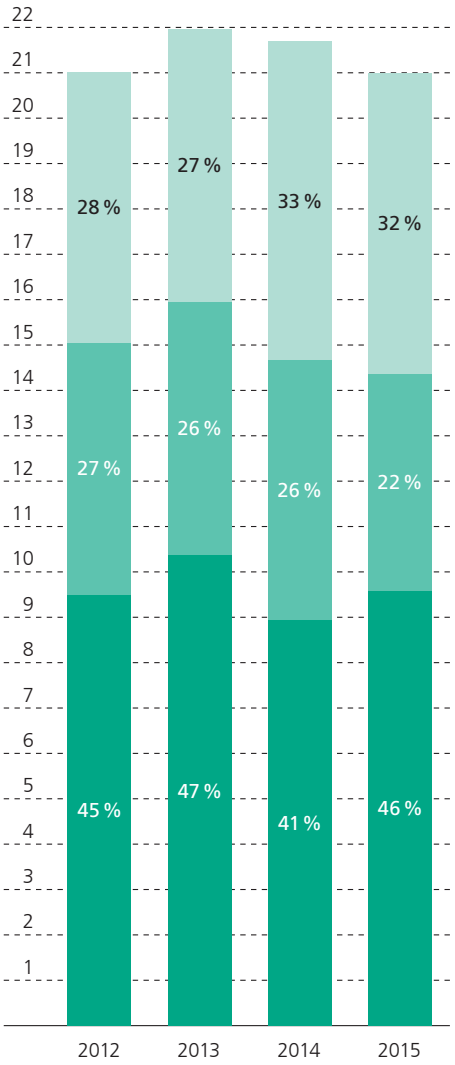
- Processing of data acquired from experiments and observations
- Drafting of mathematical models
- Implementation of mathematical problem-solving in numerical algorithms
- Summarization of data, models and algorithms in simulation programs
- Optimization of solutions in interaction with the simulation
- Visualization of simulation runs in images and graphics

The ITWM is member of the Fraunhofer ICT Group as well as associated member in the Fraunhofer Group for Materials and Components – MATERIALS. In addition, the good networking within the Fraunhofer-Gesellschaft documents the participation in numerous Fraunhofer Alliances: Automobile Production, Battery, Big Data, Cloud Computing, Lightweight Design, Simulation, Textile, Traffic and Transportation, and Vision.

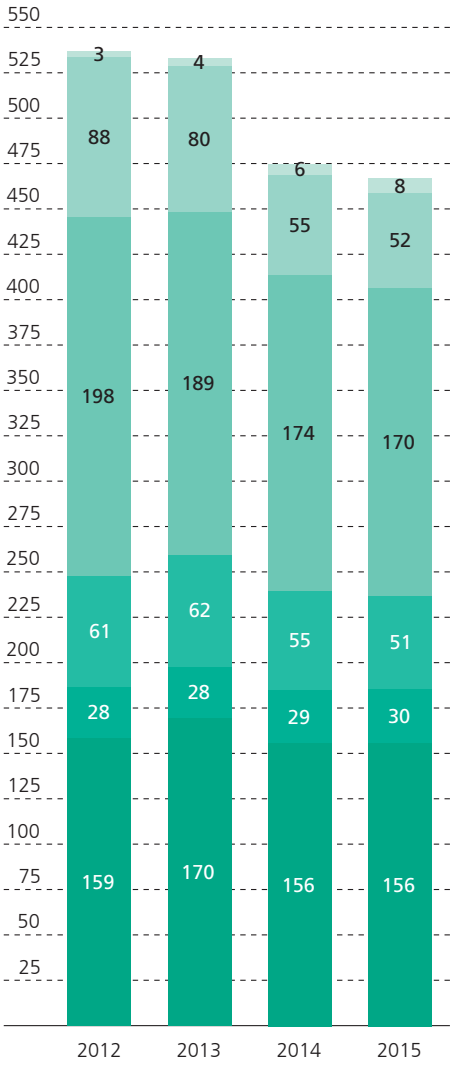
BUDGET AND PERSONNEL DEVELOPMENT

Operation budget in million €

- industry
- public projects
- base funding and Fraunhofer internal programs



- scientists and technicians
- central services
- PhD students
- research assistants
- interns
- trainees



CUSTOMERS AND COOPERATION PARTNERS SELECTION 2015

- AbbVie Deutschland GmbH & Co. KG, Ludwigshafen
- ante-holz GmbH, Bromskirchen-Somplar
- Audi AG, Ingolstadt
- Autefa, Friedberg
- BASF SE, Ludwigshafen
- Bayer CropScience AG, Monheim
- BJS Ceramics, Gersthofen
- BMW Group, München
- BorgWarner Turbo Systems GmbH, Kirchheimbolanden
- BPW Bergische Achsen KG, Wiehl
- Brückner, Siegsdorf
- BSN, Hamburg
- Burgmann, Wolfratshausen
- Centre de Recherche en Automatique de Nancy, Nancy (F)
- Centrica, Stavanger (N)
- Continental Automotive Systems AG, Frankfurt/M.
- Cummins, Marktheidenfeld
- DAF Trucks N. V., Eindhoven (NL)
- Daimler AG, Stuttgart
- delta h Ingenieurgesellschaft mbH, Witten
- Deutsche Apotheker- und Ärztebank, Düsseldorf
- Dilo, Eberbach
- Ebm-papst, Mulfingen
- ElringKlinger AG, Runkel
- Elsevier Ltd., Kidlington (GB)
- ESI Group, Paris (F)
- fleXstructures GmbH, Kaiserslautern
- FLSmidth, Kopenhagen (DK)
- Ford-Werke GmbH, Köln
- Forschungsinstitut für Leder und Kunststoffbahnen, Freiberg
- Freudenberg Filtration Technologies SE & Co. KG, Kaiserslautern, Weinheim
- Glatfelter, Pritzwalk
- Gneuss, Bad Oeynhausen
- Goldbeck Solar GmbH, Hirschberg a. d. Bergstraße
- Goodyear S.A., Colmar-Berg (L)
- Grimme Landmaschinenfabrik GmbH & Co. KG, Damme
- GRS mbH, Köln
- Haag-Streit AG, Köniz (CH)
- HegerGuss GmbH, Enkenbach-Alsenborn
- Helmholtz-Institut, Ulm
- Hexagon Metrology GmbH, Wetzlar
- Hilite, Nürtingen
- Hospitals: Essen, Frankfurt/M., Mainz
- IBS FILTRAN GMBH, Morsbach-Lichtenberg
- Imilia Interactive Mobile Applications GmbH, Berlin
- Institut für Textiltechnik (ITA), Aachen
- IPConcept S.A., Luxemburg (L)
- John Deere, Mannheim, Kaiserslautern
- Johns Manville Europe GmbH, Bobingen
- KITE China, Beijing (CHN)
- Knauf Gips KG, Iphofen
- KSB Aktiengesellschaft, Frankenthal
- KTM-Sportmotorcycle AG, Mattighofen (A)
- Liebherr, Kirchdorf, Colmar (F)
- LONZA Group AG, Basel (CH)

- MAGMA Gießereitechnologie GmbH, Aachen
- MAN Truck & Bus Deutschland GmbH, München
- Mann+Hummel GmbH, Ludwigsburg
- Marathon Oil, Houston (USA)
- Massachusetts General Hospital (MGH) / Harvard Medical School, Boston (USA)
- Math2Market GmbH, Kaiserslautern
- Merck KGaA, Darmstadt
- MeVis Medical Solutions AG, Bremen
- MVZ Dres. Englmaier, Waldkraiburg
- Nettowelt GmbH & Co. KG, Goslar
- Nissan, Kanagawa (J)
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- Plastic Omnium, Brüssel (B)
- Porsche AG, Weissach, Stuttgart
- proALPHA Software AG, Weilerbach
- Procter & Gamble, Schwalbach, Cincinnati (USA)
- Progress Rail Inspection & Information Systems, Bad Dürkheim
- PSA Peugeot Citroën, Velizy-Villacoublay Cedex (F)
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- Schmitz Cargobull AG, Altenberge
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- ThinkparQ, Kaiserslautern
- TRW, Alfdorf
- Universities: Aachen, Bordeaux (F), Bremen, Chemnitz, Dijon (F), Dresden, Erlangen, Freiberg, Freiburg, Heidelberg, Kaiserslautern, Karlsruhe, Kassel, Mainz, Münster, Nancy (F), Paris/Fontainebleau (F), Saarbrücken, Thuwal (KSA), Ulm
- Universities of Applied Sciences: Berlin, Birkenfeld, Darmstadt, Kaiserslautern, Mainz
- Varian Medical Systems Deutschland GmbH, Darmstadt
- Voith Hydro, Heidenheim
- Volkswagen AG, Wolfsburg
- Volvo CE, Konz, Göteburg (S)
- Wikon Kommunikationstechnik GmbH, Kaiserslautern

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NETWORKING AND COOPERATIONS

ITWM is integrated in a network of national and international partnerships and a member of several associations within the Fraunhofer-Gesellschaft:

- Fraunhofer ICT Group
- Fraunhofer Group for Materials and Components – MATERIALS (as associated member)
- Fraunhofer Alliances: Automobile Production, Battery, Big Data, Cloud Computing, Lightweight Design, Simulation, Textile, Traffic and Transportation, and Vision
- Fraunhofer Innovation Cluster "Digital Commercial Vehicle Technology"
- High Performance Center "Simulation and Software-based Innovation"

Further cooperations

- Innovation Center "Applied System Modeling"
  The Fraunhofer Institutes IESE, ITWM, IPM (Department Materials Characterization and Testing) as well as the departments of Computer Science and Mathematics at TU Kaiserslautern work in close cooperation at ASM to bring high tech products to market quickly.
- Center for Mathematical and Computational Modeling
  $(CM)^2$ co-located in the Mathematics department of TU Kaiserslautern, is focused on mathematical applications in the engineering sciences.
- Felix Klein Center for Mathematics FKZM
  The FKZM is an institutional pooling of resources from the Mathematics department at TU Kaiserslautern and Fraunhofer ITWM, with a focus on the promotion of young researchers, to include modeling weeks for schools, scholarships, and a mentor program for students of mathematics.
- Science Alliance Kaiserslautern
  Network of academic and research institutes as well as regional enterprises in Kaiserslautern

THE FRAUNHOFER-GESELLSCHAFT AT A GLANCE

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

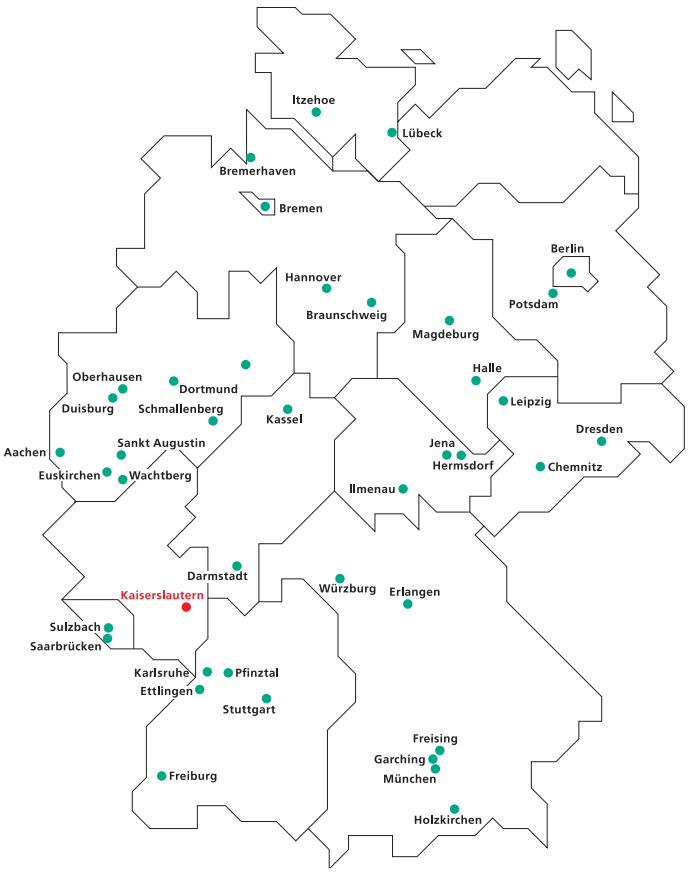
At present, the Fraunhofer-Gesellschaft maintains 67 institutes and research units. The majority of the nearly 24,000 staff are qualified scientists and engineers, who work with an annual research budget of more than 2.1 billion euros. Of this sum, more than 1.8 billion euros is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and Länder governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers.

As an employer, the Fraunhofer-Gesellschaft offers its staff the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institute, at universities, in industry and in society. Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects of starting and developing a career in industry by virtue of the practical training and experience they have acquired.

The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787–1826), the illustrious Munich researcher, inventor and entrepreneur.



In industrial applications FIDYST is used to optimize nonwovens production processes. With FIDYST several companies improve their spunbond, meltblown, and airlay processes. The engineers systematically use the fiber dynamics simulations in order to design the machinery as well as the process parameters.

TRANSPORT PROCESSES

▪ FLEXIBLE STRUCTURES

Modeling and numerical simulation of flexible structures in turbulent flows, especially fiber dynamics

▪ FLUID DYNAMICS

Simulation and optimization of flows, fluid-structure coupling

▪ MESHFREE METHODS

Finite Pointset Method (FPM) for simulation of fluid and continuum mechanical problems

▪ OPTICS, RADIATION, HEAT

Design of freeform lenses, heat transfer, diffusion

▪ MODEL REDUCTION

Transfer of huge finite element models to parametric reduced state space models

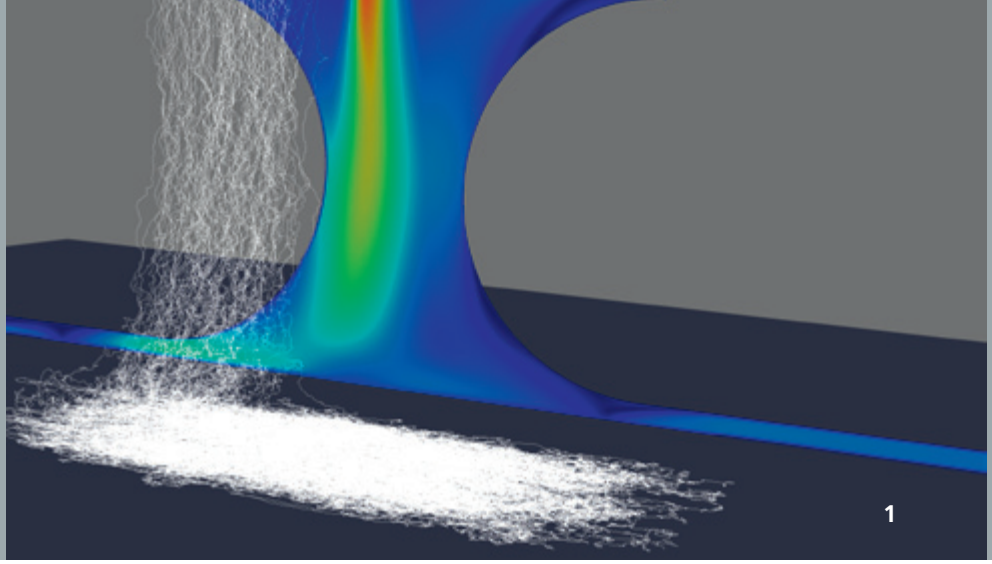
www.itwm.fraunhofer.de/en/tv

DR. RAIMUND WEGENER
HEAD OF DEPARTMENT

The core competence of the department Transport Processes is mathematical modeling of complex manufacturing problems and the development of efficient algorithms for their numerical solution (simulations). The problems primarily worked out in the context of the technical-natural sciences (fluid dynamics, radiative transport, optics, acoustics, structural mechanics, etc.) and mathematics, lead to differential equations that can be mainly characterized as transport equations. Our industry customers are primarily interested in optimization or the technical design of products and production processes. The department's product range includes collaborative research projects with the engineering-oriented R&D divisions of the partner firms, studies that include design and optimization proposals, and software development from components to complete tools.

Scientifically and economically, the year 2015 was a very successful one for the department. The Institute's strategy audit confirmed the department's excellent positioning and attests to outstanding prospects for the future. Additionally, important organizational guidance was established for the future. A decision was taken to rotate the department's leadership every two years: starting in 2016, Dietmar Hietel begins a two-year term at the helm; in 2018, it will rotate back to Raimund Wegener.

The year 2015 was also the 20th anniversary of ITWM and, appropriately, two of three project reports below are closely related to the history of the Institute. In the founding year 1995, work began on a simulation of the paper flow in a printing machine – one of the department's first projects with industry and the starting point for at least two subject areas that are pursued today at the group level. Essentially, a two dimensional paper management system presents a fluid-structure interaction problem. Particle methods are appropriate because of the varying flow above and below the paper; while on the other hand, the shell models of continuum mechanics work for the paper dynamics, which are mathematically equivalent to the Cosserat rod models for filament dynamics in the one dimensional variant. The development of the ITWM **FPM** (Finite Pointset Method) software emerged from the work on particle methods to become one of the most efficient meshfree simulation tools available on the market today for a wide field of continuum mechanical problems. The study of paper dynamics provided the structural-mechanical foundation for all later research in the area of filament dynamics and the basis for our simulation software **FIDYST** (Fiber Dynamics Simulation Tool).



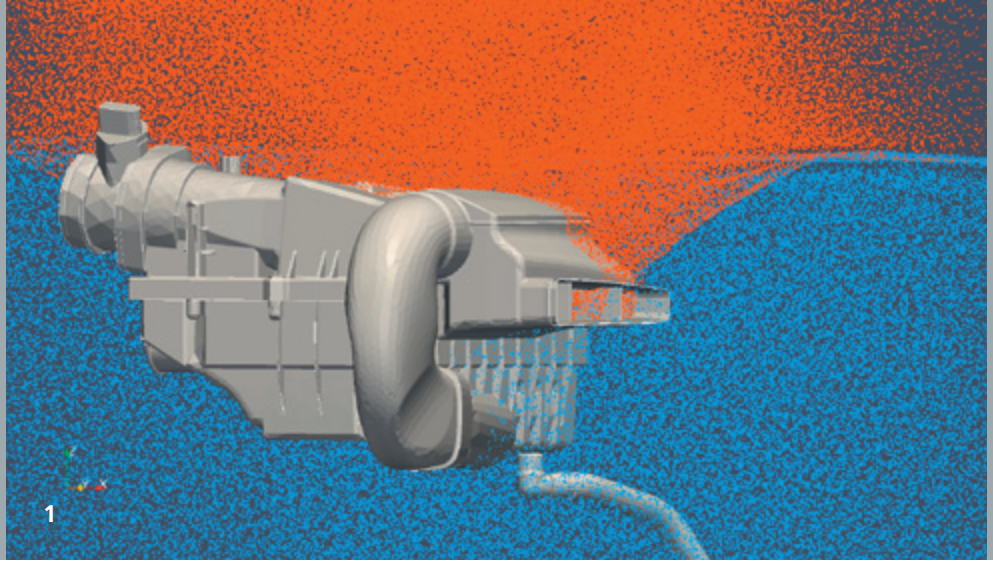
VIRTUAL PRODUCTION OF FIBERS, FILAMENTS, AND NONWOVEN FABRICS

For many years, the department Transport Processes has advanced the virtualization of the manufacture of fibers, filaments, and nonwoven fabrics together with customers from a broad spectrum of industry. This application area, embedded in the research field of fluid-structure interaction, presents a variety of mathematical challenges because the complexity of the observed processes does not allow standard simulation. In several key aspects, in-house models, methods, and tools must first be developed to make an efficient, simulation-based contribution to the design and control of production processes for technical textiles.

1 *Spunbond process of Oerlikon Neumag (former development status)*

The resulting software components like **FIDYST** (Fiber Dynamics Simulation Tool for simulating fiber and filament dynamics in turbulent flows) and **SURRO** (generator for virtual nonwoven structures) are unique competencies that the department uses to successfully occupy a leading position in a niche market. The range of targeted industries promises long term sustainability because of the continuing strong presence of plant and machine component manufacturers in Germany. Furthermore, industrial activities have been successfully internationalized over the past business year.

FIDYST was also significantly expanded during the past year on the basis of the latest, collaborative doctoral project research. Particularly noteworthy contributions include fully developed capabilities to manage the contact with moving machine parts, the mapping of staple fibers, and new algorithms for handling turbulence and accounting for the fluid-structure interaction as an iterative algorithm. SURRO is the ideally matched partner of FIDYST in the so called FIDYST suite for virtual nonwovens and the analysis of the nonwovens forming processes. SURRO applies stochastic differential equations for the highly efficient simulation of the analogous models for forming nonwovens developed by the department. SURRO can map large structures with thousands of filaments. The parameters used in SURRO are provided by an identification algorithm based on representative FIDYST simulations. In this way, the two simulators working in tandem can map the production process parameters to the quality parameters of the nonwoven fabric and, in effect, the simulation-based setup and control of the processes.



MESHFREE SIMULATION IN FLOW AND CONTINUUM MECHANICS

1 *Air intake of a car engine, two phase flow, suction of water by flowing air*

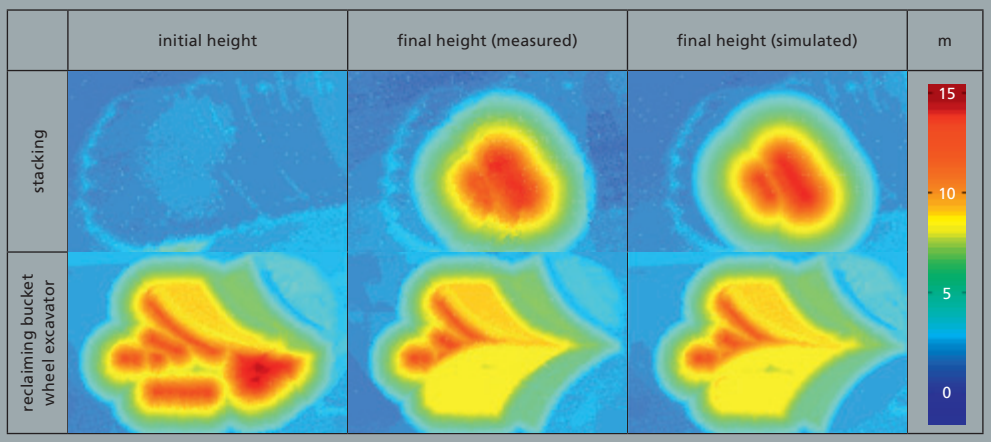
Meshfree numerical methods are used with increasing frequency in the simulation of industrial processes and operations, in particular, for problems in fluid dynamics or continuum mechanics. Since 2000, the department Transport Processes has been developing an original mesh free simulation software based on the Finite Pointset Method (FPM). FPM itself is based on a non-networked cloud of numerical points that map the continuum and move with the material velocity (Lagrange method). Therefore, FPM facilitates a very simple and natural modeling of processes with free surfaces, phase boundaries, and moving parts in the local geometry.

An explicit FPM solver for compressible, high Mach number flows for industrial use with airbag simulations has been in use since 2001. The process is based on the discretization of classic gas dynamics while neglecting the effect of viscosity (Euler equations). Subsequently, the algorithm was expanded to fit the Navier-Stokes equations and turbulence models were integrated in FPM. Today, FPM is a fixed component of the VPS crash simulation software manufactured by the ESI Group.

Since 2002, the main focus has been on developing an implicit FPM variant, which enables incompressible or slightly compressible processes (low Mach numbers) to be simulated. The range of industrial applications is wide; currently, the main field of application is in the automotive industry where problems involve water flow, filling and sloshing, or water run-off.

The method is based on a generalized finite differences approach. FPM can very easily implement the user's targeted approximation rules. At the core of the implicit approach is a special numerical algorithm for FPM that relies on linking velocity and pressure equations. The challenge is in finding the most efficient solution to the resultant large systems of sparsely populated linear equations. Against this background, an internal Fraunhofer project is currently working on linking FPM with SAMG (the Fraunhofer SCAI's algebraic multi-grid solver).

FPM promises an enormous potential for scientific advances, which is particularly reflected in the high volume of doctorates in the meshfree subject area. The ongoing effort is concerned with the topic of the conservative characteristics of FPM, transport operators for non-Lagrange fixed point cloud applications) and droplet populations.



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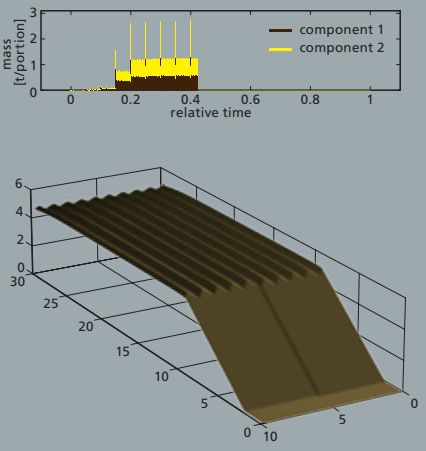

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PHARAOH – SIMULATION CORE FOR MONITORING STOCKPILES

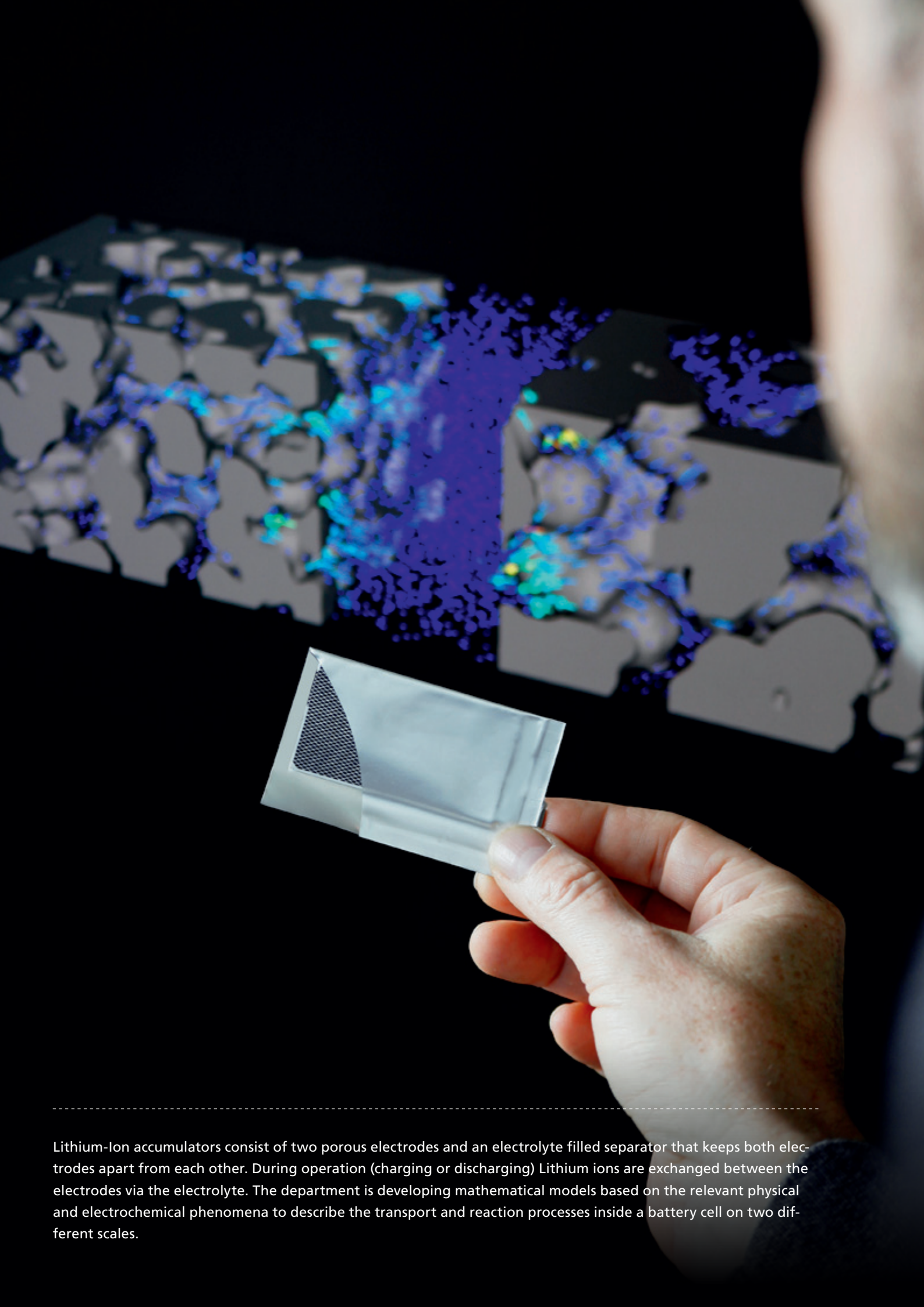
Bulk materials like coal, ore, cement, or grain are stockpiled at large storage areas for subsequent shipping or further industrial-scale processing. Stacking is usually done by conveyor belts with a mobile head. In the process, the location, the delivery volume, and the composition of the stacked portion can be recorded. Reclaiming requires different equipment like bucket excavators and side or front scrapers depending on the material and purpose. Monitoring software can help operators get the optimal use of the storage area, recover materials from a certain origin or quality, or – as in cement manufacturing – fill a blending bed so that the reclaimed material can mostly be dispensed directly at a later time without mixing any additional correction materials. This requires not only the correct simulation of the surface formation of the stockpile, but also knowing the composition at each location within the storage area.

1 *Measured and simulated heights of ore piles*

2 *Proof of homogenization in bucket excavator store by simulation*

On behalf of FLSmidth, one of the leading global suppliers of systems and services for the minerals and cement industry, mathematical methods have been developed and combined in the simulation core known as Pharaoh, which enables a standard workstation to simulate the entire process of stacking and reclaiming bulk materials for simultaneously operating equipment – and to do this, of course, much faster than in real time. In addition to purely monitoring, this software also facilitates running an entire optimization cycle, for example, planning the stockpiles or adjusting the simulation to actually measured surfaces. A simulation based on partial differential equations or even the discrete element method is not feasible given the following requirements: grain sizes of less than 1 cm, storage areas larger than 2 km², resolution of 10 cm. Instead, the solution is formed by the cone method that was developed several years ago at ITWM. It guarantees that the mass and slope of the stockpile remain the same after each stacking and reclaiming operation.

Two independent products BlendExpert® and BulkExpert® are currently used in operations at FLSmidth. The first product requires fixed stacking and reclaiming cycles, as can be guaranteed only in the cement industry. The latter takes scanned surfaces into account, but allows only a rough view of the local composition and is thus limited to coal and ore stockpiles. The capabilities of the two products will be merged in the future based on the Pharaoh simulation core.



Lithium-Ion accumulators consist of two porous electrodes and an electrolyte filled separator that keeps both electrodes apart from each other. During operation (charging or discharging) Lithium ions are exchanged between the electrodes via the electrolyte. The department is developing mathematical models based on the relevant physical and electrochemical phenomena to describe the transport and reaction processes inside a battery cell on two different scales.

FLOW AND MATERIAL SIMULATION

▪ COMPUTER-ASSISTED MATERIAL DESIGN AND MICROSTRUCTURE SIMULATION

Structure-property-relationship and design of porous media and composites using the digital material laboratory **GeoDict®**

Multi-scale simulation of composites: Calculation and optimization of deformation, stiffness, compressibility and resilience using the micro-mechanical solver **FeelMath**

▪ SIMULATION ASSISTED DESIGN OF COMPLEX FLOW PROCESSES

Numerical simulation of flow through porous media on multiple scales using the filter element simulation toolbox **FiltEST**

Computational fluid dynamics of complex fluids: Fluid and bulk material handling in process technology under the software framework **CoRheoS**

▪ MODEL ASSISTED DESIGN OF ELECTROCHEMICAL ENERGY STORAGES

Physical modeling of electro-chemical processes in Li-ion batteries and PEM fuel cells

User friendly simulation software **BEST** for 3D-battery simulation on electrode- and cell-scale

www.itwm.fraunhofer.de/en/sms

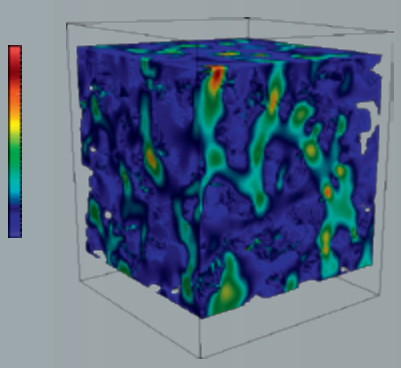
DR. KONRAD STEINER
HEAD OF DEPARTMENT

The Flow and Material Simulation department develops multiscale methods and software tools for the product development and the corresponding process layout. Typical are the simulation challenge of the mutual influences of manufacturing processes and restrictions with the multi-functional, local material properties of complete composites under dynamic strain. In industrial application projects we work, amongst others, on the designing of adsorption materials and filter systems as regards fluid mechanics and structural mechanics or on the thermomechanical operating behavior of composite components or hybrid components. The strength of the department lies in the development, enabling and specific use of multi-scale and multi-physics methods and customer-specific software solutions suitable for industrial application. Already by name, the department cuts into two larger application areas.

By means of computer-assisted material design and microstructure simulation it is possible to simulate and optimize numerically the functional characteristics of porous materials and composite materials, as shown in our example project of the multiscale simulation of a wooden fibreboard. Particularly in the area of automotive engineering there is a strong demand for our highly efficient, micromechanical methods based on our universal micromechanics solver **FeelMath** for the design of fibre reinforced composites.

The simulation-assisted design of complex flow processes works on the corresponding manufacturing processes such as mixing, dispersing, injection, filtration, coating and compacting. The long-time experience in modeling and simulation of filtration processes are bundled in **FiltEST** (Filter Element Simulation Toolbox). Modeling and simulation of the reaction injection molding processes of polyurethane foams is an actual enhancement of the simulation platform **CoRheoS** (Complex Rheology Solver) for the computation of flow of viscoelastic polymer melts and granular materials.

The model-assisted design of electrochemical energy storages, so in particular projects concerning li-ion batteries and PEM fuel cells covers different simulation issues coming from both sectors (as for example the heat propagation within a battery pack, the process simulation concerning the production of batteries (e. g. the mixing of the granular electrode material or the filling of the cell with electrolytic solution) or as well methods for the characterization and optimization of electrode structures. Aside comparable questions with chemically reactive phenomena appear for the most in functionally modified nanoporous or microporous membranes and these are also relevant in the exploration of raw materials.



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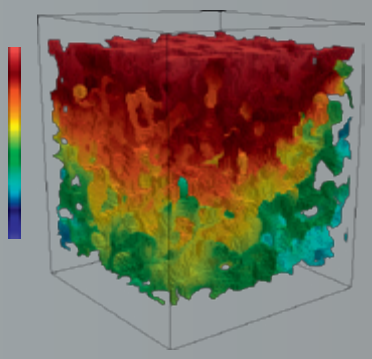

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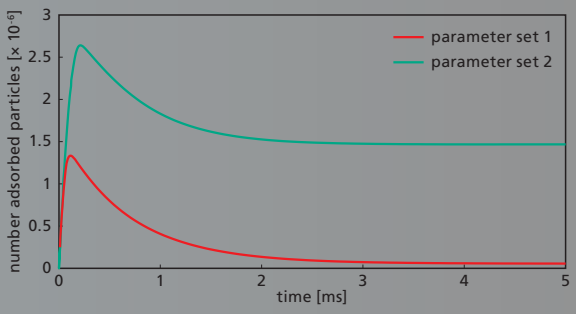

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PORECHEM – SIMULATION OF REACTIVE MASS TRANSPORT IN POROUS MEDIA

Reactive mass transport of dissolved species is highly relevant in many processes in the environment and industry. Functionalized filter membranes are examples of these, the absorption of dissolved reactive chemicals in rocks or nanoporous reactors are others. In order to study these processes and the optimization thereof in the industrial sector it is required to have information about the time dependent behavior of the reactive mass transport on the pore-scale. To this end Fraunhofer ITWM has developed **PoreChem**, a new, sophisticated software package, by means of which it is possible to simulate three-dimensional flow, mass transport and reactions of chemically reactive dissolved species in porous media.

In a first step the fluid flow through a porous medium can be simulated with PoreChem resulting in a pressure and velocity field. The transport of dissolved materials by diffusion or advection in the pore space will then be computed on the velocity field. Different reaction kinetics between the species can be considered at the same time during the simulation. These reactions can take place both within the fluid volume as well as on the surface of the porous medium.

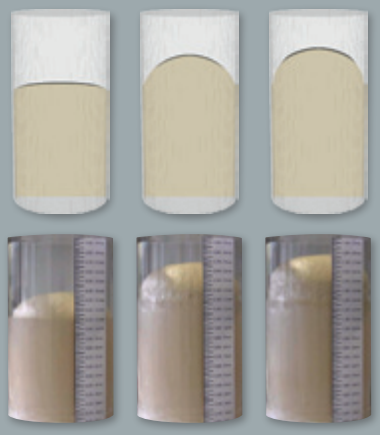
Properties that are important for the application can be derived from the simulations with PoreChem like for example the efficiency of functionalized filter membranes or the breakthrough curves of pollutants in soil samples. For time-dependent problems it is possible to analyze the concentration in the fluid or on the surface against time. Furthermore, numerical simulations can be carried out with the voxel-based solver PoreChem directly on volume images coming from micro-tomographic imaging or on virtual structures generated by the software **GeoDict**. Consequently, the dependence of transport and reactivity in the pore geometry can be examined fast and can be optimized using appropriate structural models.

Regarding different physical problems it is possible to simulate the expected experimental result with PoreChem reducing dramatically the need of expensive and time-consuming experiments as those can be better planned in advance or completely replaced by simulations.

1 *Distribution of velocity in the pore space of a microfiltration membrane*

2 *Distribution of a pollutant in the pore space of a microfiltration membrane*

3 *Change of the number of absorbed particles over time for two simulations*



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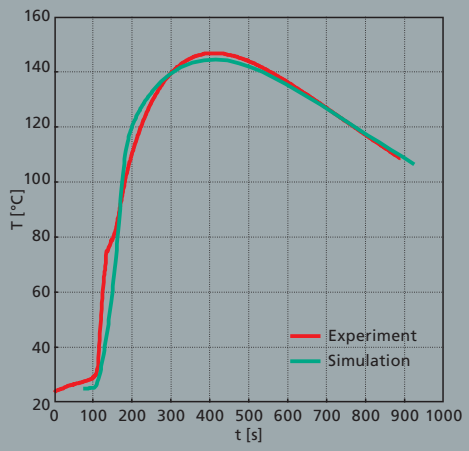

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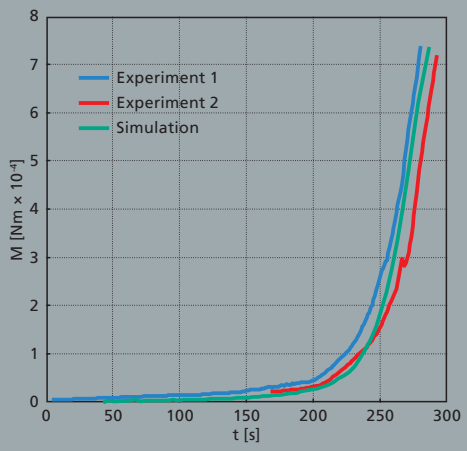

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MODELING AND SIMULATION OF RIM PROCESSES OF EXPANDING POLYURETHANE FOAMS

1 *Advancement of flow front of the foaming material in the tube after 100 s, 150 s and 200 s; above, results from simulations and below, those from experiments*

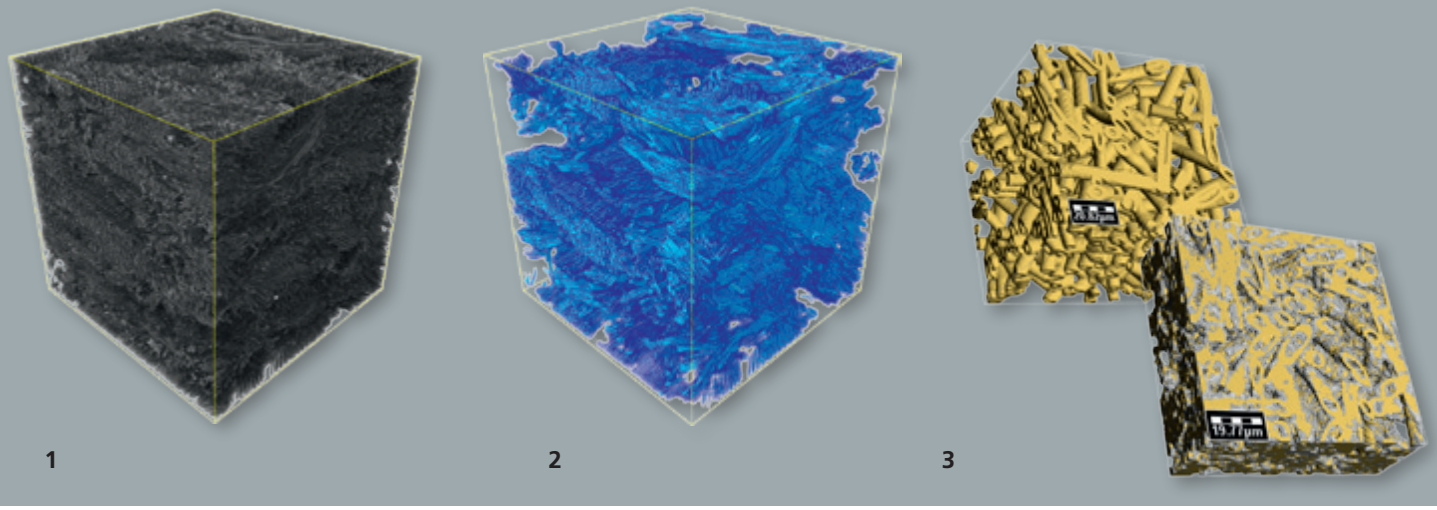
2 *Time change of temperature in the tube*

3 *Comparison of torque measurement (M) from experiments with result from our simulation*

The prevalent flow of complex fluids in industrial processes motivates several theoretical and experimental studies aimed at understanding and possibly predicting the complex dynamics exhibited by such fluids. Inspired by the vast industrial application of polyurethane (PU) foams in the aerospace, automobile, packaging and refrigerating industries, with extended application in structural and construction industries as well as domestic (home) appliances, our department at the ITWM is currently and actively involved in research activities focused on understanding some of the physical intricacies that occur in reaction injection molding (RIM) processes of expanding PU foams. This understanding will enhance the existing practical applications of these foams. In addition, it will promote cost effectiveness both in the process design stage and material fabrication stage of the RIM processes.

In the RIM process of PU foams, shear thinned reacting polymer mixture of adequate isocyanate and polyol group is injected into a mold where after a few seconds the material evolves from a low molecular weight emulsion (through polymerization with the evolution of heat and CO_2 gas) to a complex polymer network via chain-linking and polymer entanglement. Generally, the final structure and attributes of expanding PU foams depends strongly on the evolving material properties of the reactant mixture used in producing them. For instance the mixture viscosity exhibits chemo-rheological behaviour, thus, changing in space and time with the degree of cure and temperature of the foaming system. In the mathematical framework, this behaviour initiates a coupling between viscosity, degree of polymerization and temperature. With this form of coupling in the state variables it becomes very difficult to estimate associated model parameters analytically. Although the chemistry of reactive blown PU foams has a well documented history, however, obtaining adequate mathematical description of the complex dynamics which occurs in the RIM process still remains an issue of current research.

With the efforts of our collaborators from the Department of Mechanical Engineering in TU Chemnitz who performed all the relevant experimental studies under the MERGE project on light weight structures, we formulate adequate mathematical framework capable of predicting the complex dynamics of the expanding PU foam system. Furthermore, with our in-house robust numerical simulations platform (**CoRheoS**), we are able to predict the flow behaviour and other physically relevant flow variable necessary for describing the expansion process. The results from our solution platform provide accurate description of the mass and heat transfer in the expanding foam setup. In addition, the comparison with the available experimental data gives both qualitative and quantitative agreement.



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SIMULATION-ASSISTED DEVELOPMENT OF MEDIUM DENSITY FIBERBOARDS

The properties of materials composed of wood fibers like particleboards, oriented strandboards OSB or medium density fiberboards MDF) are primarily affected by the size and orientation of the particles. These boards are produced by compressing lower density boards and exhibit a higher degree of homogeneity, inducing a increased tensile and bending strength. In particular, medium density fiberboards with thickness of approx. 2 to 6 cm and a density below 650 km/m qualify for the production of furniture and (higher densification provided) for laminate flooring panels.

To develop boards with lower density, yet comparable strength characteristics, the basics for the fabrication and virtual strength assessment of light-weight MDF boards consisting of layers with aligned fibers similar to plywood or OSB were laid within the framework of an AiF project supported by BMWi, in cooperation with the Fraunhofer Institute for wood research WKI, Braunschweig. The project was co-financed by European Regional Development Fund (ERDF).

On the basis of micro-computed tomography images (µCT images) virtual wood fiber network models were generated. The software **FeelMath** developed at ITWM enables the computation of the deformation of the individual wood fibers taking into account mechanical loading on a small section of the fiber board. Treating microstructures with such a high complexity is unequaled globally. Furnishing the generated microstructure model with the mechanical parameters of both wood fibers and glue reproducing enables predicting the experimentally determined strength of the MDF boards accurately.

In contrast to classical experiments the virtual material cycle permits fast design and parameter studies, investigating the effects of changing the fibers' length or degree of orientation on the mechanical properties of the MDF board. Furthermore, in the project it was possible to characterize fiber bundles and to explain their influence from a mechanical point of view. Consequently, improvements of the production process can be gauged more accurately than by visual inspection.

1 *Computed tomography image of an MDF microstructure*

2 *Segregated fibers and fiber bundles concerning the µCT image of figure 1*

3 *Virtual microstructures, left: microstructure before- right: microstructure after compression*

We deeply regret that our colleague Dr. Brigitte Dix, who led this project in an excellent way, passed away suddenly and completely unexpectedly. We will forever treasure the time we spent together.

Automated surface inspection of natural materials such as leather is very challenging because of the high degree of variance. The department Image Processing developed a system that retains the expertise and flexibility of the manual inspection through the use of semi-automated quality inspection and yet represents substantial time and cost savings.

IMAGE PROCESSING

▪ SURFACE INSPECTION

Online-evaluation of the optical appearance of industrial products

▪ MICROSTRUCTURE ANALYSIS

Characterization and stochastic modeling of microstructures based on 3D image data

▪ IMAGE UNDERSTANDING AND SCENE ANALYSIS

Semantic analysis of image data

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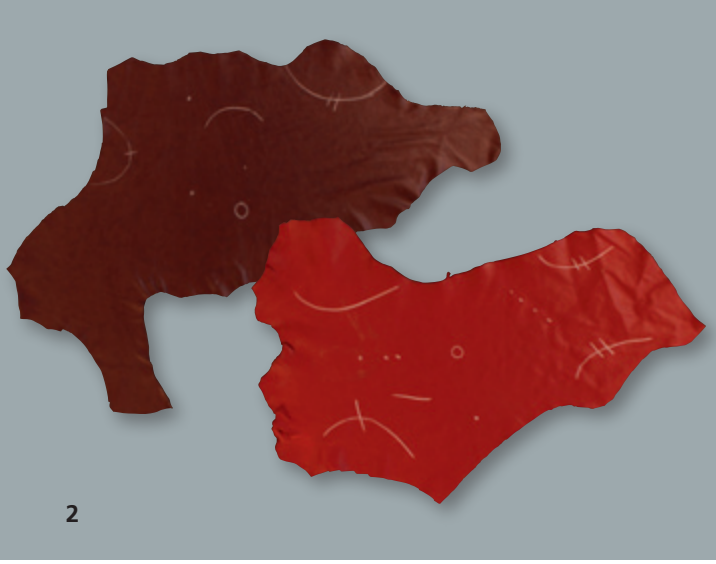
DIPL.-INF. MARKUS RAUHUT
HEAD OF DEPARTMENT

The aim of the Image Processing department is to develop, in close cooperation with industry and research partners, custom solutions in the field of image and signal processing, with a particular focus on quality assurance and optimization and on the characteristics of surfaces and materials. In 2015, the department added a new priority 'image understanding and scene analysis', which is seen as a nucleus to be further expanded in the coming years. The image processing industry continues to be a growth market; specifically, in Europe where revenues in this sector increased by about 10 percent in 2015. As a consequence, the department has not only successfully implemented many customer projects in recent years, but also managed the sharp increase in the number of joint ventures with companies in the image processing industry. Furthermore, the two image processing software packages – MAVI and ToolIP – extended their successful sales trend to customers in industry and research.

One highlight can be found in the area of "quality assurance and optimization" and the development of efficient and innovative, image-based, integrated solutions for automated quality assurance in manufacturing. The mathematical core of these solutions – the processes and algorithms for image processing – and their implementation in efficient, complex software provide the department's unique selling points over other suppliers of image processing systems.

The micro- and nanostructures of modern materials determine their macroscopic material properties. The analysis of these structures is constantly gaining importance with the constant advance of the technical possibilities of three dimensional, high resolution imaging of very different kinds of materials. The work of ITWM is focused on defining the geometric characteristics of the microstructures of materials using the methods of stochastic and integral geometry. This provides the foundation for the construction of spatial models of these materials that clearly show the geometric structural relationships, which enables or simplifies computations and simulations.

Emerging from the advances in algorithmic development and the industrial requirements of recent years, the research priority subject "image understanding and scene analysis" was established. This field is concerned with the semantic analysis of image data often captured outdoors. A simple example of this is road sign recognition. Besides the industrial projects, there were also two Ph.D. dissertations on this subject in the department and further research applications are planned.



CONTOUR AND MARKING RECOGNITION OF LEATHER HIDES

Over the years, the Image Processing department has cooperated and gained experience with the leather processing industry. As a natural material, the characteristics of leather present many interesting challenges.

Generally, the materials produced in industrial applications are analyzed and checked for shape, structure, and faults. Natural materials, in contrast, are much more challenging because of the high degree of variance, both in the good pieces and the bad pieces. A series of interesting questions, long resolved in other industries and manual solutions that are already fully automated for other applications, remain topics of interest in this area.

In response, the department is currently developing software in cooperation with IsoDev, which is attracting a broad following in the leather processing industry. In this context, the aim is to create a fast, uncomplicated quality control tool to support manual inspection, which is still the standard. The system provides fully automatic recognition of the leather contours as well as any fixed specification manual markings. The image is recorded by optical sensors that scan either the complete hide (up to 3 × 3 m) or smaller sections.

The most cost effective and widely applicable system uses a standard camera at a working distance of two meters. Measuring accuracy is, nevertheless, maintained by means of a specially developed calibration. Although the hide geometry and the color requirements cannot be set, the contours are recognized without false detection. In a final step, thanks to modern morphological processes, markings are detected and classified according to industry norms. The detection results are converted on the basis of the calibration to a vector graphic for direct use in subsequent machine processing. In this way, a system is created that retains the expertise and flexibility of the manual inspection through the use of semi-automated quality inspection and yet represents substantial time and cost savings.

1 *Entire cowhide with manually created labels of the various quality areas*

2 *Sections of dyed and labeled leather hides*

WOOD ANALYSIS AND COMPUTING LAB

1 *Interior view of the new CT. On the left you can see the detector, in the middle the rotation unit and on the right the X-ray tube.*

2 *Exterior view of the new CT*

Wood is very versatile as a material. However, as a natural material wood also is a very complicated material; this is true for solid wood as well as fiber sheets and wood composites. In Germany, several research institutes conduct research on wood, but only Kaiserslautern has instituted an image processing department that manages a lab that combines innovative image processing with timber construction. The fundamental concept is not only to combine various analytical techniques, but also to replace or expand traditional testing methods, at least partially, through modeling and simulation of wood materials. The lab is not intended to compete with other labs existing in Kaiserslautern (TU Kaiserslautern, Institute for Composite Materials IVW), rather to complement them with new methods and simulations.

The structural design of wood depends on the intended use as the requirements for durability/strength, resistance to moisture, and temperature fluctuations, thermal insulation, sound absorption, etc. vary greatly depending on the application. This applies to the wood itself as well as to combinations with other wood parts and with other materials. The situation is similar with composite materials based on other natural fibers (e.g., flax, hemp). An overview of the available analytical methods at ITWM is presented below:

One of these methods is microstructural analysis based on image data obtained by means of computed tomography. ITWM develops high performance methods of fiber analysis, which enable the determination of fiber direction, fiber diameter and, in the near future, also the distribution of fiber lengths. In addition, reliable statements can be made concerning the topology of a certain material. Defects and inclusions can also be detected. The same is true for joining compounds and adhesives, which is important because that is where force application is critical. All these attributes have a significant influence on the physical properties of the materials.

The stochastic microstructure models used at ITWM simulate the properties of real materials (on the basis of microstructural analysis). Additionally, it is possible to change the material parameters. This feature enables the physical properties of materials to be predicted by the computer. This is an important tool in the design of modern wood composites. High resolution recording of large areas is possible with image processing. Although inner defects cannot be detected, structural changes are also generally visible on the surface. Although the possibilities for calculating structural properties lag behind those available in microstructure analysis, these can now be quickly determined for large areas without sampling. This means that 2D microscopic-macroscopic properties that partially complement a microstructure analysis are obtained and can be used for the overall evaluation of the component. Additionally, such systems can be

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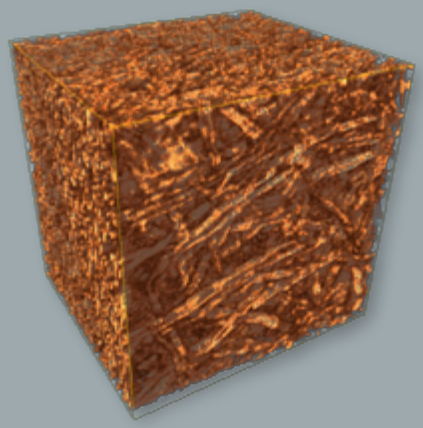

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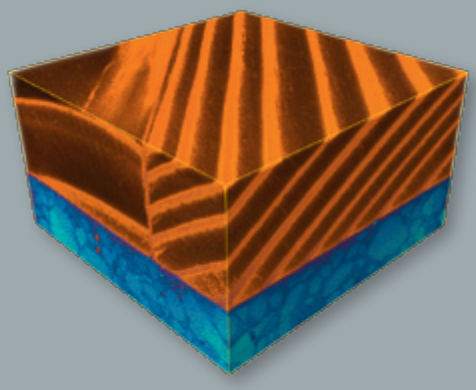

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applied in production quality control: using mathematical processes, it is possible to predict major properties of a material. Typical properties are durability, moisture absorbance/resistance, characteristics of the adhesives and joints, thermal transfer, acoustics, etc. Calculations have been conducted at ITWM using image data from microstructure analysis or microstructure models. The combination with complementary results from the surface scanning leads to a new simulation quality, especially, for large wood components.

Thanks to the funding support from EFRE (EU and Rhineland-Palatinate), equipment could be procured and/or upgraded that enables us to effectively apply the methods described. An overview of the major equipment:

- The existing CT scanner was upgraded. The upgrade included retrofitting the detector with a resolution of 3k × 3k, improved image contrast (dual energy), faster reconstruction, and the addition of laminography – a special form of computed tomography that is particularly well-suited for large scale components.

- A high resolution industrial scanner with multiple illuminations was purchased for use in surface testing, which enables the visualization of material defects through a special arrangement of lighting and camera. The scanner facilitates simple testing of various arrangements.

- Using a near infrared spectral camera, entire spectra can be recorded. The spectra reveal chemical information that is important for wood and natural fiber components for two reasons: first, wood decay and composition can be analyzed and second, the percentage and the composition (if required) of synthetic materials in a composite can be determined.

- A measuring instrument is also available for frequency and temperature dependent studies of elastic components and damping values (DMA/DMTA) to support the characterization of structural-mechanical properties. These material parameters are also required for the simulations.

3 *The DMTA-Tester*

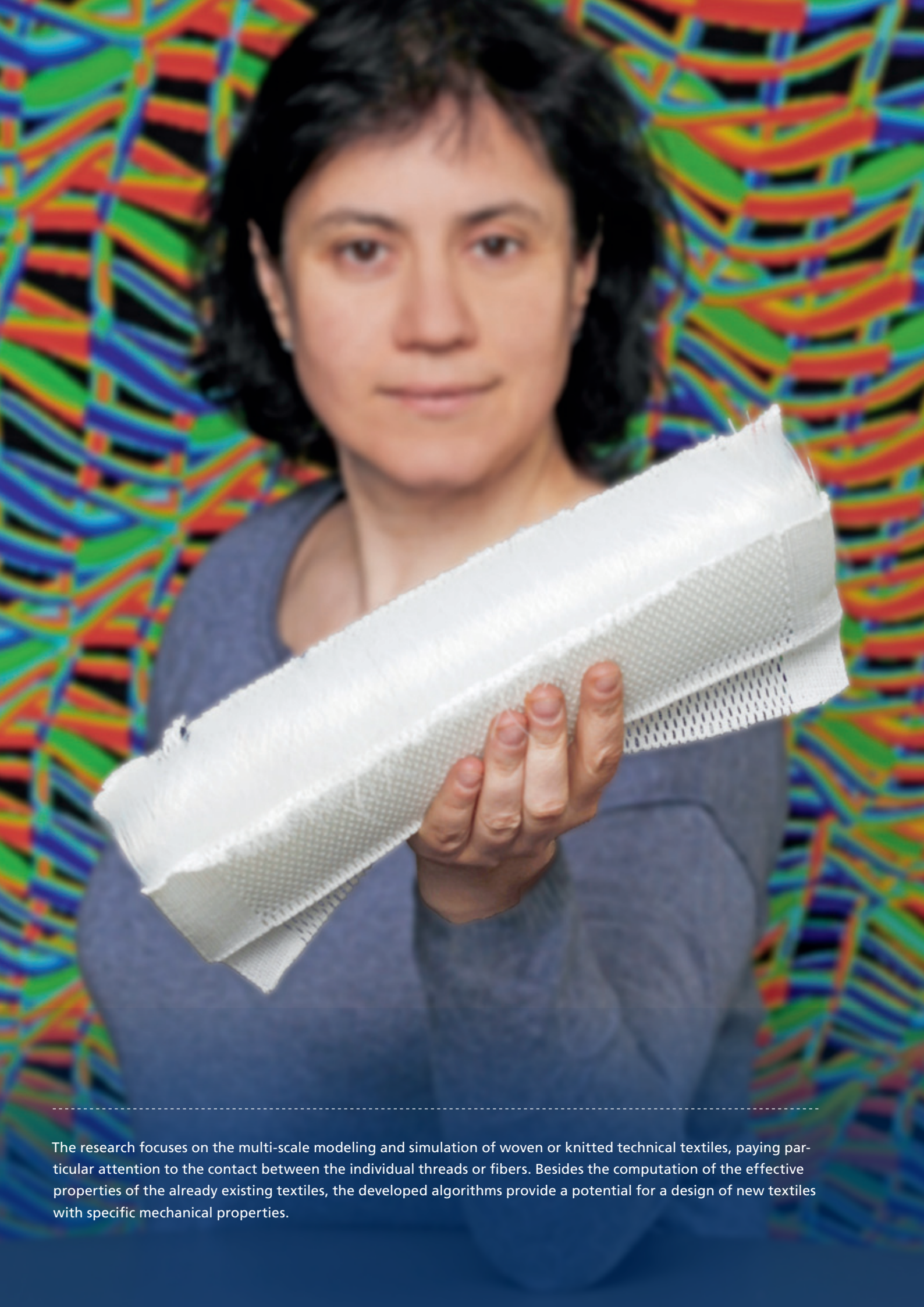
4 *Microstructure of a wooden food packaging, Pixel edge length 1.5 µm, clipping size ca. 5 × 6 × 6 mm, sample: TU Dresden, Working group Processing Machines and Processing Technology*

5 *Wood-polymer concrete composite, sample: Dr. techn. Wieland Becker, Hochschule Trier. Pixel edge length 21 µm, clipping size 19 × 19 × 10 mm*

Wachstum durch Innovation – EFRE

RheinlandPfalz

Das „Holzanalyse- und Berechnungslabor" des Fraunhofer ITWM wurde von der Europäischen Union aus dem Europäischen Fonds für regionale Entwicklung und vom Land Rheinland-Pfalz kofinanziert.



The research focuses on the multi-scale modeling and simulation of woven or knitted technical textiles, paying particular attention to the contact between the individual threads or fibers. Besides the computation of the effective properties of the already existing textiles, the developed algorithms provide a potential for a design of new textiles with specific mechanical properties.

SYSTEM ANALYSIS, PROGNOSIS AND CONTROL

▪ SYSTEM ANALYSIS AND CONTROL

Development of model based monitoring systems and control strategies as well as their hardware integration

▪ DATA MINING AND DECISION SUPPORT

Development of data based prognosis tools and technology for visual analytics

▪ MULTISCALE STRUCTURE MECHANICS

Numerical algorithms for computing the effective mechanical properties of multiscale materials

www.itwm.fraunhofer.de/en/sys

DR. PATRICK LANG
HEAD OF DEPARTMENT

The focus of the Systems Analysis, Prognosis, and Control department is on products and processes that because of their complexity, deny pure physical modeling. In these cases, sections must be described on the basis of measurement data and expert knowledge. The department is resourced with core competencies in system and control theory, data mining, and multi-variant statistics as well as in multi-scale analysis methods.

The main areas of application are energy systems and projects dealing with monitoring and stabilization of energy production and transmission, but also for increasing energy efficiency in manufacturing processes. Other significant areas include the analysis and verification of the behaviors of electronic control units early in the design phase, in the context of "hardware-in-the-loop" and highly integrated electronic components, often in connection with mechanical components. In the Life Sciences group, the analysis and assessment of Omics data related to clinical trial data play a major role in the diagnosis and prognosis of disease progression and the assessment of therapy efficiency. The analysis and optimization of production chains and business processes in terms of quality, error sources, or energy efficiency are also among the department's focus areas. The Material and Product Design group develops models for the prediction, classification, and simulation of product and material behaviors, which are then used as a basis for design decisions. Technical textiles represent a special focus, where actual material properties are calculated and optimized on the basis mathematical homogenization methods.

In addition to its own products, the department provides a full range of consulting services and customer-specific software development in these areas. The department's positive economic development in 2014 continued through 2015 with additional industry cooperation. The research competence, especially, in the field of intelligent energy systems (Smart Grid) and technical textiles was also further expanded through two successfully completed doctorates.

The selected project examples below represent a cross section of the department's application areas. Here we report on the evaluation of software for the primary analysis of NGS data, the simulation of the mechanical behavior of textiles and the hardware-in-the-loop verification of electronic control units.

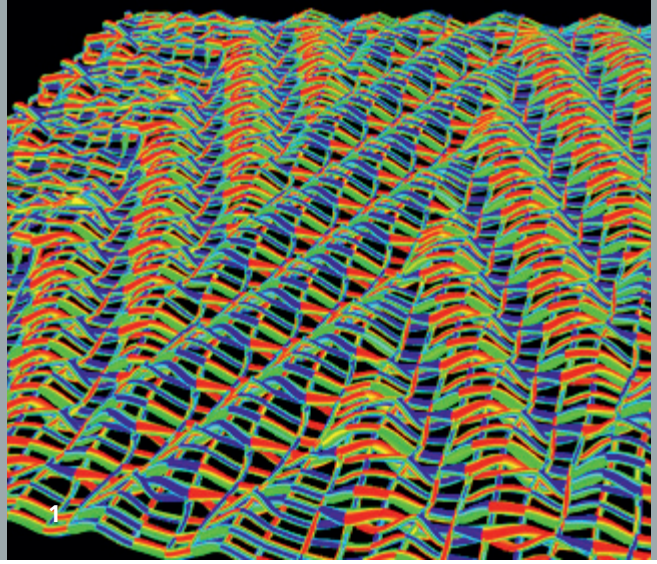
1

EVALUATION OF SOFTWARE FOR THE PRIMARY ANALYSIS OF NGS DATA

1 *QIAGENs GeneReader NGS System*

At the turn of the millennium, the first decoding of the human genome required the efforts of laboratories worldwide and extended over a period of time that lasted more than a decade (Human Genome Project, 1990 – 2003). The second generation sequencers (Next Generation Sequencing, NGS) in contrast, fit on the desktop and get the job done within a few days. A large part of the high throughput technology used depends on replicating an original section of DNA (deoxyribonucleic acid), which carries the genetic hereditary information in the form of base sequences, base for base (Sequencing by Synthesis). These short DNA sections are initially fixed on micron-sized beads and reproduced in a chemical process. The prepared beads are then placed on the surface of a flow cell, where they are exposed in multiple cycles to modified, fluorescent DNA-bases that attach in specific accumulations. By using a different fluorescence molecule for each of the four possible nucleotide bases, specific patterns of fluorescence emerge that can be recorded by photo-optic sensors using special color filters. The recorded images are then assessed by the software to determine every base attached to each bead, together with a quality measure.

QIAGEN is a globally operating supplier of molecular-biologic testing technologies with its headquarters in Hilden, a city near Düsseldorf. QIAGEN's recently developed sequencer (GeneReader NGS System) works on the principle of "Sequencing by Synthesis." The SYS department at Fraunhofer ITWM, in a joint project with QIAGEN, views and evaluates a segment of the software developed at QIAGEN for the primary analysis of the fluorescent imaging data to include the recognition of the base sequences and quality measures. ITWM also submits specific recommendations for improvement for possible incorporation in a future version of the product. The software must manage several tasks: shifts among the various fluorescent images (the flow cells must be mechanically moved in each cycle); unequal illumination of the images caused by the photo sensor optics; different optical properties of the four fluorescence molecules used and the color filters; crosstalk of the color channels and adjacent beads; and, degeneration of the fluorescent signal caused by an increase in autofluorescence and faulty incorporation of the modified bases (Lead/Lag Effect). All effects always include a stochastic component. The SYS department contributes to the project through its competence in the area of complex stochastic modeling and algorithms.



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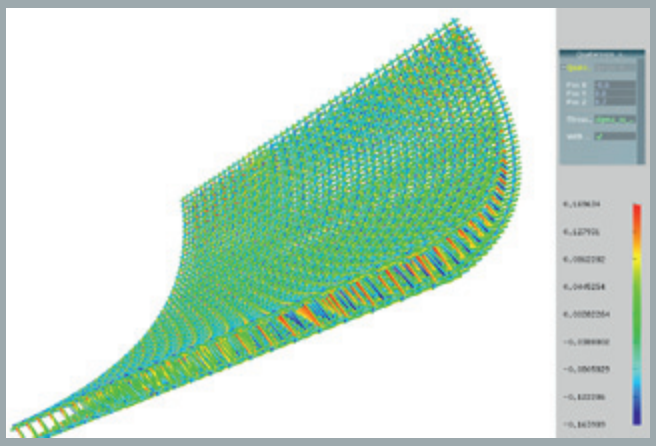


2

SIMULATION OF MECHANICAL TEXTILE CHARACTERISTICS

1 *Local shear stresses in a tensile test of a weave*

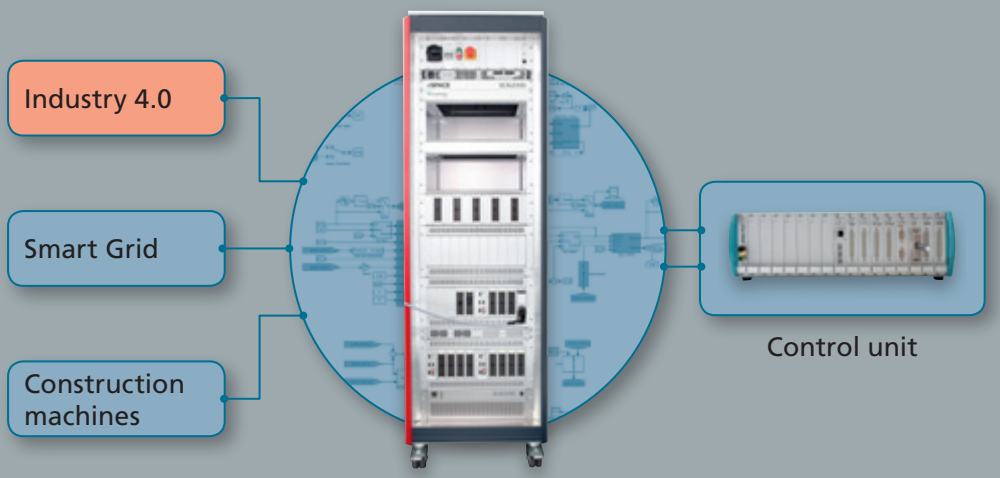
2 *Local axial stresses in a spacer fabric at the curve*

The System Analysis, Prognosis, and Control department has been working for about eight years on the modeling and simulation of mechanical characteristics of textiles. The focus is on simulation methods that enable efficient predictions of the behavior of woven and knit textiles. Important parameters to be considered are the mechanical attributes of the individual weaving yarns and a suitable description of the mesh geometry used. While the elongation properties of the individual fibers can be quite easily determined experimentally, determining the coefficients of friction between the various fiber types requires a much greater effort. The necessary fiber parameters are usually defined by suitably equipped experimental textile institutes and then provided to ITWM.

In this case, the main application area is especially in technical and medical textiles, which must strictly adhere to certain performance specifications. Some examples include: bandages that are supposed to exert pressure when in contact with the patient's skin or, perhaps, there is a need to find a material specifically made to provide maximum protection, for example, either for a bullet proof vest or for work clothes like cut protective trousers.

Generally, the work of the textile group does not end with a specific textile product, rather more in the advanced development of appropriate simulation tools that the customer then uses to run various simulations – with changing materials or geometric parameters. Besides the evaluation of a specific textile design by simulation, the tools also enable the optimization of the performance characteristics for different design variants.

Our customers include manufacturers of compression bandages and auto textiles as well as companies that produce protective safety systems of all kinds and other companies that supply occupational and protective clothing. Other potential customers include companies that produce textiles in the broadest sense for use in the construction industry; for example, the materials built into drainage systems that must be able to withstand a certain pressure. In addition to the current focus on mechanical attributes of fabrics, other characteristics such as fluids transport will be studied in the future.



1

HARDWARE-IN-THE-LOOP VALIDATION OF ELECTRONIC CONTROLS

1 *Hardware-in-the-Loop simulator at Fraunhofer ITWM*

The growing technical importance of distributed systems is accompanied by the demand for design changes in the control systems. A single control unit is no longer used to control a process. Instead, a dynamic, digitally networked system formed by multiple controllers acting in concert with sensors and actuators as well as the controlled system itself is required. To an increasing extent, validation of the control concept relies on "Hardware-in-the-Loop (HiL)" systems. According to practice, the electronic control unit being tested is not directly connected to the real system, but to a test stand with a mathematical system simulation. By means of the appropriate electronic interface the control device is connected to the HiL platform in a way that it does not recognize the difference between the test stand and the planned controlled system. HiL testing is well established in the automotive industry while there are no pre-fab components for simulations of special construction equipment like tractors, cranes, and excavators.

A high degree of networking between the mechanical functions – coupled with the hydraulics and electronics as well as numerous actuators and sensors – rapidly leads to a complex dynamic model. Furthermore, many components pose technical constraints (e. g. hoses) that depend on the overall system status. The department has many years of experience in the development of appropriate mathematical system representations for heavy construction equipment and other commercial vehicles. These systems are capable of real time use and are very robust against noise, for example, as present in analog control signals. In addition, a monitoring environment is always implemented, which facilitates the detection of faulty adjusting signals and the control of the functional efficiency of the controller being tested.

In 2015, the department acquired an HiL simulator with a sophisticated I/O interface, which enables the connection of the electronic controllers to simulations of the implemented systems for testing. This facilitates the generation of turnkey system models, for example, for customers that do not have access to an HiL simulator, and the testing and validation can be performed directly at ITWM. Besides the special machinery, issues in Industry 4.0 and intelligent energy grids are also being addressed. In addition to the development of real-time simulation models, the control units and the design of the control algorithms and logic dependencies are a key area of interest to the department. For HiL testing, the department develops efficient controls for the modeled systems based on experience in system modeling and status monitoring. If necessary, these can be implemented on in-house programmable control units and tested on the HiL simulator.

Faceting turns an irregularly shaped raw gemstone into a shining jewel; but only if the geometry of every facet is correct and as little as possible of the precious stone is removed during grinding. An industrial process developed in the department Optimization can grind the gemstones optimally and bring out up to 30 percent more precious stone from the raw gemstone.

OPTIMIZATION

▪ MEDICAL THERAPY PLANNING

Development of new methods for clinical therapy planning based on multicriteria optimization

▪ OPTIMIZATION IN VIRTUAL ENGINEERING

Physically and technically based models and their simulation in algorithmic software (virtual engineering)

▪ OPTIMIZATION OF ENTERPRISE STRUCTURES AND PROCESSES

Modeling of planning systems for logistics and organizational tasks and development of specialized software applications

▪ MODELING, SIMULATION, AND OPTIMIZATION IN PROCESS ENGINEERING

Customized development of software components from conceptual chemical engineering through process- and aggregate-design to control and feedback control issues

www.itwm.fraunhofer.de/en/opt

PROF. DR. KARL-HEINZ KÜFER
HEAD OF DEPARTMENT

The aim of the department is to develop custom solutions for planning and decision problems, especially, in the logistic, engineering, and life sciences while working in close cooperation with our partners in research and industry. Our work is characterized by the methodical study of the interrelationships among simulation, optimization, and decision support. Simulation in this context refers to the construction of mathematical models while taking into account the design parameters, restrictions, and the optimization of quality and cost. The department's core competencies include the development and implementation of application and customer-specific methods to calculate the optimal solutions in the design of processes and products. In developing and implementing interactive decision support tools, we give special consideration to multiple criteria approaches focusing on the integration of simulation and optimization algorithms. Overall, optimization is viewed not so much as a mathematical problem to be solved, but rather as a continuous process to be supported by the department with the development of suitable tools. The main focus areas of our research are:

Optimization of corporate structures and processes

The portfolio includes consulting and support for the modeling of logistical and organizational planning systems and the development of individual software components. Decision support solutions are generated using custom software tools and optimization methods that provide the best compromise between the competing planning goals of "minimum costs" versus "maximum quality." Based on discrete event simulation and combinatorial optimization, the departmental activity focuses on efficient strategies for transport logistics, design problems, planning and control of production and R&D processes, and for models and algorithms used in process planning and activity scheduling in hospitals and health care systems.

Optimization of medical therapy planning

The trade-off between the prospect of a cure for a serious illness and the prevention of side effects routinely poses a difficult planning challenge to doctors in therapy planning. The focus of interactive therapy planning is on the development of new planning methods for clinical therapies on the basis of multiple criteria optimization. The group develops innovative planning modules for ionizing-radiation therapy, ultrasonic therapy, radio frequency ablation, and the systemic therapy in senology, which gives medical doctors and the attending physicians a relatively simple way to balance the chances and risks of the treatment.

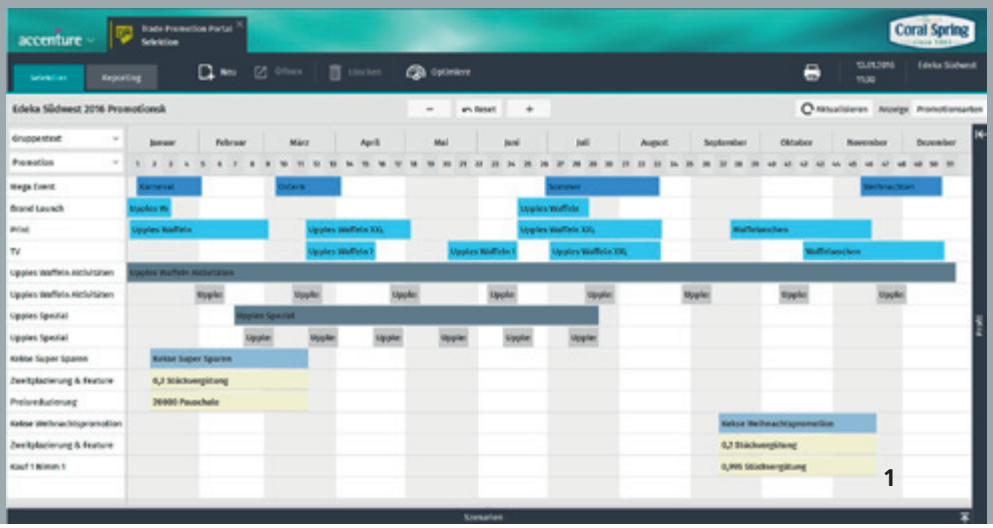
Optimization in virtual engineering as well as modeling, optimization, and simulation in process engineering

The use of mathematical optimization methods in the engineering disciplines relies on the modeling of physical relationships and technical processes and mapping them in computer programs (Virtual Engineering). Optimization assists engineers to ensure, that quality and cost targets are satisfied to the maximum extent possible in the designs of products and processes. The projects aim to create software components for simulation supported optimization, which solve the high dimensional problems using specially developed integration techniques for simulation and optimization algorithms. Multi-criteria optimized product and process layouts are represented in interactive decision support tools to decision makers for evaluation and selection.

The business year 2015 was a tremendous success for the department. Special highlights include:

- Start of a multi-year cooperation with Goldbeck Solar for the multi-criteria optimization of hybrid energy systems for commercial and industrial buildings.
- Completion of the "HI-P" demonstrator system, a BMBF Software Cluster project for horizontally integrated production planning services with partners proALPHA, Mineway, SIEDA, and Insiders.
- The BMBF Project "H2OPT" realized energy savings of nearly ten percent during field testing the EWR water utility in the city of Worms through improved operations of the feed pumps at the waterworks.
- Patent approval and start of a research and development project with the global market leader Varian Medical Systems, Palo Alto (California) in the area of radio therapy planning. The project is one of ITWM's most relevant in terms of the social importance: more than 65 percent of the cancer patients worldwide will benefit from the innovative ITWM planning methods.

In the area of science, in addition to the launch of the Fraunhofer funded project "ESource" for electro-chemistry, other major successes include: the approval of a research (DFG) project in the field of tribology, approval of the BMBF "GamOR" proposal for cooperative, game-oriented personnel management, and the "1st Process Engineering Day in Kaiserslautern" attended by more than 70 scientists who discussed the use of mathematical methods in mechanical and fluid process technologies. The cooperation between the department of process engineering at TU Kaiserslautern and Fraunhofer ITWM will play a key role in the recently established Performance Center for Simulation and Software-Based Innovation.



OPTIMIZING SALES PROMOTIONS

1 *Demo view of a promotion calendar*

"Buy two, get one free", "30% more content", "Valentine's Day Special Edition" are familiar images at the supermarkets. Taken together, price discounts, special packaging, displays, giveaways, and other actions to promote a product comprise an area called consumer-focused trade promotion.

The manufacturer must decide what products to pair with which of these sales driving measures so the use of the budget will result in the biggest profit. Product managers have the job of not merely selecting an appropriate tactic for an individual product; rather, they have to build a portfolio of measures for various products. The main targets are costs, total sales, and volume. Each measure produces not just an increase in sales, but also can have a negative influence on the sale of other owned brands. This effect is known as cannibalization. For example, an increase in the sales of nut chocolate at a reduced price can mean fewer sales of milk chocolate at the regular price.

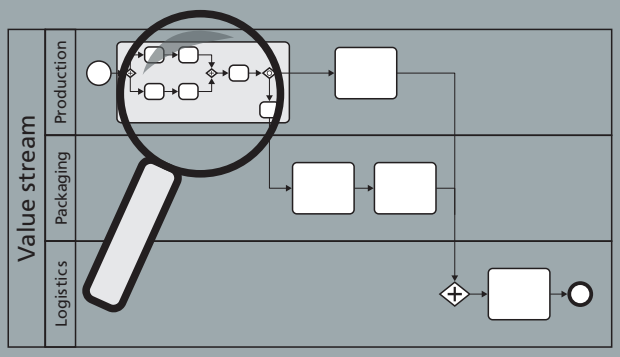
A product is typically promoted not just once per year, but at irregular intervals throughout the entire year. The key account managers usually maintain a promotion calendar for their products that takes into account the seasonal trends, (clearly, cold drinks sell better in the summer and gingerbread cookies go fast in the winter). When preparing, they must always keep an eye on the overall budget, balanced coverage, and the effects on stock purchasing.

This is a very difficult task for a human being – both in estimating the response to the individual promotional activities as well as simultaneously having to calculate their interactions. Therefore, decisions are often taken that are based simply on personal experience and do not see the impact in its entirety. This explains why a large part of the budget is often not invested wisely. Consumer goods manufacturers spend more and more money for consumer oriented trade promotions without actually gaining any increase in market share. They demand new, more effective ways of doing their promotion planning.

The aim of the cooperation between ITWM and the software company Accenture CAS is to create a decision support tool for the preparation of the promotion calendar. It should generate optimized suggestions that are evaluated against various criteria. The necessary forecasting algorithms on a single product basis have already been developed in earlier projects. A proven method is to apply a combination of data and model driven algorithms. In this way, the descriptive model assumptions (e. g., "a sales volume increase follows a promotion activity") are calibrated with historical checkout and market research data.

The sales forecast for a trade promotion is one of many project examples in which smart data – the linking of framing models with calibration data – has proven itself superior to the pure, data driven, Big Data models. This is particularly due to the fact that the available sales data provided from various sources does not always have the quality required to be sound for both the base model and the exception (response to the promotion measure). The underlying model resolves this problem by providing control over the forecasts to ensure they are always plausible, or that otherwise data quality problems are exposed.

The individual forecasts are linked while giving consideration to potential side effects – like cannibalization – to compute the optimal package of products and measures. These promotions are then appropriately embedded in the promotion calendar. In practice, such a calendar is not created from scratch each year. Instead, proven promotions from previous years are taken over. The optimization tool takes into account this input, but may also suggest slight modifications (such as postponements, changes in tactics, changes in product range) to identify additional optimization potential.



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CAPACITY PLANNING FOR COMPLEX VALUE STREAMS

1 *Value flow with complex process logic of individual process steps*

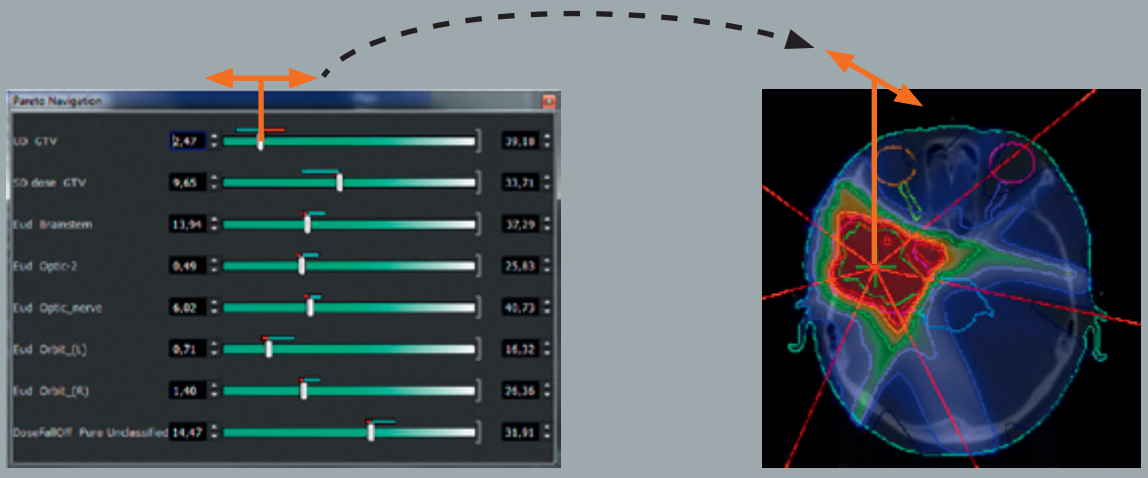
2 *Sample capacity planning forecast using value flow simulation*

People and machinery are needed in factories to produce products and process orders. From manufacturing to shipping, various steps are carried out in a value adding stream. These steps must mesh together like interlocking gears. If only one cog fits, orders cannot be properly processed and overloads and backlogs occur at other points. Such unforeseen bottlenecks can lead to substantial economic losses.

Sufficient capacity is critical for smooth operations in the value stream. It is not enough to plan each step in a process separately: Perhaps, production is equipped with efficient machinery and achieves top throughput rates, but this is ultimately of little use if the logistics is inadequately staffed to perform the picking. All process steps and their interactions must be taken into account to coordinate each capacity. Another problem is created by short-term capacity planning. Bottlenecks occur that can only be partially alleviated or are associated with high costs, such as leasing expensive storage areas. For this reason, a forward-looking view is important so that countermeasures may be implemented in the early stages. Of course, a forward looking capacity planning also carries risks such as an uncertain order book in the future.

The Optimization department develops a tool for proactive capacity planning that addresses these challenges through practical modeling. The trick is in having the appropriate level of detail in the mapping of the individual process steps. A detailed simulation of all operations is not practical as there are too many assumptions about the internal decision processes that affect the results. Similarly, an approximate forecast of capacities using average values only is too imprecise. Instead, each process step is parameterized with capacity relevant parameters. Process related internal fluctuations are taken into account by stochastic distribution functions. The appropriate mix of data-driven and expert modeling is key, for example, representing highly complex production operations or hard to describe human resources.

A Monte Carlo simulation provides a sufficiently accurate, highly realistic capacity forecast with throughput times and flow rates. The user can measure the target values in “What-if” scenarios or explore different calibrations in parametric studies. The capacities and their effects on the value stream can be planned in a transparent and proactive manner.



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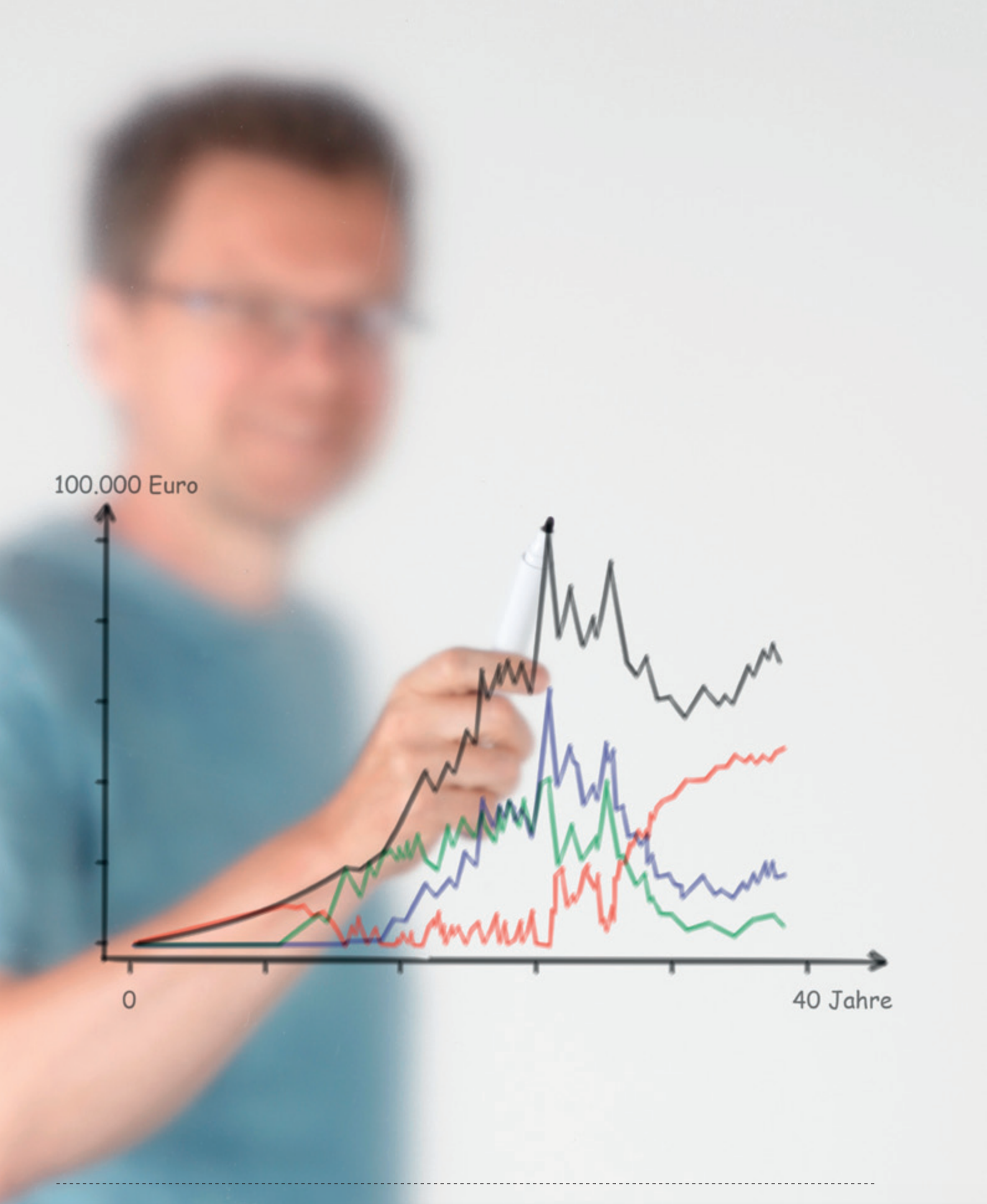
SOFTWARE FOR ADAPTIVE RADIATION THERAPY

The purpose of the BMBF funded project SPARTA is to develop innovative and sustainable features for medical IT systems in radiation therapy planning. A system for clinics is developed, which over the full course of the therapy (which in general lasts several weeks) promptly detects any deviations from the original therapy plan, identifies medical treatment requirements and gives the attending physician appropriate choices of corrective measures. The goal is an optimal therapy and chances of patient recovery throughout the course of treatment.

Thanks to the technical improvements in recent years in medical imaging technologies like computer tomography or magnetic resonance imaging, high precision systems have been developed for radiation therapy, which permit accuracies in the prediction and planning of the dosages in the body of the patient down to the millimeter range. Consequently, even these precise dosage settings have to be adjusted for small changes in the body (e. g., weight loss over the course of treatment), since a high dosage range for a tumor could now possibly affect healthy adjacent organs. In addition to ITWM, the project consortium consists of several leading clinics in the field of radiation therapy, research institutes like the German Cancer Research Center (DKFZ), Fraunhofer MEVIS, and several SMEs as well as the world's biggest imaging device supplier SIEMENS. The membership covers the entire spectrum of sciences for the proposed system: from medical expertise to state of the art image processing and medical IT, in addition to the mathematical competence and experience in the development of algorithms for interactive radiation therapy planning. The medical therapy planning working group draws on more than ten years of decision support experience in radiation therapy planning.

The special challenge facing ITWM in SPARTA is the development of new software based planning tools for physicians, to enable them to respond to a deviation in the plan at any time with the usual high precision in a highly dynamic situation of a radiation therapy stretching over several weeks. Innovative solutions are developed such as the multi-criteria interactive patient positioning to within a few centimeters, or the fine tuning of the treatment device parameters to provide the greatest possible range of action for adjusting the plan, but without necessitating additional time-consuming quality assurance procedures or affecting the course of the treatment.

1 *Interactive patient positioning correction: To react to a change in patient geometry, the planner uses the controls to make requests in terms of the quality measurements in the treatment plan and the system automatically computes the optimal repositioning of the patient.*



Simulated developement of a pension plan and its investment components: cover fund (red), capital protection fund (blue), and equity fund (green). A large number of such simulated developments can be used to classify pension contracts into risk-categories.

FINANCIAL MATHEMATICS

▪ CHANCE RISK ASSESSMENT

Modeling and simulation of financial products as well as classification into chance risk classes

▪ RISK MANAGEMENT

Development of software components for risk management of banks and insurance or energy companies

▪ FRAUD DETECTION AND EXTRAPOLATION OF DAMAGE

Data based detection of abnormalities (e. g. for fraud identification) and assessment of damage due to accounting fraud

▪ MARKETMODELS

Modeling of price dynamics in finance and commodity markets

▪ INSURANCE MATHEMATICS

Simulation and optimization of strategies for asset liability management

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DR. ANDREAS WAGNER
HEAD OF DEPARTMENT

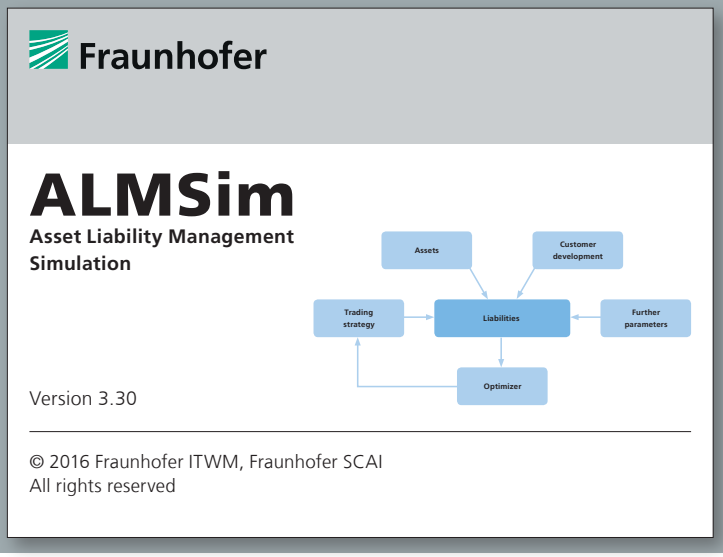
The "Financial Mathematics" department offers modern solutions to all kinds of problems in development, analysis and numerical implementation of mathematical models for the finance and insurance industry. Our approach is based on most recent research in finance and statistics to develop concepts, algorithms, models and software platforms for finance and insurance.

We benefitted from our strategical focus on the area of retirement planning during the last years and won the bid of the Federal Ministry of Finance to classify subsidized retirement planning products into chance-risk classes. To this end, the independent firm "Produktinformationsstelle Altersvorsorge gGmbH" (PIA) has been founded. It will carry out this classification which is based on probabilistic computations for different products. Therefor, the "Financial Mathematics" department developed a simulation concept and it will perform necessary simulation processes for PIA.

To increasingly focus on his scientific contribution to the work of our department, Prof. Dr. Korn vacated his position as head of the "Financial Mathematics" department. As of December 2015, Dr. Andreas Wagner is the new head of the department which adds also a new strategic focus to our portfolio: In the future, modelling of commodity prices (e.g. power, natural gas), valuation of complex storage products (e.g. for pumped-storage power plants) and general solutions for risk management of energy suppliers will be part of our business.

2015 has been a successful year for our department. Results from the WISA-project "Stochastic modelling and numerical simulation for risk management of insurance companies" (jointly with Fraunhofer SCAI) could be used for the PIA-related chance-risk classification. We conducted pre-studies in the area of fraud detection which let us expect new projects in 2016. Within this area, we also rendered an opinion about computing the "guaranteed claim" for fraud in the public health sector. The methods explained therein are used for prosecuting submissions of false claims within the health system. We also expect future projects in this area.

We are looking forward to 2016. Simulations for PIA will be performed and larger projects related to fraud detection and in the area of energy supply are expected. On this account, our department's staff is on a growth course in 2016.



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ASSET-LIABILITY-MANAGEMENT-SOFTWARE ALMSim

1 *Welcome screen of ALMSim displaying a flow-chart of an ALM-study*

Since January 2014 our department collaborates with the department Computational Finance of Fraunhofer SCAI in a Business-Oriented Strategic Alliance (WISA). The collaboration aims at the development of a modern Asset-Liability-Management-Tool (**ALMSim**).

Asset-Liability-Management (ALM) matches assets and liabilities of a financial institution and addresses the risk arising from mismatches. Future earnings from assets have to be adjusted to expenditures from liabilities and the structure of the asset portfolio should be optimized. This process has to take into account the uncertainty in financial markets as well as e. g. the age structure of the policy holders.

There are no satisfying financial models for the current low interest period, in particular when it comes to long term modeling and simulation. Moreover due to longevity the liabilities from pension payments are more and more difficult to earn. The project will offer solutions and proposals for these and other challenges and make the solution available in ALMSim.

In the past year, we could develop a first version of ALMSim, which allows to stochastically simulate various assets under different models. On the other hand the liabilities of an insurance company can also be considered. The current version even allows for a link between assets and liabilities. Such a link could e.g. arise if during a decline of the equity market the gains of pension plans decline as well and therefore less new customers can be acquired. This would have consequences again for the liabilities of the insurer. Currently ALMSim is used in the project together with the "Produktinformationsstelle Altersvorsorge gGmbH" (PIA). In this project scenarios are generated for the capital market and depending on these scenarios the development of different pension and retirement policies is calculated. This allows to compare chances and risks of these policies.

During the next year the software ALMSim will be further developed. In particular regulatory requirements from Solvency II will be taken into account when optimizing asset allocation. Also several market risks such as sudden drops or interest rate changes will be considered. Other possible risks to take into account are e.g. mortality and cancellation risk. ALMSim enjoys a modular structure and uses cloud techniques for distributed processing. By using the Netbeans Platform ALMSim has a graphical user interface that is easy to use and extendible. All input and output uses XML-files, this allows for a flexible adaption to other front-ends.

1

AUTOMATED TRADING AND ALM

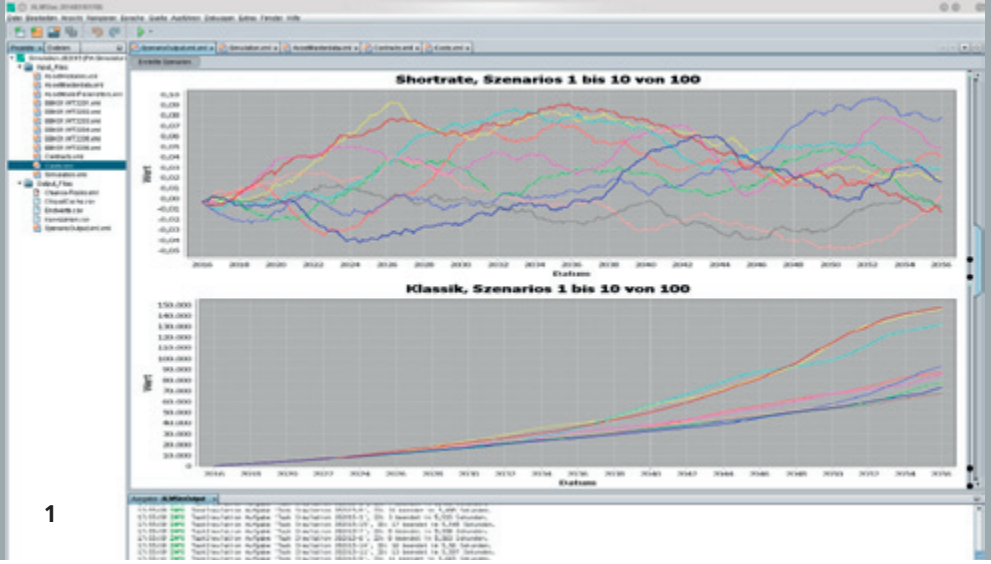
1 *Trading room of a bank*

Over the last year, our department intensified the long-standing relationship with the company OptiRisk Systems, UK. Currently we are working on projects in the field of trading strategies for equities and asset liability management.

For the project on trading strategies, we develop software for equity traders. Here we incorporate recent research on portfolio optimization as well as sentiment analysis from news feeds in order to generate buy and sell signals. The optimization model is based on the concept of second order stochastic dominance. Given two investment alternatives, this means that all values of the integrated distribution of the dominating alternative are less or equal – and at least one value is less – than the values of the integrated distribution of the dominated alternative. This criterion is closely related to decisions of a risk-averse investor and her expected utility. Besides, we particularly focus on the additional value of news data. Here, amount as well as relevance of incoming news items effect the estimation of asset return means and volatilities and thus the estimated asset performance.

The second project focuses on the development of software used for asset liability management (ALM). Here the challenge is to match earnings and liabilities of an investor or a fund for a long investment horizon. This matching can also be relevant for a single individual or a household. In case of an individual ALM, private revenue and expenses are matched to make up investment and credit decisions and to account for all relevant capital gains. Typically, in case of an individual ALM, the motivation is private financial planning for retirement. The optimisation criterion is to maximise the expected utility generated by private consume. When it comes to ALM decisions for pension funds and insurance companies, the optimisation typically tries to minimise deviations between the future values of the assets and liabilities.

We need to create adequate scenarios for both issues. This means that we have to generate sample paths for assets like stocks as well as for other financial instruments like interest rates. To create reliable scenarios, we apply and enhance existing scenario generation methods to produce realistic forward-looking decisions.



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SIMULATION OF PENSION INSURANCE PRODUCTS

The simulation of pension insurance products is based on a market model, consisting of a capital market and an interest rate model, so that stocks and funds as well as interest rate related products, e. g. fixed-income funds, bonds, saving plans, etc., can be simulated. This market model allows us to approximately represent and to consistently simulate all standard pension insurance products in our framework and thus to make their up-side chances and down-side risk comparable. In particular the model allows us to analyze classical insurance products based on a cover pool as well modern products such as hybrid products, index participation products and so-called CPPIs (constant proportion portfolio insurance).

In order to qualify as a state-subsidized Riester pension scheme, a product has to provide a gross premium guarantee at maturity. The construction of financial products with such a minimum guarantee during low interest rate regimes poses a challenge. Especially for short maturities it might become difficult to earn enough return from low risk or high credit rating investments in order to cover possibly substantial acquisition cost and management fees. More risky positions with higher expected returns will at the same time require a (not for free) hedging strategy or other risk management methods in order to be able to fulfill the gross premium guarantee without losses, and possibly provide still some growth potential (e. g. as protection against inflation risks).

In the current difficult low interest rate environment the calibration of the interest rate model is of crucial importance. On the one hand negative interest rates are an anomaly, since holding cash provides an arbitrage opportunity, on the other side most products strongly depend on the expected or modeled stochastic interest rate (and term structure) dynamics, even if the currently observed term structure is reproduced by the model. In part this problem is ameliorated by the fact that our task is not primarily to estimate exact return distributions but rather to determine the relative positions of different pension products in a chance/risk diagram.

1 *Simulation of an interest rate model (Shortrate) and a classic pension insurance*

The rapid prototyping platform RODOS® and the 3D laser scanner vehicle REDAR facilitate the analysis of the driver influence in the earliest phases of development. The test scenarios designed employ georeferenced laser scanned 3D point cloud with sub-centimeter resolution. In this way the optical complexity of the scene is extremely close to the reality. Thus large scenarios and complete cities can be reproduced for the virtual vehicle tests in real-time.

MATHEMATICAL METHODS IN DYNAMICS AND DURABILITY

▪ MODELING AND SIMULATION OF USAGE VARIABILITY AND RELIABILITY

Design targets for durability and optimization of highly variable design attributes like reliability and energy efficiency

▪ SYSTEM SIMULATION IN VEHICLE ENGINEERING

Tire, soil, and driver models as well as interactive simulation

▪ NON-LINEAR STRUCTURAL MECHANICS

Simulation of highly deformable components and structures such as tires, rubber bushings, hydro-bushings, air-springs, hoses and wiring harnesses

www.itwm.fraunhofer.de/en/mdf

DR. KLAUS DRESSLER
HEAD OF DEPARTMENT

The department MDF is dedicated to the development and deployment of new technology for modelling and simulation of usage variability, durability and energy efficiency of vehicles. To enable virtual product development for those attributes, it is key to simulate the 'complete life' of vehicles including their interaction with the rest of the world, i.e. road – vehicle interaction and driver – vehicle interaction. Towards that goal, in cooperation with our partners from car, truck and commercial vehicle industry, we develop and implement new methods and processes:

- Statistics and Monte-Carlo simulation methods using geo-referenced data (**U·Sim** and **VMC®** – Virtual Measurement Campaign®). VMC® can be seen as a 'model of the world for vehicle engineering', including a geo-referenced data base and software for simulation and analysis of vehicle usage variability.

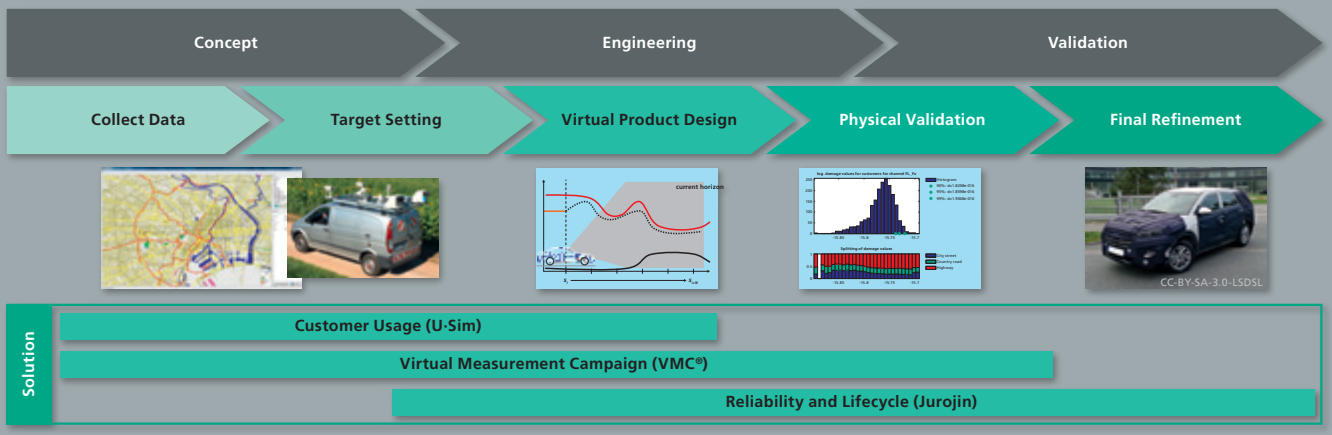
- Simulation of vehicle – environment interaction (**CDTire**, tire and ground interaction).

- Simulation of vehicle – human interaction/driving simulator **RODOS®**.

- Nonlinear structural mechanics: Fast and interactive functional and manufacturing simulation of cables and hoses (**IPS Cable Simulation**).

The Fraunhofer Innovation Cluster Digital Commercial Vehicle Technology plays an important role in developing this portfolio (www.nutzfahrzeugcluster.de). The innovation cluster now constitutes one of the three application domain centers in the newly established High Performance Center Simulation and Software-based Innovation.

A special highlight in 2015 has been the successful deployment of our new 'Road & environment-data acquisition rover' **REDAR**. This is a measurement vehicle with high resolution laser scanners and a high-end inertial platform. REDAR allows very efficient measurement of road and environment data: on one hand the data are so detailed that they suit as input for 'digital-road' CDTire-vehicle simulation, on the other hand they are so far reaching that they can be used as environmental data in interactive RODOS® simulations. Please read the following pages to learn more about these capabilities.



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TOOLS FOR STATISTICAL ASSESSMENT OF VEHICLE LOAD AND STRENGTH

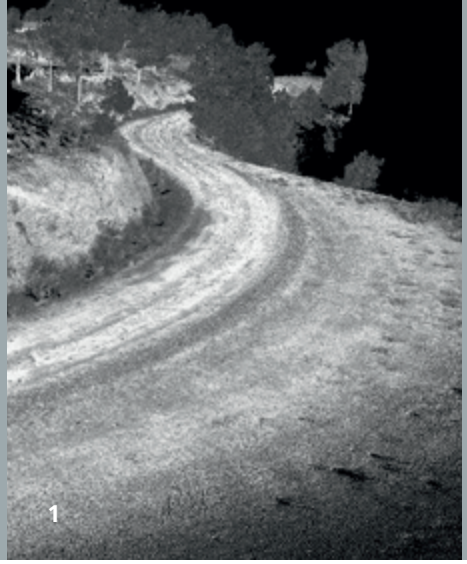
Along the complete durability engineering process in vehicle engineering, statistical methods are indispensable for the description and modeling of load and strength of systems and components. Our **VMC®** activities (Virtual Measurement Campaign) provide three software tools in order to accompany our customers in their process from early design phases up to component testing for final release or production monitoring.

1 *The tools in the process chain*

With a variety of methods and plots, VMC® supports the analysis of target markets, e. g. South America, with respect to vehicle-relevant environmental conditions and the comparison to known markets, e. g. Central Europe. Especially the road network, its composition of different road types, topographical properties, as well as climate conditions may be evaluated. This is important in an early concept phase as well as for the planning of a data collection or the analysis of warranty issues. During the planning of a measurement campaign we need to know which roads in a region should be selected and how many kilometres we should go in order to end up with a statistically well-founded database. This process is supported by **VMC® GeoStatistics** with a variety of analysis features. The subsequent evaluation of data is strongly facilitated and enhanced by **VMC® GeoLDA**, which automatically maps the data to the road network and performs a segmentation and classification according to the road properties.

The central idea within this approach is the systematic separation of the operating conditions (driving on a flat country road with maximum payload or distribution traffic in a city) and the expected frequency of their occurrence within a certain groups of customers. This separation allows to extrapolate the data with **U·Sim** (Usage Simulation) to the desired target life for a customer population and to obtain the load distribution including high quantile loads for the component development and testing. All methods described so far are also applicable within the design and development of drivetrain components towards fuel consumption and emissions.

The final release of components for production requires the optimal balance between expensive rig tests and high quality requirements. **Jurojin** calculates efficient test plans, which leads to fast and reliable decisions, reduced costs, and especially reduced risk of overdesign. If, nevertheless, components fail during operation in the field, well-founded decisions about possible actions are needed. Especially in the early phase of mass production and usage with only few complaints so far, it is difficult to distinguish between having a real problem and having some complaints just by accident. Jurojin solves this problem by modeling the non-failure components in a suitable way. Once this missing-data problem is handled, reliable predictions are obtained based on specific maximum-likelihood algorithms.



REDAR – LASER BASED 3D-ENVIRONMENT ACQUISITION VEHICLE

1 *Digitized environment*

2 *3D measurement vehicle REDAR*

The main task of the laser-based data acquisition system **REDAR** (Road & Environmental Data Acquisition Rover) is the digitization of the environment in millimeter accuracy. Startup of REDAR was middle of the year 2015 after a design and construction phase of several years. In the last few months it was used in first application projects with customers from agricultural machinery, automotive and motorsport. The current core equipment of the carrier vehicle is composed of:

- two high-performance laser scanners
- a high-precision inertial measurement unit
- GPS
- distance sensor
- four industrial color cameras
- on-board data acquisition computer
- generator and uninterruptible power supply.

The modular design can be adapted as needed to different requirements and tasks. It is possible to use additional sensors or any other carrier vehicle (e. g. air or water vehicles).

As kinematic data acquisition unit, REDAR is able to measure the road during moving traffic without the need of expensive closures or night driving. Simultaneously, the data density can be increased significantly at reduced speed. Thereby, it is for example possible to detect smallest cracks in road surfaces or in tunnels and represent them visually. Depending on customer requirements, the high-precision data can be treated in a variety of post-processing steps and can be provided according to the purposes of fatigue strength applications or status detection. In addition to customer application projects, REDAR is also used for the evaluation, development and complementary support of other activities at the ITWM. The captured environments can be used for ambient illustration in the driving simulator **RODOS©**. This offers both: a very realistic visual simulation environment and a highly accurate description of the road surface as basis for calculating the vehicle movement for vehicle or tire simulation (for example with **CDTire**). Additionally, REDAR can enlarge the road database of **VMC©** with each driven kilometer and expand its comprehensive datasets with variables which are derived from the measured data. The synchronous detection of 'cheap data' (acceleration, etc.) in conjunction with the accurate knowledge of the real road surface allows for the first time to validate methods to back-calculate the road surface based on easy-to-sense data (research topic 'invariant excitation'). With the increasing importance of virtual product development in automotive industry (especially in autonomous driving), the need for high quality stock data from real streets and environments is also rising. REDAR is an important device in order to meet this demand and merge simulation and reality even further.

DRIVING AND OPERATION SIMULATION WITH RODOS®

During the design phase of a vehicle, attributes such as structural durability and reliability must be examined in the very early stages of the project. To accurately analyze the relevant processes during the simulation, all external influences on the vehicle have to be considered. These include the driver as well as driver assistance systems which affect the driver's response to the vehicle. For the interpretation of active/reactive systems, the driver actions have to be considered in order to ensure the accurate operability of new automation systems.

Prototype testing usually comes with major disadvantages. First, it is often not possible in such early stages of development. In addition, field measurements are much less reproducible. Lastly, in a prototype it is not possible to observe all the internal states of the system and only a few of them are controllable. Overcoming these drawbacks is one of the principal competitive advantages that the Rapid Prototyping Platform **RODOS®** can provide. The Rapid Prototyping Platform RODOS® has been developed in recent years at Fraunhofer ITWM. It features a 6-axis robot kinematics with 1,000 kg payload, installed and incrementally improved since its commissioning in 2012.

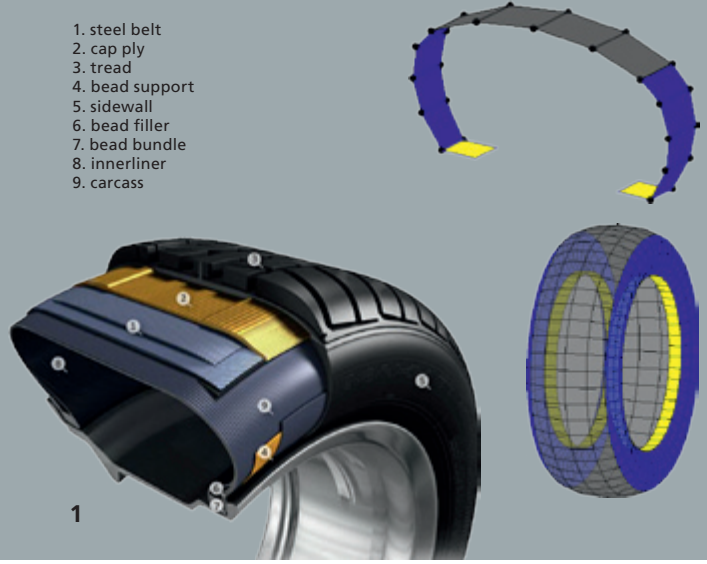
The latest addition is the integration of 3D laser scanner measurement data in the interactive simulation. With **REDAR** the environment is scanned and integrated in a virtual world. This extremely large amount of data (a 20 km long test section needs a data volume of more than 4 TB) needs to be read directly from a network drive and processed in real time. The scanned data is used for both, the visualization as well as for the vehicle simulation and the tire simulation. This new technique allows the integration of arbitrarily large scenarios in RODOS® that closely matches the optical complexity and level of detail of reality. In addition, the time required for creating a scene is minimal.

With this approach, an interactive simulation such as a ride from Kaiserslautern to Berlin becomes possible. Innovative driver assistance and automation systems for vehicles can be studied and tested under realistic conditions with typical drivers. Additionally, new operational concepts, human-machine interfaces, information systems and vehicle configurations can be tested and optimized with test drivers, experts and developers.

Soon, the point cloud data will be supplemented with color information from images, increasing the realism of the virtual world. These projects are part of the current development in RODOS® and REDAR.

1 *Geo-referenced 3D point cloud of the Fraunhofer Center in Kaiserslautern*

2 *Interactive simulation with RODOS® in a point cloud scenario*



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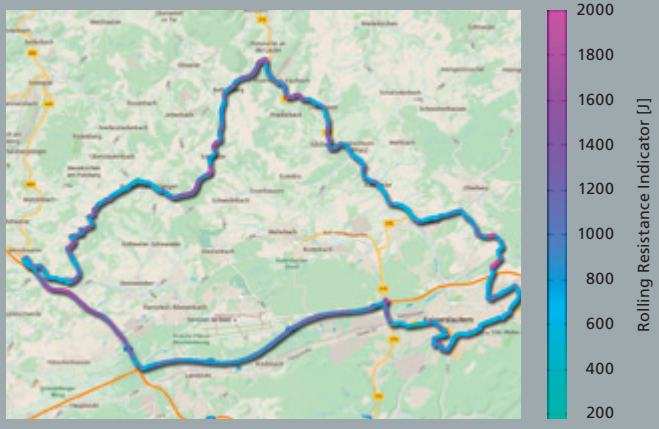

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PREDICTION OF ROLLING RESISTANCE AND TREAD WEAR OF TIRES IN REALISTIC APPLICATION SCENARIOS

1 *Construction of radial tire (left)*

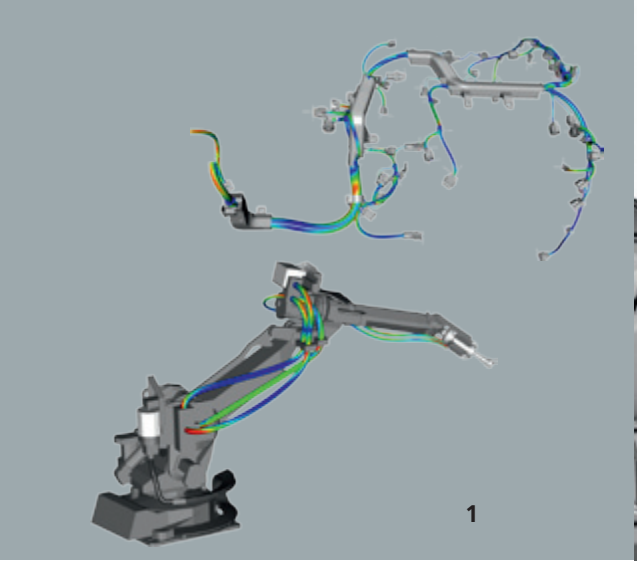
Model mass distribution and cross section (right)

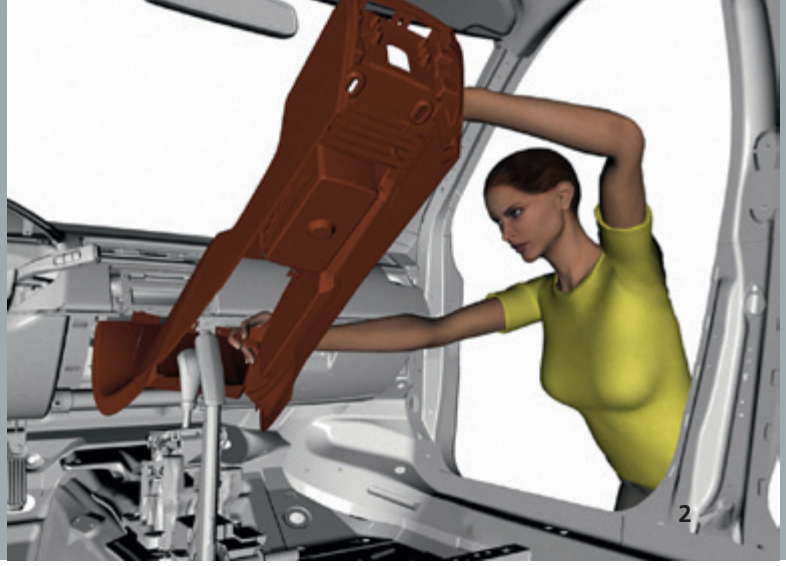
2 *Representation of rolling resistance indicator along a reference track*

At ITWM the tire model **CDTire/3D** is continuously developed as part of the **CDTire** model family. CDTire/3D is a shell-based model with materialized sidewalls and belts. Modern tires consist of different component layers like inner liner, carcass, steel belt layers, cap plies, tread etc. Most of these layers are reinforced by synthetic cords or steel wires with materially preferred direction. All these functional single layers are separately represented within the tire model such that their structural characteristics can also be parametrized separately and may vary with local cross section position. CDTire/3D's simulation times are comparable to those of well-established tire models used in multi-body dynamics and, therefore, orders of magnitude below those of FEM-models.

In order to estimate the tire's rolling resistance, one locally computes the energy loss for all dissipative structural elements and accumulates these results. Hereby, viscous local damping terms within the rubber and the reinforcement layers are sources of energy loss, as well as inner friction terms – particularly in the tread rubber – and friction losses between tire and road surface. The tread wear cannot be calculated directly, so the friction energy loss between tire and road surface serves as an indicator, as these two quantities are directly and strictly monotonically related. With the help of this tread wear indicator it is immediately possible to perform A/B-comparisons, alternatively it is also possible to quantify the tread wear via a respective previous calibration.

Within the scope of the European FP7- funded project LORRY (coordinated by Goodyear), the ITWM is developing a method to predict indicators for rolling resistance and tread wear of tires in realistic application scenarios. The basic idea is the decomposition of actual routes into a suitable set of load cases depending on curvature, longitudinal slope and velocity. The respective tire energy losses are computed for all load cases – by means of a simulation model of the vehicle equipped with a CDTire/3D tire model – and are finally stored in a result catalogue. In order to predict the tire energy loss for a realistic application scenario one partitions actual routes (track, velocity profile) into the predefined load cases and superposes the total energy loss from the result catalogue. This method allows considering application-based factors of influence like specific customers, operation circumstances, regional dependencies, etc. when predicting rolling resistance and tread wear of tires.





INTERACTIVE SIMULATION OF FLEXIBLE STRUCTURES FOR VIRTUAL PRODUCT DEVELOPMENT

Since more than a decade, there has been an intensive collaboration of the departments MDF and "Geometry and Motion Planning" of FCC in Gothenburg, with a particular focus on fast, physically correct simulation models that provide the possibility to work interactively with strongly deformable structures in the computer.

The original motivation to start the first joint project in 2004 has been the task to compute the deformation of robot dress packs as an integral part of computational path planning of robot motions, such that spatial movements and deformations of the hoses can be accounted for, if possible without any loss of computational speed. The ansatz that has been developed to solve this problem consisted in a novel approach to Cosserat rod models involving ideas from Discrete Differential Geometry in combination with efficient computational methods from computer graphics, instead of using traditional (yet somewhat cumbersome) nonlinear finite element techniques. The resulting computational models provide accurate physical behavior at interactive speed. Soon it turned out that the models and algorithms developed by FCC and ITWM for interactive simulation of flexible cables and hoses are a key technology within the framework of digital validation of assembly processes. This was actually the point of departure for the separate module **IPS Cable Simulation**, which is part of the **IPS** (Industrial Path Solutions) software package developed at FCC for automatic path planning of the assembly or disassembly of rigid part geometries. Using IPS Cable Simulation, one can digitally plan and validate the assembly of cable systems, which minimizes (or even eliminates) time and cost efforts for hardware prototypes. The software is currently used by all of the leading automotive OEMs, and is likewise considered by suppliers of cable and hoses systems as a useful tool for system design. Sales and marketing of the software are persued by the two spin off companies IPS AB (Gothenburg) and fleXstructures GmbH (Kaiserslautern).

Difficult assembly tasks, as occurring e. g. within the final assembly of cars, often require fine tuned manual work by human work force. The ergonomically favorable design of work places as well as the optimal support of human work by suitable tools and mechanical assistance requires that humans are properly accounted for in assembly simulations. ITWM and FCC, together with four other institutes (IPA, IPK, IGD und IAO), are currently performing research work on this topic within the Fraunhofer MAVO project EMMA-CC (Ergo-dynamic Moving Manikin with Cognitive Control), the focus of ITWM and FCC being the enhancement of the digital human model IMMA by adding dynamics and including actuation by muscle models for a proper assessment of physical loads on the human during an assembly task.

1 *IPS model of a wiring harness, consisting of different cable strands; stresses caused by the deformation of cables and hoses are indicated by the colors displayed on the structures (above); industrial robot with attached dress pack (below).*

2 *Assembly simulation of the of the middle console inside the interior of a car chassis using the digital human model IMMA developed by FCC.*

The Competence Center High Performance Computing works on advancing 3D visualization by using CPUs exclusively and omitting the GPU altogether. This, together with the parallel design, fast communication methods between the nodes, and scalable render kernels, sets the XtreemView Render Engine apart from anything else on the market. It is perfectly suited for interactive visualization of many kinds of large scale datasets as found in all kinds of industries, from seismic, through medicine, over filming, and gaming, on to automotive.

COMPETENCE CENTER HIGH PERFORMANCE COMPUTING

- BIG DATA – BeeGFS, GPI, GPI-Space
- HPC TOOLS
- SEISMIC IMAGING
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- PERFORMANCE OPTIMIZATION
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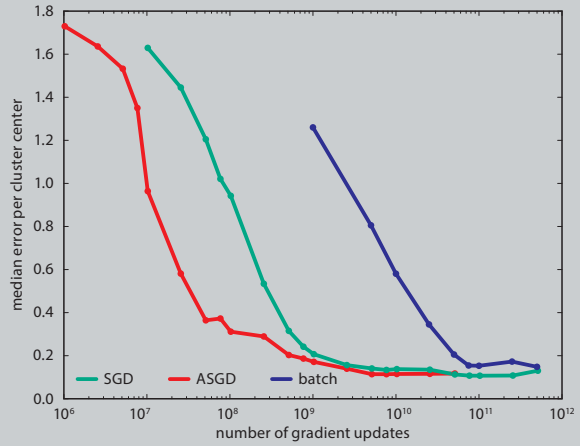
DR. FRANZ-JOSEF PFREUNDT
HEAD OF DEPARTMENT

High Performance Computing is indispensable for research and economic competitiveness. Basic research in the fields of energy, the material and life sciences, or even climate research is unthinkable today without detailed simulations. This is also true for key areas of the German economy: Whether electronic devices, autos, airplanes, modern medicines, or innovative operational processes – they all have their basis in simulations. High Performance Computing opens the way for new applications in the simulation of complex social phenomena or more demanding tasks in logistics.

At the same time, the increasing complexity of the underlying HPC architectures and their efficient use poses great challenges for industrial users: Programs today have to work in parallel and account for both locally stored data as well as content from storage that can be accessed only via a network. The additional possibilities opened through the use of specialized hardware like graphic processors, further increase the complexity of these programs. In close cooperation with industrial and academic partners, the Competence Center for High Performance Computing develops solutions to the question of how the increasingly complex processors and parallel computers can be used efficiently. In addition to developing tools for the management of supercomputers, it also produces integrated software solutions.

One of these tools is the Global Address Space Programming Interface (**GPI**) that can be called European standard by now. It enables the programming of scalable, tightly coupled software, that is, software that on the one hand needs to exchange small data packets at a high frequency, and on the other hand runs proportionally faster when deployed on more compute resources.

Whereas, GPI assumes an explicit formulation of the communication patterns of the application, the **GPI-Space** tool goes further and automates the parallelization and fault tolerance as well as the storage management. These tools and the world's leading parallel file system **BeeGFS** (also developed at CC HPC) are successfully deployed in complex client-specific applications. Last but not least, CC HPC is working on the management of the energy revolution and the associated fluctuation in the generation of alternative energies. All aspects of the issue are being studied: temporal decoupling of energy production and consumption, consumption forecasting and shifting, optimization of power consumption as well as the use of net services to manage distributed battery systems. Comprehensive knowledge in the design and control of complex IT systems is being applied to achieve the goal of a safe, environmentally-sound, and economic energy supply. The concept of "Green by IT" has become a significant business segment.



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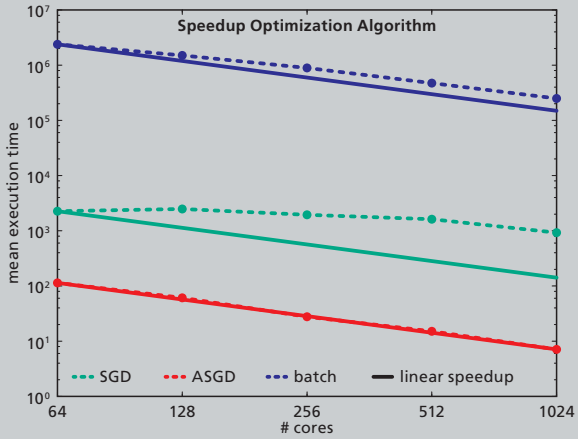


2

LARGE SCALE MACHINE LEARNING

In recent years, Machine Learning (ML) methods have evolved to become one of the most dynamic research areas with great impact on our current and future everyday life. Astonishing progress has been made in the application of ML algorithms to areas like speech-recognition, automatic image-analysis and scene understanding. Machine Learning enables computers to drive cars autonomously or to learn how to play video games, pushing the frontier towards abilities that have been exclusive to humans.

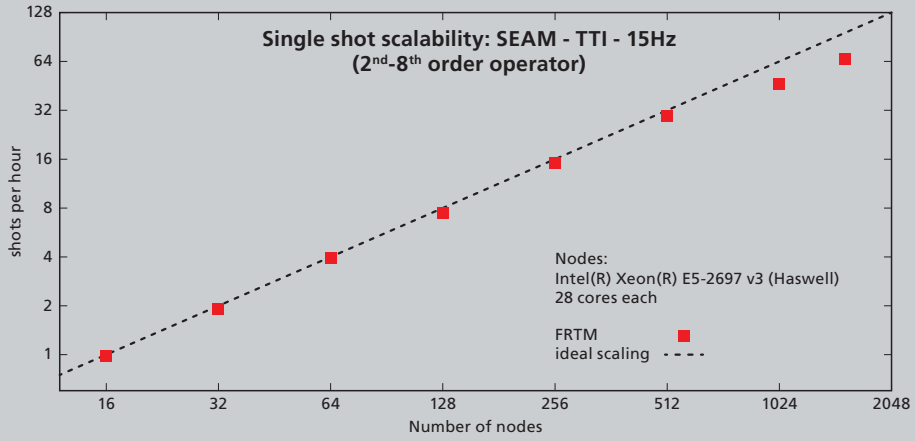
This development is driven by the vastly increasing usage of compute power and growth of datasets training more and more complex ML models. Hence, Machine Learning is becoming a High Performance Computing task. The CC HPC at ITWM denotes this ongoing development by increased research activities on the scalability of large ML problems. Currently we focus on the distributed parallelization of optimization methods used to train large ML models. Our approaches, i. e. the Asynchronous Stochastic Gradient Descent (**ASGD**) solver, are based on the existing CC HPC tools like our asynchronous communication framework **GPI 2.0** and the distributed file system **BeeGFS**.

Asynchronous Stochastic Gradient Descent (ASGD)

ASGD is a fast parallel optimization method for Machine Learning on HPC cluster and HTC cloud applications. Stochastic Gradient Descent (SGD) is the standard numerical method used to solve the core optimization problem for the vast majority of machine learning algorithms. In the context of large scale learning, as utilized by many Big Data applications, the efficient parallelization of SGD on distributed systems is a key performance factor. ASGD outperforms current, mostly MapReduce based, parallel SGD algorithms in solving the optimization task for large scale machine learning problems in distributed memory environments. We were able show, that ASGD is faster, has better convergence and scaling properties and leads to better error rates than other state of the art methods. With ASGD, non-convex optimization problems in high-dimensional parameter spaces can effectively be parallelized over hundreds or thousands of CPU and GPU nodes.

1 *Convergence properties of our ASGD algorithm compared to parallel SGD and MapReduce BATCH optimization applied to K-Means clustering with k=100, d=100 and ~1TB of data samples*

2 *Scaling properties of ASGD applied to K-Means clustering with k=10, d=10 and ~1TB of data samples*



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PALATINE HIGH PERFORMANCE COMPUTING MADE IN KAISERSLAUTERN FOR EUROPE

1 *Scalability on the SuperMUC Cluster*

Since a few years the CC HPC is involved in projects in the scope of the European framework program for research and innovation. While the first projects will end in 2016, the second batch of projects has started in late autumn 2015. It is a good time to evaluate the developments and give an outlook on exciting new research perspectives.

Today all academic fields need ever increasing compute performance and the ability to analyze big amounts of data. The primary goal of the research program Horizon2020 is to build computer systems which calculate in the exa-scale regime by the year 2020. Combining a lot of individual components enables a huge computer power. Taking into account today's computer power one can calculate that about 2 million computer cores will be needed, to reach Exascale. The hardware architecture has enormous consequences on the required software. It is essential that the programs compute tasks in parallel. Intermediate results need to be exchanged between the components to ensure the progress of the whole program. In general the following statement holds: Using more cores on the same problem size (i. e. strong scaling) means that the computation time for each core declines, while the communication overhead stays constant in a best case scenario. For very big systems the time spent for communication is crucial. It is necessary to employ sophisticated concepts for the communication of data. **GPI** (Global Address Space Programming Interface), which has been developed at Fraunhofer ITWM, allows an asynchronous, multi-thread communication avoiding temporary copies of data. GPI, which is a world-leading communication model for HPC, is utilized in two mature EU projects (EXA2CT and EPiGRAM).

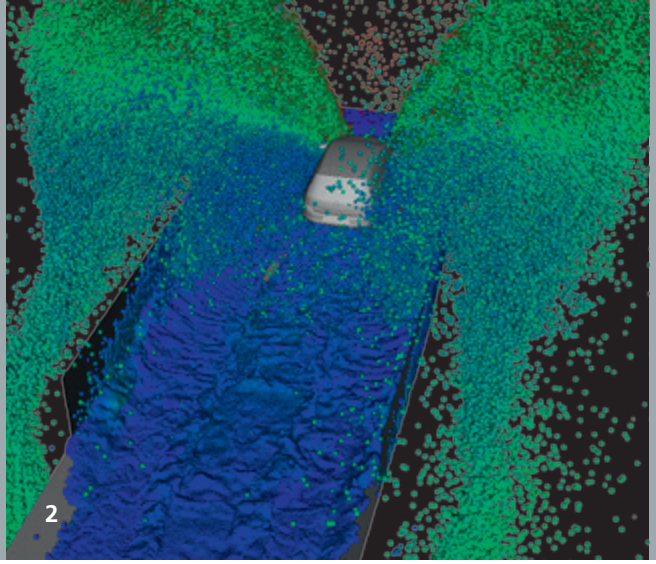
In the scope of the EPiGRAM project the limits of the communication model GPI are tested, extensions and changes are proposed and the applicability to diverse, heterogeneous memory models is investigated. The interoperability of GPI with other – on the HPC market available communication models – has been tested successfully. The interoperability of diverse HPC programming models will be unfolded elaborately in the scope of an EU project called INTERTWINE which has just started. The scalability of GPI has been tested in the scope of the EPiGRAM project on the newest extension of Germany's largest supercomputer, the SuperMUC at the Leibniz Supercomputing Centre in Munich. In 2015 SuperMUC has a computer power of about $3.5 \cdot 10^{15}$ floating point operations per second, which is about factor 400 smaller than an exa-scale-ready machine. It has been shown that GPI scales strongly over three orders of magnitude and that the application reaches over 90% parallel efficiency. During the tests up to $4 \cdot 10^{14}$ floating point operations per second on 84,000 compute cores have been reached.

Even at the SuperMUC computer cluster it can be seen that the hardware components of the whole system fail often. The number of hardware failures will increase with the number of hardware components.

To ensure that a failure of a component of the system does not immediately have effects on the massively parallel programs, the hardware and the software needs to be fault tolerant. This has to be guaranteed at all levels, thus also on the level of the communication software. This challenge has been addressed in the scope of the European EXA2CT project. The EXA2CT project brings together experts at the cutting edge of the development of solvers, related algorithmic techniques, and HPC software experts with the goal to develop an user-friendly communication software. In the scope of the project we have built a library, which expands the fault tolerance of GPI and allows the application developers to store the data during the execution of the program in the memory of a preassigned neighbor node. In case of a failure of a compute node, the data, which has been distributed in such a way, can be copied and the whole program can be started from a checkpoint. This method is clearly faster than the copy of data from disk.

In addition to the described software-oriented projects, we are involved in three European HPC projects, which develop specialized computer architectures for the exa-scale regime: DEEP-ER, EXANODE and EXANEST. For the DEEP-ER project, which proposes a cluster-booster architecture, we have extended our parallel file system BeeGFS, to use the different hierarchy levels of the storage systems efficiently. The EXANODE and EXANEST projects, which have just started, will use energy-efficient processors and nanotechnologies. The projects will use a system-wide, uniform memory concept.

Many of the presented ideas will be used for the first time in high performance computing and it is exciting to observe, how these ideas will influence the research direction of the HPC. To incorporate our extensive knowledge in the European strategic research agenda, we collaborate in the scope of the EXDCI project with leading HPC experts and contribute significantly to the decisions for the scientific program of the EC. Exciting times in the race to the first exa-scale computer cluster are imminent.



WORLD CLASS 3D MADE IN GERMANY

1 *Diffuse path tracing of the model of a Boeing 777 with approximately 300 million triangles (detailed view of landing gear); BVH creation took only 15 seconds.*

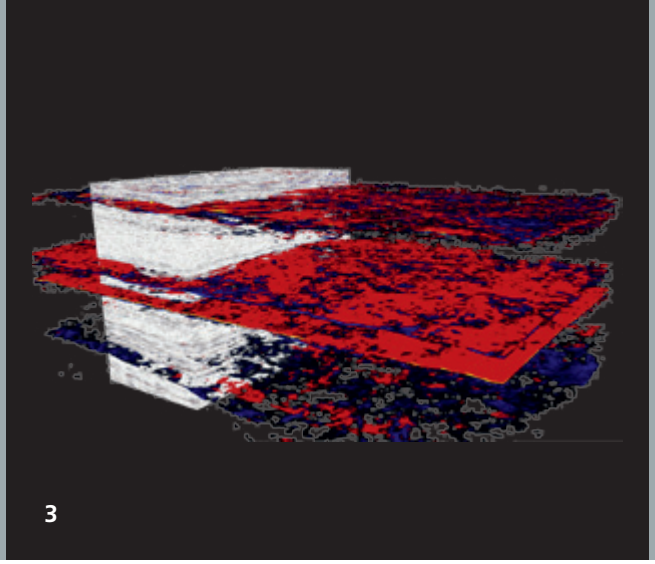
2 *Fast update of BVH allows interactive visualization of pre-calculated particle simulations with more than 1 million particles*

For many years, the Competence Center High Performance Computing has been working on advancing 3D visualization off the beaten path, by using CPUs exclusively and omitting the GPU altogether. This, together with the parallel design, fast communication methods between the nodes, and scalable render kernels, sets the PV-4D render engine apart from anything else on the market. With these features, the PV-4D engine is perfectly suited for interactive visualization of all kinds of large scale datasets as found in all kinds of industries, from seismic, through medicine, over filming, and gaming, on to automotive. The capabilities and possibilities of the engine are virtually endless: It allows visualizing volume datasets like seismic surveys or MRI imagery with or without volume rendering, efficiently renders large triangulated objects and scenes, or creates photo-realistic images from scenes using HDR environment maps for lighting, thus creating completely new scenarios for its use.

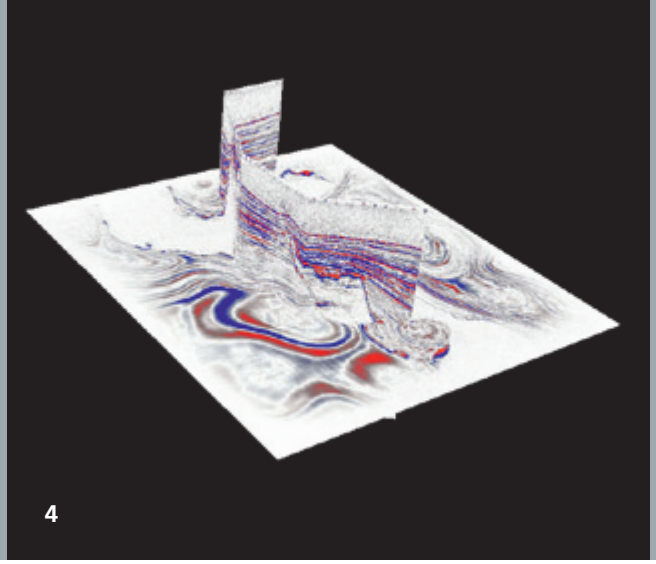
Scientist of the visualization group at CC HPC are continuously developing new optimization strategies and methods to stay ahead any competition and keep creating cutting edge technologies. The ever increasing computational power of new hardware, including new architectures like Intel's KNL, makes it possible to regularly provide more compute intensive methods for interactive visualization or large scale datasets.

The integration of path tracing algorithms into PV-4D marks the next evolutionary step in photo-realistic rendering, after interactive ray tracing has been available for a while now. As opposed to ray tracing, path tracing also illuminates diffuse surfaces correctly, generating much more realistic lighting effects. The better image comes at a cost, however. To create an image with little to no noise, the number of rays that have to be traced and tested against the objects in the scene has to be relatively high. This requires state-of-the-art methods to create and update the so called bounding volume hierarchies (BVHs), and to test rays against those BVHs and the objects they contain. Researchers work on new and efficient algorithms for both these tasks and could already publish two algorithms for BVH traversal, one for coherent and one for incoherent rays. Measured against other solutions, such as Intel Embree, these algorithms are already faster by a factor of 2 to 4. The ultimate goal of the team is nothing less but being able to interactively render whole movies, provided there's enough compute power available.

Fast methods for BVH construction and update also open new possibilities for visualizing particle simulations. The method of choice for this right now is to pre-calculate those image by image and put together a video clip from those images. This method, however, limits the viewer to



3



4

one single point of view. With Fraunhofer's technology, interactive visualization of such scene is possible and allows completely new insights.

Besides working on staying cutting-edge with its 3D visualization, the CC HPC also started an initiative to commercialize this technology and take it to a broader market. Leveraging the Fraunhofer internal concept of "Intrapreneurship", a startup was formed within the department to push efforts on this commercial track. This startup is partly funded by the "Fraunhofer-Innovator" program which has the mission to methodically support technology projects with the transition from research to the creation of a market ready product. Its ultimate goal is to make the technology available to the market, either by licensing or by forming spin-offs.

Leveraging the long standing engagement of the CC HPC in the oil and gas market, the first phase of this commercial path is targeting this market and offers – besides the actual PV-4D engine – a new and lightweight viewer for seismic data, which is fast, parallel, and easy to use: XtreemView.

XtreemView brings the strengths of the PV-4D engine right to the end user. It's simple and easy to user interface make it a great tool, whether used daily or just occasionally. Using the full 32-bit float values for visualizing the data allows working with real amplitudes, and seamlessly blending two arbitrary volumes, like seismic and a velocity field, delivers an extra layer of information. This little extra can be critical when it comes to interpretation and analyzation of datasets. Different ways of displaying the same volume, together with volume rendering, the addition of multiple seismic horizons, as well as being able to define arbitrary planes make a well-rounded visualization tool for even seasoned users.

The most important advantage of XtreemView is its scalability which allows to match the hardware to the problem size and not vice versa. Not only can two compute nodes visualize twice the data, because all I/O operations are also implemented in parallel, data loading is no longer the hurdle it used to be. Adding more nodes drastically reduces loading times from industry standard formats such as SEGY, JavaSeis, SU, and others. XtreemView was presented on both big industry shows, EAGE in Madrid and SEG in New Orleans and hit the spot with users and visitors alike.

3 *Two seismic datasets of 120 GB, one rendered as opaque body, the other with volume rendering to look at specific amplitude values*

4 *XtreemView allows to select arbitrary paths in the dataset and map the volume data onto those planes.*

Modeling and simulation of absorption, distribution, metabolism, and excretion of a drug as well as its effect are important tools in the drug development pipeline. FCC has a long-time experience in pharmacokinetic and pharmacodynamic data analysis in both applied research projects and in delivering contract services.

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DR. JOHAN CARLSON
DIRECTOR OF FCC

FCC is offering contract research, services, algorithms and software based on advanced mathematics within Modeling, Simulation and Optimization (MSO). MSO provides a significant leading edge in industrial innovation of products and production systems. In 2015, we have successfully proved this together with clients from the automotive and vehicle, metrology, pharmaceutical, wood and paper, and electronics industries. Examples include simulation and optimization of robotized adhesive stations, simulation of assembly ergonomics, modeling and simulation of drug compound distribution and effect, off-line programming of robot carried inspection sensors, and edge wicking of paperboards.

I am proud to say that during 2015, we have performed around forty projects for our industrial clients and twenty public projects financed by public research agencies such as SSF, VINNOVA and the EU. The revenue shows a growth of almost 5 percent since last year, an industrial income of 44 percent and a positive net result. Our work and technologies have helped clients mainly in Sweden, but also in Germany, US, Finland, Denmark, Japan, Israel, Korea, Great Britain, and China.

However, the full potential of using advanced mathematics in industry is far from reached and new technologies together with increased efforts in marketing and sales will hopefully continue our growth in 2016 and beyond.

We have been fortunate to recruit eight new coworkers. To be attractive for our clients and employees in the long run, the scientific activities of FCC are indeed important. In 2015 we have published thirty scientific papers including sixteen in journals. We have recruited one new student to our advanced engineering mathematics research program (AEM) and can also congratulate two of our coworkers who earned their Licentiate degree during 2015. Also, thirteen students from Chalmers worked half a day a week as contracted students and six students from Chalmers did their master thesis work at FCC.

A great advantage for FCC is the possibility of long term collaborations with Fraunhofer and Chalmers. The cooperation and exchange of projects with ITWM during 2015 have involved a variety of subjects such as dynamics, biomechanics, the simulation of flexibles, virtual paint, position tracking systems, product configuration optimization, continuous production, the simulation of ultra-fast electronics, and big data analytics. We have also extended our cooperation with several other Fraunhofer units.

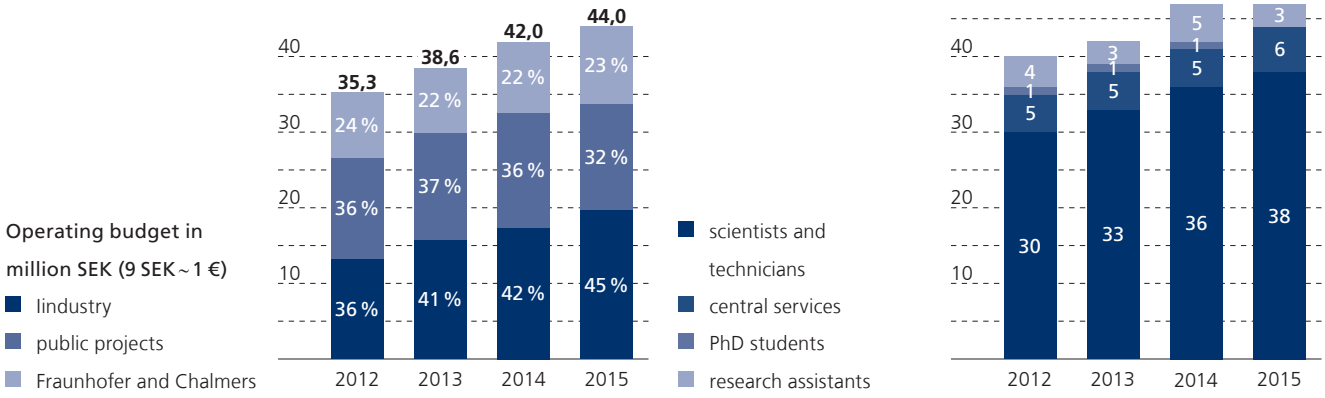
The well-established collaboration with Chalmers centers and departments includes in 2015 projects, grant applications, guest lectures, PhDs and master students with Wingquist Laboratory, Product and Production Development, Systems and Synthetic Biology, Fluid Dynamics, Biomedical Engineering, Chalmers e-Science Centre CheSC, Signals and Systems, and Mathematical Sciences.

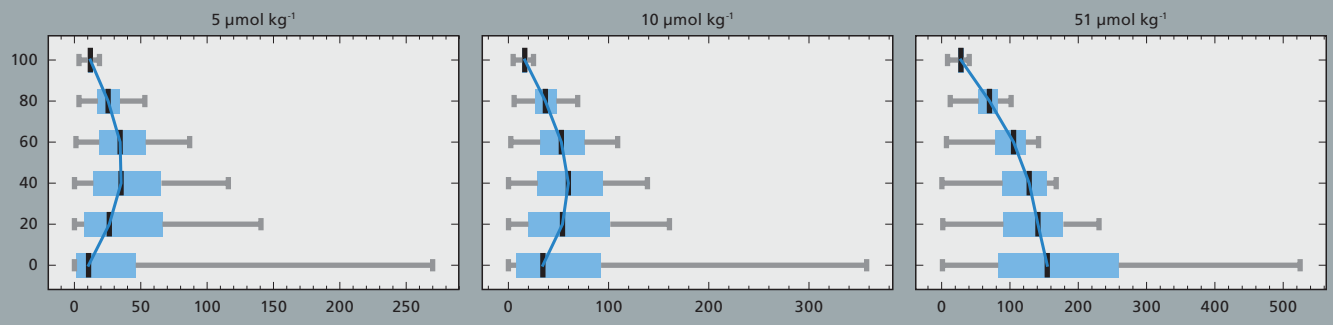
FCC is also very active in Production, Built Environment, Materials Science, and Life Science Engineering within the areas of advance.

I am proud and impressed by the excellent work done by my co-workers at FCC and I appreciate the fruitful collaboration with my colleagues at Chalmers and Fraunhofer ITWM. In May 2015, FCC was evaluated by an international committee selected by Fraunhofer and Chalmers. The mission was to assess the scientific and economic development and future strategy of the centre. The successful evaluation concluded that the centre has since its start in 2001 developed into an excellent research institution and that all targets have been achieved or surpassed.

Strengthened by the evaluation and the increased support and interaction with our founders we will continue the challenging but rewarding work with FCC – A Swedish centre in industrial mathematics following the Fraunhofer model with a high level of contracted research boosted by pre-competitive research funded by Fraunhofer and Chalmers.

Dr. Johan Carlson
Director of FCC





1

MODELING AND SIMULATION FOR PREDICTIVE MODEL BASED DRUG DISCOVERY AND DEVELOPMENT

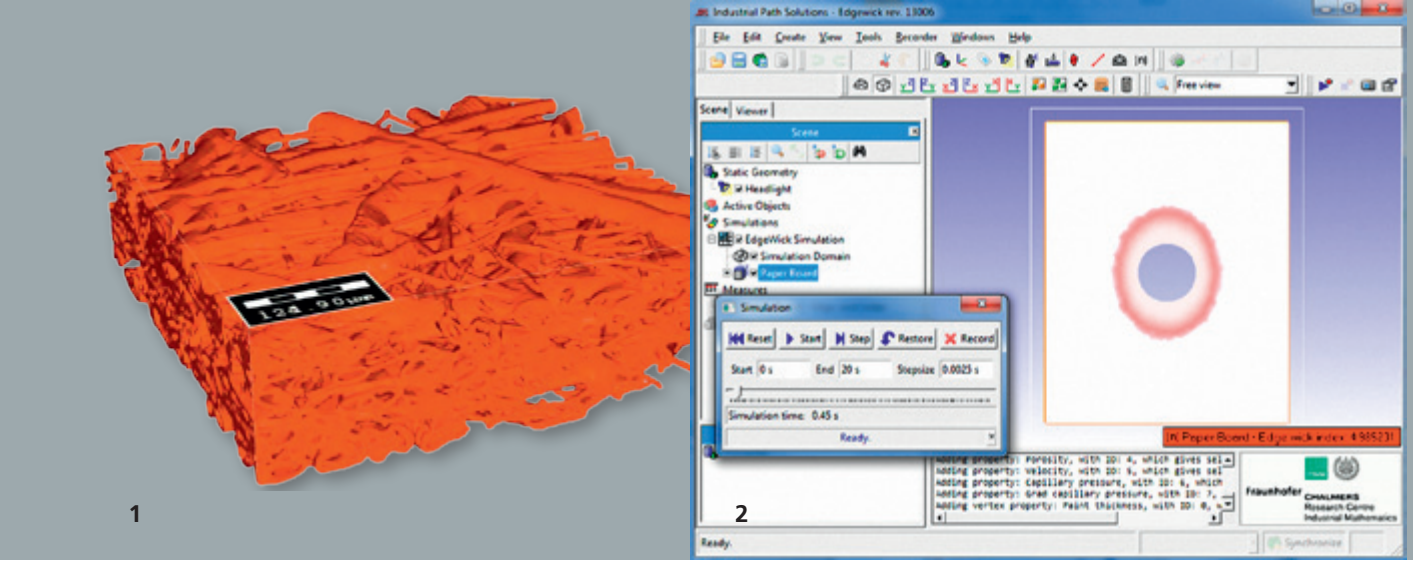
1 *The effect of degree of disease on extent and variability of rebound: The extent of rebound following the termination of a 300 min infusion was quantified as the maximum level of NEFA reached, expressed in percentage above the baseline, for different degrees of disease (0%-100%), using box and whisker plots.*

Modeling and simulation are important tools in a rational approach to drug discovery and development and can help prioritizing and assessing the potential of compounds. The work at FCC aims at delineating and streamlining the modeling and simulation process in model based drug discovery and development to increase both the pace of model development and the predictive power of future models. FCC has worked together with AstraZeneca in a three-year project to develop new tools and increase the usage of advanced modeling and simulation.

Mathematical model based analysis of experimental data on how novel compounds are taken up, distributed, and eliminated as well as their pharmacological effect are used both in preclinical studies as well as in translational science to rationally design dosage regimens for clinical studies. However, the use of already existing data and models to answer questions of integrative character is often under-used. Here meta-analysis of already existing studies can be utilized. Quantification of uncertainty is another important topic where there has been a lack of proper tools and techniques.

To provide predictions of drug effects when scaling from healthy to diseased individuals, a joint analysis of the data from normal and diseased animals is of interest. The purpose of a meta-analysis carried out during this project was to determine in what way disease affects the level of non-esterified fatty acids (NEFA) in response to administration of nicotinic acid and to quantify this effect by a combined analysis where data sets from both normal and obese rats have been used. The vast majority of today's PKPD models are not able to handle uncertainty in the model dynamics. However, so called nonlinear mixed-effects (NLME) modeling allows for variability and uncertainty both within and between subjects being modeled. We have investigated how to also incorporate uncertainty in the model dynamics in NLME modeling. This turns out to provide both more robust estimation methods (modified and regularized likelihood function to be optimized) and the ability to quantify and detect model misspecification.

We have developed a sensitivity-equation-based parameter estimation algorithm for NLME models, which uses sensitivity equations for determining gradients for both the optimization of individual random effect parameters, and for the optimization of the fixed effect population parameters. The algorithm is applicable to models based on ODEs as well as on SDEs. Because of its high accuracy in determining the gradients, the new algorithm shows more robustness to pre-optimum termination and to converge in situations where current industry-standard software such as NONMEM fails.



ISOP – INNOVATIVE TOOLS FOR THE SIMULATION OF PAPERMAKING

The aim of the ISOP project is to develop novel tools for simulation of papermaking and paperboard package quality that are based on microstructure models of the fiber web. The project is performed together with a consortium of the companies AkzoNobel Pulp and Performance Chemicals, Albany International, Stora Enso and Tetra Pak.

The main innovation in ISOP is to perform simulations on the fiber microstructure to predict macroscopic paperboard properties with industrially relevant accuracy. Substantial progress in the fundamental understanding of the papermaking process is achieved, and is particularly important to be able to develop products with increased functionality but with less material and energy input. Our efforts focus on the development of a simulation tool that can be used to study the dependence of the build of the paper in the forming section and the paperboard's resilience to edge penetration depending on pulp, chemical and forming fabric properties, and process conditions. This means that in the long term, paperboard packages with better functional properties can be developed. The software is based on an object-oriented C++ framework and consists of the following tightly coupled modules: **PaperGeo** for virtual structure generation, **IBOFlow** for fluid dynamics simulation, and **LastFEM** for structural dynamics. The **IPS** platform is used for pre- and post-processing.

Product quality – edge wicking

When the Tetra Brik Aseptic (TBA) filling machine starts operating, after a short stop the bath is filled with a liquid mixture of water and peroxide, and the liquid starts to penetrate the open edge of the paperboard. Only a few millimeters penetration can be allowed, otherwise a tube break might occur that destroys the aseptic environment in the filling machine. The resulting penetration depends on fiber properties, chemical additives, sheet structure and other process parameters.

To simulate the edge penetration a multi-scale framework has been developed. The micro-scale stochastic realizations of the paper microstructure are generated in PaperGeo. A pore-morphology model and single-phase flow simulations generate input to the macro-scale. Two-phase porous media flow simulations on a virtual macro-board give the liquid front as a function of time in each ply. This unique multi-scale framework shows excellent agreement with stationary edge wicking experiments.

1 *Stochastic realization of the microstructure of a paper in the PaperGeo module in the software GeoDict*

2 *A snapshot from the software IPS ISOP Edge Wicking: The simulation shows the penetration of liquid through the hole in a paperboard.*

TALKS

Andrä, Heiko; Fink, Andreas; Godehardt, Michael; Kabel Matthias; Sliseris, Jannis; Staub, Sarah; Wirjadi, Oliver
Mikrostruktursimulation der mechanischen Deformation von Fasermaterialien
VVD 2015, Radebeul, March

Andrä, Heiko; Fink, Andreas; Kabel, Matthias; Schneider, Matti
Digital Rock Physics Benchmarks and FFT-Based Elasticity Solvers
Interpore 7th International Conference on Porous Media, Padova (I), May

Andrä, Heiko; Kabel, Matthias; Spahn, Johannes; Staub, Sarah; Müller, Ralf
Multiscale Simulation of Progressive Damage in Fiber Reinforced Plastics
3rd DVM/SF2M-Seminar, Kaiserslautern, April

Arne, Walter; Hietel, Dietmar; Wegener, Raimund
Modeling and Simulation for Spinning Processes
Nonwovens Innovation Academy, Leeds (GB), November

Bäcker, M.; Gallrein, A.; Roller, M.
NVH model of a rotating tire
Guildford (GB), April

Barthlen, Andreas; Lang, Patrick
Stability-Preserving Parametric Model Reduction by Matrix Interpolation using Invariance Properties of Krylov Subspaces
GAMM 86th Annual Scientific Conference, Lecce (I), March

Bortz, Michael; Maag, Volker; Schwientek, Jan; Benfer, Regina; Böttcher, Roger; Burger, Jakob; von Harbou, Erik; Asprion, Norbert; Küfer, Karl-Heinz, Hasse, Hans
Decision Support by Multicriteria Optimization in Process Development: An Integrated Approach for Robust Planning and Design of Plant Experiments
25th ESCAPE, Kopenhagen (DK), June

Bortz, Michael; Schwientek, Jan; Burger, Jakob; von Harbou, Erik; Blagov, Sergej; Hirth, Oliver; Asprion, Norbert; Küfer, Karl-Heinz; Hasse, Hans
Minimizing the impact of uncertain model parameters on process design
ProcessNet Jahrestreffen der Fachgemeinschaft Fluiddynamik und Trenntechnik, Bamberg, September

Bortz, Michael; Schwientek, Jan; Welke, Richard; Burger, Jakob; von Harbou, Erik; Benfer, Regina; Blagov, Sergej; Böttcher, Roger; Asprion, Norbert; Küfer, Karl-Heinz; Hasse, Hans
Sensitivity analysis and robust chemical process design
ACHEMA 2015, Frankfurt, June

Burger, M.
Function Space Optimal Control Methods for Tracking Problems in Vehicle Engineering
Halle, September

Burger, M.
Optimal Control of Delay Differantial-Algebraic Equations
Potsdam, September

Calabrese, F.; Bäcker, M.; Gallrein, A.
A full thermo-mechanical tire model for advanced handling applications
München-Dornach, June

Calabrese, F.; Bäcker, M.; Gallrein, A.
A Method to Combine an MBD Tire Model with a Thermo-dynamical one to improve the accuracy in the tire simulations
Barcelona (E), June

Calabrese, F.; Bäcker, M.; Gallrein, A.
Thermo-mechanical Tire Model to Predict Temperature Creation-Propagation and Rolling Resistance
Köln, February

Calabrese, F.; Bäcker, M.; Gallrein, A.
Tire Handling Simulations: Closing The Gap With A Full 3d Scalable Thermo-Mechanical Model
Graz (A), August

Cesarek, P.; Zupan, D.; Linn, J.
Conceptual and numerical aspects of the mixed variational formulation of geometrically exact beam models
Barcelona (E), June

Dalheimer, Mathias
Wie man einen Blackout verursacht
32. Chaos Communication Congress, Hamburg, December

Dobrovolskij, Dascha
Modelling of Ultrasonic Scattering Phenomena due to Polycrystalline Microstructure
Fontainebleau (F), October

Dobrovolskij, Dascha; Hirsekorn, Sigrun; Spies, Martin
Simulation of ultrasonic materials evaluation experiments Including scattering phenomena due to polycrystalline microstructure
International Congress on Ultrasonics, Metz (F), May

Dörlich, V.; Linn, J.; Scheffer, T.; Diebels, S.
Towards viscoplastic constitutive models for Cosserat rods
Barcelona (E), June

Dörlich, V.; Scheffer, T.; Diebels, S.
Experimental characterization of inelastic cables and hoses
Deidesheim, June

Dreßler, K.
Fraunhofer ITWM - related products and technologies
Deidesheim, June

Dreßler, K.; Bäcker, M.; Calabrese, F.; Halfmann, T.
The Tyre as Part of the Vehicle and of the Road-Tire-Vehicle System
Nürnberg, June

Dreßler, K.; Bäcker, M.; Gallrein, A.; Calabrese, F.
Structural Tire Modelling with CDTire3D: Closing the Gap Between Physicality and Performance
Stuttgart, July

Easwaran, Prakash
Extension of the Altendorf-Jeulin fiber system model to incorporate fiber bundles
Fontainebleau (F), October

Erlwein-Sayer, Christina
Investmentstrategies within a regime-switching model for asset returns
London (GB), December

Fütterling, Valentin
Core Algorithms for High-Performance, Interactive Rendering of Large-scale Scientific Data
Platform for Advanced Scientific Computing Conference (PASC), Zürich (CH), June

Fütterling, Valentin
Interaktive server-basierte Visualisierung großer Daten
ZKI Tagung Arbeitskreis Supercomputing, Leibniz-Rechenzentrum Garching, October

Gallrein, A.; Bäcker, M.
Overall tire model solution on extended frequency range in combination with VL Motion
München, April

Gizatullin, A.; Calabrese, F.; Kleer, M.; Bäcker, M.; Dreßler, K.
Interactive tire simulation for motor sport applications
Köln, November

Gizatullin, A.; Pena Viña, E.; Kleer, M.; Dreßler, K.
RODOS Driving Simulator - a platform for Human-In-The-Loop systems design
Trieste (I), April

Gramsch, Simone
Mathematische Modellierung von Airlay-Prozessen
ISTRON-Tagung, Kaiserslautern, October

Gramsch, Simone
Virtuelle Vliesproduktion
Tag der Verfahrenstechnik, Kaiserslautern, September

Gramsch, Simone; Arne, Walter; Wegener, Raimund
FIDYST – Simulation of Fiber Dynamics for Nonwoven and Fiber Processes
ITMA, Mailand (I), November

Gramsch, Simone; Michel, Isabel
FPM (Finite Pointset Method) und FIDYST (Fiber Dynamics Simulation Tool) in der Verfahrenstechnik
Kompetenznetzwerk Verfahrenstechnik Pro3, Leverkusen, May

Grünewald, Daniel
RTM - Asynchronous Constraint Execution for Scaleability and Heterogeneity on Shot Level
2015 Rice Oil & Gas HPC Workshop, Rice University, Houston (USA), March

Halfmann, T.
Using the Virtual Measurement Campaign® (VMC®) methodology for evaluating vehicle loads and tyre performance
Köln, February

Hietel, Dietmar; Arne, Walter; Schnebele, Johannes
Simulation-based design of a new rotational spinning process for polymer fibers
Man-made Fibers Congress 2015, Dornbirn (A), September

Hietel, Dietmar; Arne, Walter; Wegener, Raimund
Modelling and Simulation of Fiber Spinning and Nonwoven Processes
ITMA, Mailand (I), November

Hietel, Dietmar; Gramsch, Simone; Wegener, Raimund
Simulationsbasierte Analyse von Vliesstoffstrukturen: Stochastik birgt reelle Chance
Vliesstofftage Hof, November

Hoffmann, Anna; Bortz, Michael; Burger, Jakob; Küfer, Karl-Heinz; Hasse, Hans
Robuste Simulation und gleichzeitige Optimierung von Fließbildern mittels Schießverfahren
ProcessNet Jahrestreffen der Fachgemeinschaft Fluiddynamik und Trenntechnik, Bamberg, September

Hoffmann, R.; Miezal, M.; Bleser, G.; Leyendecker, S.; Gail, T.
Towards bridging the gap between motion capturing and biomechanical optimal control simulations
Barcelona (E), June

Iliev, Oleg; Efendiev, Yalchin; Latz, Arnulf; Maday, Yvon; Taralova, Vasilena; Taralov, Maxim; Zausch, Jochen; Zhang, Shiquan
On computer simulation of multiscale processes in porous electrodes of Li-ion batteries
InterPore, Padua (I), May and FEM Workshop of 2015 Peking University Summer Academic Activities on Numerical Partial Differential Equations, Beijing (CHN), August

Iliev, Oleg; Efendiev, Yalchin; Latz, Arnulf; Maday, Yvon; Taralova, Vasilena; Taralov, Maxim; Zausch, Jochen; Zhang, Shiquan
On some mathematical challenges in studying multiscale electrochemical processes in Li-ion battery
MIRAW Day on Modelling and simulation of electrochemical flows in Lithium-ion batteries, Warwick (GB), November

Iliev, Oleg; Iliev, Dimitar; Kirsch, Ralf
On Dimension Reduction Approach for Simulations of Poroelastic Deformations in Pleated Filters
ICIAM, Beijing (CHN), August

Iliev, Oleg; Iliev, Dimitar; Kirsch, Ralf
On solving of poroelasticity problems related to simulation of filtration processes
Large Scale Scientific Computing, Sozopol (BG), June

Iliev, Oleg; Kirsch, Ralf; Osterroth, Sebastian
Cake filtration simulation for poly-dispersed spherical particles
FILTECH conference, Köln, February

Iliev, Oleg; Leonard, Katherine; Lakdawala, Zahra
Pore scale simulation of reactive flows on 3D CT images
1st Annual Meeting of UK InterPore Chapter, Manchester (GB), August and Advanced Computers for Innovation, Sofia (BG), November

Iliev, Oleg; Nessler, Katherine; Lakdawala, Zahra; Prill, Torben
Pore scale modeling and simulation for surface activated filtering media
Fall Meeting of American Filtration Society, Franklin USA), October

Kabel, Matthias; Andrä, Heiko; Fink, Andreas; Schneider, Matti; Fliegener, Sascha
FFT-Based Homogenization of Long Fiber Reinforced Thermoplastics
ESMC2015 - 9th European Solid Mechanics Conference, Madrid (E), July

Kabel, Matthias; Kirsch, Ralf; Staub, Sarah; Bernards, Daniel; Dedering, Michael
Experimental study and numerical simulation of the flow-induced deformation of filtering media in automotive transmission filters
FILTECH 2015, Köln, February

Kabel, Matthias; Schneider, Matti
Finite strain computational analysis of stacked unidirectional prepreg materials
28. Workshop Composite Forschung in der Mechanik, Paderborn, December

Keuper, Janis
Asynchronous Parallel Stochastic Gradient Descent: A Numeric Core for Scalable Distributed Machine Learning Algorithms
MLHPC Workshop at Super Computing 15, Austin (USA), November

Keuper, Janis
Balancing the Communication Load of Asynchronously Parallelized Machine Learning Algorithms
ISC Cloud and Big Data, Frankfurt, September

Keuper, Janis
Deep Learning and the SGD Algorithm
Summer School des Graduiertenkollegs 1932, Kaiserslautern, October

Kleer, M.; Gizatullin, A.; Pena Viña, E.; Dreßler, K.
Interactive real-time driving simulation for assistance system development
Stuttgart, June

Klein, Peter
EMMC and the value chain: CAE upstream to Materials
International CAE Conference 2015, Pacengo del Garda (I), October

Kleinert, J.; Simeon, B.
A conical interior point method for nonsmooth rigid body dynamics
Rhodos (GR), March

Kühn, Martin
Experience with GPI-Applications in Extreme Scale
Result Workshop of the Extreme Scale-Out Phase2, Leibniz Supercomputing Centre, München, June

Kuhnert, Jörg
Finite Pointset Method (FPM) simulations in airbag deployment: challenges and advantages
CAE Grand Challenge 2015, Hanau, April

Kuhnert, Jörg
Meshfree simulation of solution processes of minerals
8th International Workshop on Meshfree Methods, Bonn, September

Küsters, Ferdinand; Trenn, Stephan
Duality of switched ODEs with jumps
54th IEEE Conference on Decision and Control, Osaka (J), December

Leithäuser, Christian; Feßler, Robert; Hietel, Dietmar
Analysis and Optimization of Polymer Spin Packs
ITMA, Mailand (I), November

Linn, J.
Dynamic cable simulation – challenges and technologies
Deidesheim, June

Linn, J.; Dreßler, K.; Hermanns, O.; Sadiku, V.
Simulation des nichtlinearen Verhaltens von Kabeln und Schläuchen für Anwendungen in der Montageplanung
Nürnberg, March

Losch, Katharina
Stereology for SEM images of a Metal-Matrix-Composite
Fontainebleau (F), October

Merten, Dirk
GRT Angle Migration: A 5D Data Mapping Problem
International Conference on High Performance Computing & Simulation (HPCS), Amsterdam (NL), July

Migunova, Anastasia; Orlik, Julia
Homogenization via unfolding in periodic layer with contact
Regensburg, January

Mohring, Jan
Mode Assignment in Parametric Model Order Reduction
EU-MORNET Workshop, Luxemburg (L), November

Montag, Martin
Hyperspectral Unmixing from Incomplete and Noisy Data
Applied Inverse Problems Conference (AIP), Helsinki (FIN) May

Neunzert, Helmut
Alles Leben ist Problemlösen (frei nach Karl Popper)
ISTRON-Tagung, Kaiserslautern, October

Neunzert, Helmut
Aus Kaiserslautern in die Welt – Die Welt in Kaiserslautern
Kaiserslautern, September

Neunzert, Helmut
Tysk-Svensk Samarbete: Fraunhofer-Chalmers since 2001
Fraunhofer-Zentrale München, September

Nowak, Dimitri; Bortz, Michael; Roclawski, Harald
Decision support for the design and operation of water supply systems
13th Computer Control for Water Industry CCWI2015, Leicester (GB), September

Orlik, Julia
Estimates for the rescaling of Korn's, trace inequalities and norms of Bessel potentials in periodic domains
St. Etienne (F), November

Orlik, Julia
Evolutional contact with Coulomb's friction on a periodic microstructure
Vilnius (LV), May and WIAS, Berlin, December

Orlik, Julia
Homogenization of periodic contact problems
Regensburg, January

Orlik, Julia
Homogenization, simulation and optimization of textile-like materials
Ecole Politenique, Dep. Mech. Eng., Paris (F), June

Orlik, Julia
Simulation of compressible stockings
IMWF, Universität Stuttgart, March

Osterroth, Sebastian; Iliev, Oleg; Pinnau, René
Using sensitivity analysis in the framework of proper orthogonal decomposition with application to cake filtration
MoRePaS conference, Triest (I), October

Pena Vina, E.
Der Mensch als Teil der Testumgebung: Fahrsimulator und 3D-Messfahrzeug am Fraunhofer ITWM
Wörth, November

Pfreundt, Franz-Josef
BeeOND: (BeeGFS on Demand)
HLRS/hww Workshop on Scalable Global Parallel File Systems, Stuttgart, April

Pfreundt, Franz-Josef
Data Management und Workflow Automatisierung in Big Data-Umgebungen
Big Data Strategiedialog, Bonn, June

Pfreundt, Franz-Josef
Energiemonitoring und Identifikation von Energieverbrauchern
Energy Masters Dialog, Bonn, January

Pfreundt, Franz-Josef
High Performance Data Analytics HPDA
Big Data Minds, Berlin, September

Pfreundt, Franz-Josef
HPC and Big Data Storage- and Parallel File-systems: The Fraunhofer Parallel Filesystem
HP Cast, HP Consortium for Advanced Scientific and Technical Computing World-Wide User Group Meeting, June

Prill, Torben; Jeulin, Dominique; Willot, François;Balach, Juan; Soldera, Flavio
Prediction of Transport Properties of Nanoporous Carbon Electrodes From 3D Full Field Calculation by FFT
Electrical, Transport, and Optical Properties of Inhomogeneous Media, Neveh Ilan(IL), June

Prill, Torben; Leonard, Katherine; Iliev, Oleg
Pore Scale Simulation of Reactive Flows on 3D-CT-Images
4. Geo-CT / -Imaging Workshop, Mainz, November

Prill,Torben; Rief, Stefan; Steiner Konrad
Microstructure modeling and optimization of transport properties of gas diffusion layers in PEM fuel cells, combining graph based approaches and full field computations
ECS Conference on Electrochemical Energy Conversion & Storage with SOFC-XIV, Glasgow (GB), July

Rahn, Mirko
Datenmanagement bei High Performance Anwendungen
Universität Stuttgart, Fakultät für Informatik, May

Rahn, Mirko
Porting an MPI application to GPI-2 including interoperability MPI-GPI
EPiGRAM Exascale Applications Workshop, Wien (A), October

Rauhut, Markus
Kosteneinsparungen durch prozessintegrierte Präzisionsmessungen
Buchs (CH), September

Rauhut, Markus
Simulation von Oberflächendefekten zur Bestimmung der Fehlerauffindwahrscheinlichkeit
Salzburg (A), May

Rief, Stefan; Steiner, Konrad; Schulz, Volker
Determination of the capillary pressure – saturation relation for paper based on its 3D microstructure
Interpore 7th International Conference on Porous Media, Padova (I), May

Roller, M.; Betsch, P.; Gallrein, A.; Linn, J.
An Enhanced Tire Model for Dynamic Simulation Based on Geometrically Exact Shells
Barcelona (E), June

Rösch, Ronald
Blick über den Tellerrand der klassischen Oberflächeninspektion
Fraunhofer IOSB, Karlsruhe, December

Rösch, Ronald
Fehlerdetektion in texturierten Oberflächen im praktischen Einsatz
8. Fraunhofer-Vision Technologietag, Stuttgart, October

Sadiku, V.
Optimized design, digital validation and virtual assembly of cables, hoses and wiring harnesses
Hambach, May

Scherrer, Alexander, Jakobsson, Stefan; Küfer, Karl-Heinz
Multi-criteria optimization and decision support in focused ultrasound therapy planning
23rd International Conference on Multiple Criteria Decision Making MCDM, Hamburg, June

Schladitz, Katja; Easwaran, Prakash; Redenbach, Claudia; Wirjadi, Oliver
Stochastic modeling of 3D fiber systems with fiber bundles and parameter estimation from CT image data
International Congress for Stereology and Image Analysis, Liège (B), July

Schladitz, Katja; Föhst, Sonja; Wagner, Willi; Ackermann, Maximilian; Redenbach, Claudia; Wirjadi, Oliver; Ysasi, Alexandra B.; Mentzer, Steven J.; Konerding; Moritz A.
3D image analytical detection of intussusceptive pillars in murine lung
Internat. Congress for Stereology and Image Analysis, Liège (B), July

Schladitz, Katja; Godehardt, Michael
3D shape analysis for high performance grout
Internat. Congress for Stereology and Image Analysis, Liège (B), July

Schladitz, Katja; Kronenberger, Markus; Wirjadi, Oliver
Local curvature for 3D-characterization of fiber-reinforced materials
Internat. Congress for Stereology and Image Analysis, Liège (B), July

Schneider, F.
A general approach for efficient embedding of flexible structures in multibody dynamics
Rhodos (GR), March

Schneider, F.; Burger, M.
Co-Simulation via algebraic constraint: Influence of spatial discretization of flexible structures on the stability
Halle, September

Schneider, F.; Burger, M.; Linn, J.
Efficient coupling of a cable model in multibody dynamics using kinematic algebraic constraints
Barcelona (E), June

Schröder, Michael; Beißert, Ulrike; Jami, Neil; Motta, Marco
Konzeptionierung eines integrierten modellbasierten Ansatzes zur Prognose von transportlogistischen und intralogistischen Ereignissen in Logistiknetzwerken
16. ASIM Fachtagung Simulation in Produktion und Logistik, Dortmund, September

Schwientek, Jan; Seidel, Tobias; Küfer, Karl-Heinz
A transformation-based discretization method for solving GSIPs
27th EURO, Glasgow (GB), July

Seidel, Tobias; Schwientek, Jan; Küfer, Karl-Heinz
Solving the Gemstone Cutting Problem by Semi-Infinite Optimization
4th Symposium of the German SIAM-Student-Chapters, Trier, August

Seidel, Torsten; König Christoph; Michel, Isabel; Schröder, Simon
Application and intuitive visualization of a three-dimensional benchmark for variable-density flow and solute transport calculation
Conference on Modeling Natural Barriers, Bad Wildbad, September/October

Seifarth, Tobias; Kuhnert, Jörg; Meister, Andreas
Numerical Scheme for the Finite Pointset Method to solve Transport Equations on fixed pointclouds in 3d
Particles2015, Barcelona (E), September

Sormani, Martina; Redenbach, Claudia; Särkkä, Aila; Rajala, Tuomas A.
Classification of points in superpositions of point processes
Internat. Congress for Stereology and Image Analysis, Liège (B), July

Staub, Sarah, Andrä, Heiko, Kabel, Matthias
A FFT based mesoscopic approach for the compression and recovery of structured nonwovens
Pan-American Conference on Computational Mechanics, Buenos Aires (RA), April

Staub, Sarah, Andrä, Heiko, Kabel, Matthias
A FFT-based multi-scale approach for the simulation of progressive damage in elasto-plastic fiber-reinforced composites
ECCOMAS Young Investigators Conference, Aachen, July

Staub, Sarah; Andrä, Heiko; Kabel, Matthias; Schneider, Matti
Computation of Effective quantities for nonlinear material behavior based on the LS-FFT method
9th GAMM Seminar on MultiScale Material Modeling (MMM) on Real-Data Based Numerical Method, Kaiserslautern, November

Staub, Sarah; Kabel, Matthias; Korzhesvka, Olena; Andrä, Heiko
Generation of Binder Bonded Nonwovens using GeoDict and FeelMath
GeoDict UserMeeting, Kaiserslautern, October

Steiner, Konrad
Industrial Multiscale Simulation
Technologietag bei Procter& Gamble, Schwalbach, March

Steiner, Konrad
Originalities and Similarities in Industrial Porous Media Simulation
Interpore 7th Internat. Conference on Porous Media, Padova (I), May

Steiner, Konrad
Strömungs- und Materialsimulation
Tag der Verfahrenstechnik, Kaiserslautern, September

Steiner, Konrad; Niedziela, Dariusz; Schmidt, Sebastian
Modellierung komplexer Fluide: Anwendungen in der Verfahrenstechnik
Tagung der Deutschen Keramischen Gesellschaft in Lahnstein, June

Stephani, Henrike
Typischer Aufbau und Beispiele für Algorithmen von Oberflächeninspektionssystemen
Fraunhofer IOSB, Karlsruhe, December

Stoyanov, Dimitar
Task-based parallel sparse matrix-vector multiplication with GASPI/GPI-2
International Workshop Sparse Solvers for Exascale, Greifswald, March and 10th International Conference Large-Scale Scientific Computing, Sozopol (BG), June

Streit, A.; Speckert, M.; Seifen, S.; Seebich, H.-P.; Simatos, A.; Büttner, M.
Simulation von Kundenbeanspruchungen für Steuergeräte unter thermischer Belastung
Dresden, October

Trinkaus, Hans L.
Interactive Management of Unstructured Knowledge and Dynamic Processes
27th European Conference on Operational Research, Glasgow (GB), July

Velten, Sebastian; Ackermann, Heiner; Leithäuser, Neele, Meyer, Andreas; Küfer, Karl-Heinz
How to Unload Bulk Carriers Quickly? Mathematical Models to Identify Efficient Loading Patterns
MISTA 2015, Prag (CZ), August

Weyh, T.; Speckert, M.; Opalinski, A.; Wagner, M.
Planung einer Messkampagne durch Osteuropa mittels der Fraunhofer-Software VMC ("Virtual Measurement Campaign")
Eindhoven (NL), June

Wirjadi, Oliver
3D Bildanalyse der Mikrostruktur komplexer Materialien
8. Fraunhofer Vision Technologietag, Stuttgart, October

Wirjadi, Oliver
A statistical approach to fiber length estimation in long glass fiber reinforced plastics
EuroMat 2015, Warschau (PL), September

Wirjadi, Oliver
Tutorial: 3D Images of Materials Structures – Processing and Imaging
EuroMat 2015, Warschau (PL), September

Wirsen, Andreas
Real-Time Capable Robust State Estimation
HCO Challenge Workshop 2015 – Parameter and State Estimation: Methods – Software – Applications, Heidelberg, November

Zausch, Jochen
Computer simulation of lithium ion batteries as predictive tool for battery design and material optimization
Frankfurt/Main, June

Zausch, Jochen; Latz, Arnulf
Comparing coupled thermal-electrochemical lithium-ion battery simulations on micro and cell scale
Freiburg, March

Zémerli, C.
Application of new simulation tools to minimize cycle time and material consumption in the paint shop
Bad Nauheim, December

Zémerli, C.
Echtzeit und physikalisch korrekte Simulation eines Bordnetzes
Landshut, September

Zémerli, C.
Recent progresses on simulation technology for challenging applications of car manufacturing and product design
Nürnberg, June

TEACHING ACTIVITIES

Andrä, Heiko
Kontaktmechanik
University of Kaiserslautern, Winter term 2014/2015

Andrä, Heiko
Höhere Mathematik
DHBW Mannheim, 2015

Bitsch, Gerd
Professur für Mechatronik, Robotik und CAE-Simulation
University of Applied Sciences Kaiserslautern, Dept. of Applied Engineering Sciencesen

Burger, Michael
Numerik für Bauingenieure
University of Applied Sciences Kaiserslautern, Winter term 2015/2016

Burger, Michael
Dynamics of Mechanical Multibody Systems
University of Kaiserslautern, Winter term 2014/2015 and 2015/2016

Dreßler, Klaus
Durability Load Data Analysis
University of Kaiserslautern, Summer term 2015

Iliev, Oleg
PhD-Seminar »Technomathematik«
University of Kaiserslautern, Dept. of Mathematics

Kleer, Michael
Robotik 1
University of Applied Sciences Kaiserslautern, Winter term 2015/2016

Korn, Ralf
Professur für Stochastische Steuerung und Finanzmathematik
University of Kaiserslautern, Dept. of Mathematics

Küfer, Karl-Heinz
Theory of Scheduling Problems
University of Kaiserslautern, Summer term 2015

Küfer, Karl-Heinz
Probability and Algorithms
University of Kaiserslautern, Winter term 2015/16

Nickel, Stefan
Professur für Diskrete Optimierung und Logistik
KIT Karlsruhe, Institut für Operations Research

Prätzel-Wolters, Dieter
Professur für Technomathematik
University of Kaiserslautern, Dept. of Mathematics

Steidel, Stefan
Mathematik für Bauingenieure
University of Applied Sciences Kaiserslautern, Winter term 2015/2016

PUBLICATIONS

The list of publications of the Fraunhofer ITWM are avalaible at:

http://publica.fraunhofer.de/institute/itwm/2015

SCIENTIFIC GRADUATION THESES

Blatner, Dimitri
Automatisierte Transformationen von Petri-Netzen zur detaillierten Ablaufkontrolle in verteilten Laufzeitsystemen
Master thesis, University of Kaiserslautern, Dept. of Computer Sciences

Christiansen, Hannes
Konfidenzintervalle für kombinierte Wöhlermodelle
Master thesis, University of Kaiserslautern, Dept. of Mathematics

De Vita, Simone
Granular Flow modelling – Quantitative validation and investigation of numerical diffusivity effects
Master thesis, University of Naples (I) ‚Federico II', Department of Material Sciences

Derevenetc, Egor
Robustness against Relaxed Memory Models
Doctoral thesis, University of Kaiserslautern, Dept. of Computer Sciences

Eimer, Matthias
Modellierung und Simulation von Fernwärmenetzen
Bachelor thesis, University of Kaiserslautern, Dept. of Mathematics

Groß, Tjorben
DAE-Modellierung und mathematische Stabilitätsanalyse von Energieversorgungsnetzen
Doctoral thesis, University of Kaiserslautern, Dept. of Mathematics

Kleer, Michael
Interaktive Fahrsimulation: Roboter als Werkzeug der Mensch-Maschine-Umweltinteraktion mechatronischer Systeme
Doctoral thesis, University of Kaiserslautern, Dept. of Mechanical and Process Engineering

Kleinert, Jan
Simulating Granular Material using Nonsmooth Time-Stepping and a Matrix-Free Interior Point Method
Doctoral thesis, University of Kaiserslautern, Dept. of Mathematics

PARTICIPATION IN FAIRS AND CONFERENCES

Kobert, Maria
Application of the Finite Point-set Method to moving boundary problems for the BGK model of rarefied gas dynamics
Doctoral thesis, University of Kaiserslautern, Dept. of Mathematics

Kronenberger, Markus
Accuracy of Local Curvature Estimators for Two Kinds of Discrete Representations
Master thesis, University of Kaiserslautern, Dept. of Computer Sciences

Leis, Markus
Erfassung von Fahrdynamikdaten mittels Methoden der modellbasierten Softwareentwicklung
Bachelor thesis, University of Applied Sciences Kaiserslautern, Dept. of Applied Engineering Sciences

Ludwig, Christoph
A Reduced Basis Approach for the Stokes Problem in a Parameter Dependent Domain
Master thesis, University of Kaiserslautern, Dept. of Mathematics

Mc Stay, Daniel
Ermittlung der Auswirkung von Modellfehlern auf die Zielgenauigkeit und Handhabbarkeit eines Fahrerassistenzsystems beim rückwärtigen Rangieren
Master thesis, University Koblenz, Dept. of Computer Sciences

Mosbach, Dennis
Adaptive Surface Reconstruction for 3D CT-Data
Master thesis, University of Kaiserslautern, Dept. of Computer Sciences

Oden, Lena
Direct Communication Methods for Distributed GPUs
Doctoral thesis, University Heidelberg, Dept. of Computer Sciences

Pasalkar, Vishal
Extrapolation of tire performance properties from specific load cases to vehicle usage in the field
Master thesis, University of Applied Sciences Kaiserslautern, Dept. of Applied Engineering Sciences

Pupashenko, Daria
Robustheit für Regressionsmodelle mit asymmetrischen Fehlerverteilungen mit Anwendungen in der Extremwertstatistik
Doctoral thesis, University of Kaiserslautern, Dept. of Mathematics

Rauland, Gina-Monique
Optimales Routen von Feldhäckslern
Bachelor thesis, University of Kaiserslautern, Dept. of Mathematics

Richter, Sven
Analyse der stochastischen Mikrostruktur von Flechten in 3D Bildern
Bachelor thesis,University of Kaiserslautern, Dept. of Mathematics

Schroth, Stefan
Modellierung einer hydraulischen Anlage
Bachelor thesis, University of Kaiserslautern, Dept. of Mathematics

Shiryaev, Vladimir
Modeling and design optimization of textile-like materials via homogenization and one-dimensional models of elasticity
Doctoral thesis, University of Kaiserslautern, Dept. of Mathematics

Stöbener, Katrin
Multicriteria optimization of molecular force fields
Doctoral thesis, University of Kaiserslautern, Dept. of Mechanical and Process Engineering

Sutter, Diana
Computational Fluid Dynamics in Press Nips of Paper Machines
Master thesis, University of Kaiserslautern, Dept. of Mathematics

Taralov Maxim
Simulation of Degradation Processes in Lithium-Ion Batteries
Doctoral thesis, University of Kaiserslautern, Dept. of Mathematics

Taralova, Vasilena
Upscaling Approaches for Nonlinear Processes in Lithium-Ion Batteries
Doctoral thesis, University of Kaiserslautern, Dept. of Mathematics

Tegen, Thomas
Prozessoptimierung zur funktionsgerechten Auslegung von Tüllen
Master thesis, University of Applied Sciences Kaiserslautern, Dept. of Applied Engineering Sciences

ACHEMA
Frankfurt/Main, June, Exhibitor, Lecture

Advanced Computers in Simulation
Sofia (BG), November, Lecture

AFS
Franklin (USA), October, Lecture

Agritechnica 2015
Hannover, November

17th Annual Conference of the International Association for Mathematical Geosciences (IAMG)
Freiberg, September, Lecture

Annual Conference on Behavioural Models and Sentiment Analysis Applied to Finance
London (GB), July

Arbeit in der digitalen Welt
Herschberg, May, Poster

ASIM 2015
Dortmund, September

Asymptotic Problems: Elliptic and Parabolic Issues
Vilnius (LT), June, Lecture

ATIM 2015
Fulda, Dezenber

Automotive Circle International-Konferenz
Bad Nauheim, December, Lecture

Automotive Engineering Congress 2015
Nürnberg, June, Lecture

Autonomous Vehicle Test & Development Symposium
Stuttgart, June, Lecture

Batterieforum Deutschland
Berlin, January, Poster

57. Bildverarbeitungsforum »Visuelle Navigation und Tracking«
Offenbach ,March

58. Bildverarbeitungsforum »Bildverarbeitung und Messen«
Oberkochen, July

59. Bildverarbeitungsforum »Mobile Bildverarbeitung«
Mannheim, October

Bordnetz-Kongress 2015
Landshut, September, Exhibitor, Lecture

Business & Innovation Automotive Day 2015
Hambach (F), May

chassis.tech plus 2015: Internationales Münchner Fahrwerk-Symposium
München, June, Lecture

CompoForm 2015
München, May, Exhibitor, Poster

13th Computer Control for Water Industry (CCWI2015)
Leicester (GB), September, Lecture

Conference on microstructures in plasticity
Bonn, May, Poster

Control 2015
Stuttgart, May, Exhibitor

CVC-Jahrestagung
Wörth, November, Exhibitor, Lecture

DACH-Jahrestagung 2015
Salzburg (A), May, Lecture, Poster

Daimler EDM-CAE Forum 2015
Stuttgart, July, Exhibitor, Lecture

DKT – Deutsche Kautschuk-Tagung
Nürnberg, June, Lecture

DSC 2015 EUROPE
Tübingen, September, Poster

77th EAGE Conference & Exhibition 2015
Madrid (E), June, Exhibitor

ECCOMAS Thematic Conference on Multibody Dynamics
Barcelona (E), June, Lecture

ECS Conference on Electrochemical Energy Conversion & Storage with SOFC-XIV
Glasgow (GB), July, Lecture

EGU General Assembly 2015
Wien (A), April, Lecture

2. ERWAS-Workshop
Frankfurt/Main, September

ESCAPE
Kopenhagen (DK), June

EU-MORNET Exploratory Workshop
Luxemburg, November, Lecture

EUROMECH Colloquium 777, Micromechanics of Composite
Stuttgart, March, Lecture

EuroNanoForum
Riga (LV), June

27th European Conference on Operational Research (EURO 2015)
Glasgow (GB), July, Lecture

2015 European Vehicle Performance Engineering Conference
München, April

Fachseminar »Simulation mechatronischer Produkte und Produktionssysteme FAPS«
Nürnberg, March, Lecture

Fachtagung Produktionsmesstechnik
Buchs (CH), September, Lecture

Fakuma 2015
Friedrichshafen, October

FEM Workshop Peking University
Beijing (CHN), August, Lecture

FILTECH 2015
Köln, February, Exhibitor, Lecture

Firmenkontaktmesse Treffpunkt
Kaiserslautern, June, Exhibitor

8. Fraunhofer-Vision Technologietag
München, October, Exhibitor, Lecture

GAMM 86th Annual Scientific Conference
Lecce (I), March, Lecture

4. Geo-CT / -Imaging Workshop
Mainz, November, Lecture

Gophercon 2015
Denver (USA), July

Hannover Messe
Hannover, April, Exhibitor

HMI und unterstützende Systeme in mobilen Arbeitsmaschinen
Ulm, December, Exhibitor

Hofer Vliesstofftage
Hof, November, Exhibitor, Lecture

24th IAVSD 2015
Graz (A), August, Lecture

ICIAM
Beijing (CHN), August, Lecture

54th IEEE Conference on Decision and Control
Osaka (J), December, Lecture

IEEE Visualization Conference (VIS)
Chicago (USA), October

9. Industriearbeitskreis CVC »Das Virtuelle Nutzfahrzeug«
Konz, April

International CAE Conference
Pacengo del Garda (I), October

10th International Conference Large-Scale Scientific Computing
Sozopol (BG), June, Lecture

International Conference on Computational and Financial Econometrics
London (GB), December, Lecture

International Congress for Stereology and Image Analysis
Liège (B), July, Lecture

International Nonwovens Symposium
Prag (CZ), June, Lecture

12th International Symposium ISMM 2015
Reykjavik (IS), May, Poster

International Symposium »New Stages in Information Processing Research«
Kaiserslautern, July

29th International Symposium of the Society of Core Analysts
St. John's (CDN), August

International Workshop Sparse Solvers for Exascale,
Greifswald, March, Lecture

Interpore 2015
Padua (I), May, Lecture

IPS Cable Simulation Users Conference 2015
Deidesheim, June, Exhibitor, Lecture

ISC High Performance 2015
Frankfurt/Main, July, Exhibitor

ISTRON-Tagung
Kaiserslautern, October, Lecture

ITAFORUM 2015
Berlin, November

ITMA
Mailand (I), November, Exhibitor, Lecture

Jahrestreffen der Fachgemeinschaft Fluiddynamik und Trenntechnik
Bamberg, September

Jahrestreffen der Fachgemeinschaft Prozess-, Apparate- und Anlagentechnik
Bruchsal, November

6th KoMSO Challenge Workshop Big Data
Heidelberg, March, Lecture

Laval Virtual 2015: 17th International exhibition & conference
Laval (F), April, Exhibitor

MIRAW Day
Warwick (GB), November, Lecture

MISTA
Prag (CZ), August

ModVal 12
Freiburg, March, Lecture, Poster

MoRePaS 2015, Model reduction of parametrized systems III
Triest (I), October, Lecture

MOTEK
Stuttgart, October

MSC User Meeting 2015
München-Dornach, June, Exhibitor, Lecture

MSDM 2015
Hamburg, August

Nano Tech
Tokio (J), Poster

Nonwovens Innovation Academy
Leeds (GB), November, Lecture

AWARDS AND PRIZES

OWN EVENTS

NUMDIFF-14
Halle, September, Lecture

Nutzfahrzeuge 2015 – Truck, Bus, Van, Trailer
Eindhoven (NL), June, Exhibitor, Lecture

NVH model of a rotating tire
Guildford (GB), April, Lecture

PDE 2015 – Theory and applications of partial differential equations
Berlin, December, Lecture

PowerGEN2015
Amsterdam (NL), June

Professional Motorsport World Expo 2015
Köln, November, Lecture

Rheinland-Pfalz-Tag 2015
Ramstein, June, Exhibitor,

SAE 2015 World Congress and Exhibition
Detroit (USA), April, Lecture

SC 15, Supercomputing 2015
Austin (USA), November, Exhibitor, Lecture

SciCADE 2015
Potsdam, September, Lecture

SEG International Exposiotion 2015
New Orleans (USA), October, Exhibitor

Seminar »Inspektion und Charakterisierung von Oberflächen mit Bildverarbeitung«
Karlsruhe, December, Exhibitor, Lecture

Summer School »Hardware and Algorithmic Challenges with Emphasis on Option Priciing and Further Applications«
Kaiserslautern, October, Lecture

Tagung: Betriebsfestigkeit – Bauteile und Systeme unter komplexer Belastung; DVM-Arbeitskreis Betriebsfestigkeit
Dresden, October, Exhibitor, Lecture

TechTextil 2015
Frankfurt/Main, May, Exhibitor

Thermodynamik Kolloquium 2015
Bochum, October

Tire Technology Expo 2015
Köln, February, Lecture

UK InterPore Chapter
Manchester (GB), August, Lecture

Variational Methods for Dynamic Inverse Problems and Imaging
Münster, September

15. VDI-Tagung Reifen-Fahrwerk-Fahrbahn
Hannover, October

VI Forum – Virtual Innovation Forum
Ingolstadt, September

VI-grade Users Conference 2015
Triest (I), April, Exhibitor, Lecture

Dobrovolskij, Dascha
Einjähriges Stipendium zur Nachwuchsförderung innerhalb des DGZfP-Stipendiatenprogramms
Deutsche Gesellschaft für zerstörungsfreie Prüftechnik (DGZfP), April

9th GAMM Seminar on Multi-Scale Material Modeling (MMM) on Real-Data Based Numerical Methods
Kaiserslautern, November

Franco-German Workshop »Mathematical Image Analysis«
MINES PariTech, Fontainebleau, October

DVM/SF2M-Workshop
Kaiserslautern, April

Festveranstaltung »20 Jahre Fraunhofer ITWM«
Kaiserslautern, November

IPS Cable Simulation – Users Conference 2015
Deidesheim, June

Seminar »Lastdaten – Analyse, Bemessung, Simulation«
Kaiserslautern, May

Seminar »Statistische Methoden in der Betriebsfestigkeit«
Kaiserslautern, July

Seminar »Systemsimulation in der Fahrzeugentwicklung«
Kaiserslautern, March

Seminar: Data Scientist for Smart Energy Systems
Kaiserslautern, October

Tag der Verfahrenstechnik
Kaiserslautern, September

Technology Day JUROJIN
Kaiserslautern, November

Technology Day: CDTire: Scalable Tire Model for Full Vehicle Simulation
Kaiserslautern, December

Technology Day: Fraunhofer-RODOS®: Interactive Driving and Operation Simulator
Kaiserslautern, December

Series of lectures of the working group »Bildanalyse und Mustererkennung Kaiserslautern« (BAMEK)
Kaiserslautern, January – December

Workshop »Modellierung und Simulation in der Trinkwasserversorgung«
Kaiserslautern, January

Workshop »Robust Risk Estimation«
Kaiserslautern, February

Workshop »Systemsimulation in der Fahrzeugtechnik – Moderne Methoden und neue Entwicklungen«
Kaiserslautern, October

Series of lectures »Blick über den Tellerrand«
Kaiserslautern

Liu, Steven
University of Kaiserslautern
Die Ethik der Gelehrten aus der konfuzianischen Sicht
January

Löhken, Sylvia
Bonn
Intros und Extros. Noch ein »kleiner Unterschied« – und was er im Berufsleben bedeutet
February

Jackson, Myles W.
New York University
Über die Verantwortung der Naturwissenschaftler seit Beginn des 19. Jahrhunderts
March

Peitgen, Heinz-Otto
Bremen
Universitäten zwischen Chancen und Herausforderungen – Wer sich nicht neu orientiert wird absteigen
April

Norbury, John
University of Oxford
Predicting weather
May

Ihsen, Susanne
University of München
Reden wir doch mal über Männer – Gender und Technik zwischen »business case« und Veränderungsresistenzen
June

Keller, Heidi
University Osnabrück and Hebrew University, Jerusalem
Die Entwicklung der »Generation Ich« – Kindheit und Sozialisation in der westlichen Welt
July

Kohne, Henning
Pfalztheater Kaiserslautern
Ein Bericht für eine Akademie. Erzählung von Franz Kafka
September

Roßbach, Hans-Günther
Leibniz-Institut für Bildungsverläufe, Bamberg
Wie entwickeln sich Kompetenzen und welche Auswirkungen haben sie auf die Bildungskarrieren?
October

Krüger, Wilhelm
Kaiserslautern
»Ein Unternehmer – was ist das? Wie Unternehmer denken und handeln: Kann man das lernen?«
November

Sigmund, Karl
University Wien
Alles Walzer! – Rotierende Massen und Einsteins Wiener Weggefährten
December

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Martin-Luther-University Halle-Wittenberg
Numerik für Mehrkörpersysteme
February, April, October

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A Numerical Spectral Approach for Solving Elasto-Static Field Dislocation and G-Disclination Mechanics
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University of Liège (B)
Flexible multibody dynamics: From innovative formulations to applications in engineering
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Ciegis, Raimondas
University of Vilnius (LT)
Quantum Computing and algorithms: The Theoretical Mathematical Minimum
November

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Diskretisierungsverfahren zur Bewertung von Optionen im Heston Modell
January – December

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Bildverarbeitung
May – July

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ORT Braude College, Karrmiel (IL)
Control Theory, Differential Games and Optimization
July

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Detailmodellierung / Strukturverhalten
April

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Martin-Luther-University Halle-Wittenberg
Stochastic Optimal Control of Investment-Consumption Models
March

Gerdts, Matthias
Universität der Bundeswehr München
Anwendungen der optimalen Steuerung im Automobilbereich
May

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MKS
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Laboratorium von Lions, Paris (F)
Homogenisierung, Dimensionsreduktion
September

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July

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Computational Models for Polydispersed Turbulent Flows
July

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Variational formulation of problems involving fractional order differential
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Diskrete Mechanik und Optimalsteuerung von Bio-Mehrkörpersystemen
February, November

Lomov, Stephan
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Micromechanics of Random Fibre Composites: Quasi-static and Fatigue Damage
May

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A Fast Parallel Algorithm for Direct Simulation of Particulate Flows USING Conforming Grids
December

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Viscoelastic Materials
September

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November

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Technical and smart textiles
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Statistik
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A multiscale model for sap exudation in maple trees
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Models for poroelastic shells
September

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CPPI - Strategie für Betriebsrenten
January – November

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- AMS Mathematical Reviews (Reviewer)
- IJNME (Reviewer)
- Journal of Composite Materials (Reviewer)

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- Medical Physics (Reviewer)
- ORSpektrum (Guest Editor)
- Zentralblatt für Mathematik (Reviewer)
- Mathematical Programming (Reviewer)

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- International Journal of Telemedicine and Clinical Practices (Reviewer)

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- Book: Currents in Industrial Mathematics: From Concepts to Research to Education, Springer Spektrum Verlag (Editor)

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- Journal of Microscopy (Reviewer)
- Image Analysis & Stereology (Editorial Board, Reviewer)
- Computers (Reviewer)
- Nanomaterials (Reviewer)
- Materials letters (Reviewer)
- Proceedings of the Estonian Academy of Sciences (Reviewer)
- Graphical Models (Reviewer)
- Philosophical Magazine (Reviewer)
- Spatial Statistics (Reviewer)
- Journal of Microscopy (Reviewer)
- Conference on Industrial Computed Tomography (Reviewer)

Schulz-Reese, Marion
- Österreichisches Bundesministerium für Wissenschaft und Forschung (Reviewer)
- KOMMS – Kompetenzzentrum für Mathematische Modellierung in MINT-Projekten in der Schule (Member of scientific advisory board)

Stephani, Henrike
- International Conference on Pattern Recognition (ICPR, Reviewer)

Wirjadi, Oliver
- SPIE Optical Engineering (Reviewer)
- Image Analysis & Stereology (Associate editor)

Lojewski, Carsten
Network system, network node and communication system
US 201314078917 A1:20131113

Trinkaus, Hans; Malschofsky, Ralf
Steuerung eines Produktionsprozesses für extrudierte Profilbauteile
European patent 1 719 603 B1

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