Fraunhofer
ITWM

FRAUNHOFER INSTITUTE FOR INDUSTRIAL MATHEMATICS ITWM

ANNUAL REPORT 2016/17

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The Center Materials Characterization and Testing is part of the Fraunhofer ITWM since the beginning of the year 2017. Its laboratories and offices are situated in the left wing of the Fraunhofer Center.

ANNUAL REPORT
2016/17

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ITWM increased its revenues by 8 % and the share of business revenue in the operating budget reached an all-time high of 52.3 % in 2016. A major portion of the industrial revenues is accounted for by follow-on projects with existing customers, and, in addition, many new customers were acquired from quite different sectors. These numbers clearly show the efficient performance, economic relevance, and timeliness of our research at the Institute. Naturally, we also benefit from the stable economic conditions in Germany. Revenue forecasts for 2017 are optimistic, the staff is highly motivated for new challenges, and we anticipate a resurgence of economic growth in the future. More orders, the expansion of business areas, and new research challenges all demand more human resources. Overall, 17 new employees were hired at ITWM and it is particularly rewarding that the percentage of women among the new hires reached 41 % in 2016.

One of the special highlights of the year was the opening of the High Performance Center Simulation and Software-Based Innovation presided over by our President, Prof. Dr. Reimund Neugebauer. In three application-oriented priority research areas, the Center promotes intensive cooperation between the Fraunhofer Institutes, the two Kaiserslautern universities, the Science Alliance, and the regional economy. In the past year, ITWM significantly expanded its research and technology portfolio through the integration of a new unit. In 2016, following intensive coordination talks, the Fraunhofer Institute for Physical Measurement Techniques IPM in Freiburg, the State of Rhineland-Palatinate, and Fraunhofer ITWM came to an agreement to integrate the IPM Department of Materials Characterization and Testing located in Kaiserslautern with Fraunhofer ITWM. Over the past decade, under the umbrella of the IPM, this department advanced the development of the terahertz technology to maturity for the industrial sector. The department, well-positioned economically, scientifically, and in terms of personnel, is under the leadership of Prof. Georg von Freymann. The Science Minister of Rhineland-Palatinate, Prof. Dr. Konrad Wolf welcomed the integration of the department and the creation of the ITWM Center Materials Characterization and Testing: "This step marks another cornerstone in the sustainable development of Kaiserslautern as a technology center and a strengthening of the Fraunhofer activities in Rhineland-Palatinate. The close collaboration between the various actors at the same location promises additional opportunities for innovation."

2016 was also the year of farewell. Two people who greatly influenced the direction of ITWM: The administrative director Dr. Marion Schulz-Reese has transitioned to a well-deserved retirement and our former director, Prof. Helmut Neunzert, has moved back to Chiemsee in his home state of Bavaria. Their exceptional service to ITWM as well as the City of Kaiserslautern was recognized at farewell ceremonies organized in their honor. Many colleagues and guests contributed to the entertainment with numerous anecdotes, photos, films, and music. Following the departure of Marion Schulz-Reese as head of administration, ITWM established a new structure with Holger Westing and Dr. Markus Pfeffer dividing the functional responsibilities, which has proven to work very well over the past year. The main activities at Kaiserslautern's Felix Klein Center for Mathematics, having been strongly influenced by Helmut Neunzert, are now bundled in the Felix Klein Academy under the leadership of department head Karl-Heinz Küfer. Based on a sustainable concept of support, networking, and training, the aim of the Academy is to provide specific support to outstanding Math students and young scientists.

The "Radiation Therapy" research group in the Optimization Department received a great honor from the Stifterverband für die Deutsche Wissenschaft in winning the category "Collaborative Research Prize 2016." The aim of their project, as part of the Harvard Medical School collaborative research association, was to develop an innovative concept of radiation therapy together with researchers at DKFZ, the University Clinics of Heidelberg and Munich, and Massachusetts General Hospital.

The GPI programming model (Global Address Space Programming Interface) developed at our Competence Center High

Performance Computing was nominated for the European Commission's Innovation Radar Prize in the category "Excellent Science." In a hard fought competition with 40 European digital innovators, GPI successfully made it into the final round of four. Coming after the Fraunhofer Prize 2013, this represents a further international recognition of GPI as a key innovation for the development of parallel software.

Technology innovations were driven in a number of projects with partners in industry on the basis of our core competencies in mathematical modeling, simulation, and optimization. Besides a major expansion of the project with BASF to improve process planning methods in the area of chemical manufacturing, a project with Swiss chemical firm Lonza achieved savings of more than 10 % in energy costs at a production facility through the use of multiple criteria optimization.

Our IPS Cable Simulation product has been substantially improved. Advances in dynamic simulation and durability have made it possible to perform a simulation-based evaluation of the operational stresses on cables and hoses. Additionally, after consulting the data supplied from the simulation models, we built the MeSOMICS measuring system, a patent pending technology already purchased by partners in the automobile sector.

Another ongoing research subject is the use of additive manufacturing techniques in the fully computer-aided development and optimization of porous microstructures and their subsequent actual production. The first micro-filter structures are already being developed and built with 3D nanoprinting capabilities.

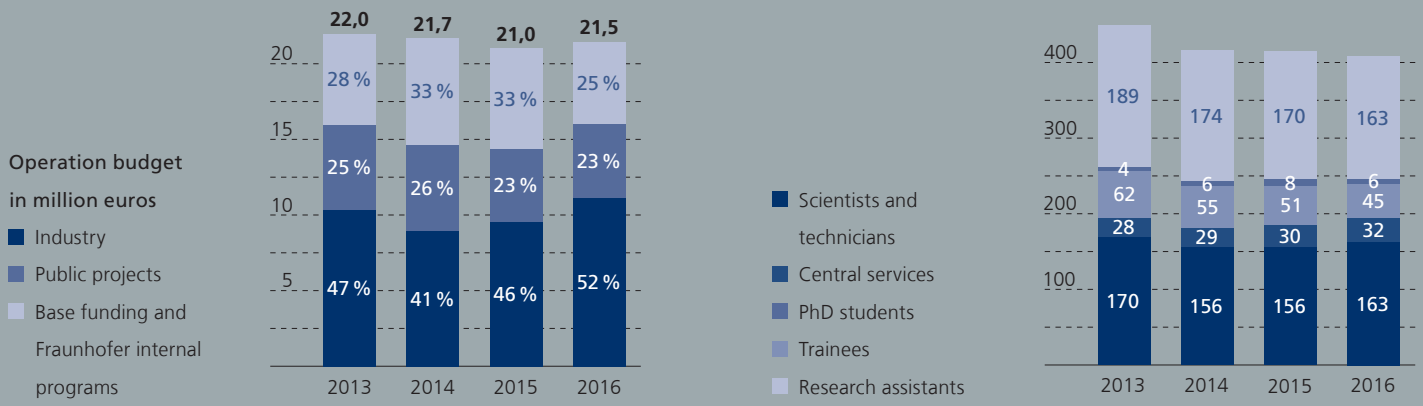
Our software products, FPM for flow and continuum dynamics and FIDYST for fiber dynamics, are now achieving significant licensing fees in addition to the application projects. The flow dynamic process design has successfully been established as a unique selling feature in the area of optimal design of hot melt distributors.

In a joint venture with the "Pension Information Center" located at ITWM, every pension plan tariff over four different terms marketed in Germany in 2016, together with its specific features, was modeled, simulated, and classified on the basis of the simulation results.

The feedback received from our customers is characterized by a high degree of satisfaction. The following quote from an official blog of SAP perfectly documents this: "After almost two years of collaboration, we are convinced that partnering with the ITWM was the best thing SAP could do to streamline the development process of SAP S/4HANA for advanced variant configuration."

My appreciation goes out to our staff and our PhD candidates, who demonstrated again in 2016 high levels of identification and autonomy in a variety of projects and created a climate of mutual respect and recognition of one another's abilities, which is what makes the scientific and economic success of ITWM possible. I also thank our customers and project partners for placing their trust and confidence in ITWM and look forward to accepting new tasks and challenges together in the year 2017.

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



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 of 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.

INDUSTRIES – WHO DO WE WORK WITH?

Thanks to the comprehensive methods resident in our departments and the broad spectrum of application areas, our customer base may range across many sectors. Fraunhofer ITWM provides core competencies in the areas:

- Modeling and simulation
- Optimization and decision support
- Data analysis and visualization

and addresses companies and organizations in the sectors:

- Process / Mechanical / Systems engineering
- Automotive and suppliers
- Pharmaceuticals and medical systems
- Power industry
- Technical textiles
- Information technology
- Finance

As a result of the long term cooperation with our regular customers, a considerable domain competence has evolved in some areas of individual sectors; to name a few in particular, the automobile sector, process engineering, and the energy sector. For all sectors: Fraunhofer ITWM's modeling and simulation competence creates a real competitive advantage in the marketplace.

CUSTOMERS AND COOPERATION PARTNERS SELECTION 2016

- AbbVie Deutschland GmbH & Co. KG, Ludwigshafen
- ACC Technologies, Turku (FIN)
- Alois Kober GmbH, Kötz
- Altair Engineering Software Co., Ltd., Troy (USA)
- ante holz GmbH, Bromskirchen-Somplar
- AUDI AG, Ingolstadt
- BASF SE, Ludwigshafen
- Bayer CropScience AG, Monheim
- Biffar GmbH & Co. KG, Edenkoben
- BJS Ceramics GmbH, Gersthofen
- BMW AG, München
- BorgWarner Turbo Systems GmbH, Kirchheimbolanden
- BPW Bergische Achsen KG, Wiehl
- Brückner Group GmbH, Siegsdorf
- BSN Medical GmbH, Emmerich
- Continental Automotive Systems AG & Co. OHG, Frankfurt
- DAF Trucks N. V., Eindhoven (NL)
- Daimler AG, Stuttgart
- Dassault Systemes, Waltham (USA)
- delta h Ingenieurgesellschaft mbH, Witten
- Dilo Machines GmbH, Eberbach
- Eagle Burgmann GmbH, Wolfratshausen
- ebm-papst Mulfingen GmbH & Co. KG, Mulfingen
- ESI Group, Paris (F)
- FLSmidth, Kopenhagen (DK)
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- Gebr. Pfeiffer SE, Kaiserslautern
- GEF Ingenieur AG, Leimen
- General Dynamics European Land Systems-Germany GmbH, Kaiserslautern
- GKN Driveline Technology Centre, Lohmar
- GKV Spitzenverband, Berlin
- Goldbeck Solar GmbH, Hirschberg
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- Hilite Germany GmbH, Nürtingen
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- Kreisverwaltung Mainz-Bingen, Ingelheim am Rhein
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- Lenzing, AG Lenzing (A)
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- mfd Diagnostics GmbH, Wendelsheim, Luckenwalde
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- Universities of Applied Sciences: Darmstadt, Kaiserslautern, Mainz, Berlin, Lübeck, Birkenfeld
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- Venios AG, Frankfurt
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- Volvo CE, Konz, Göteburg (S)
- Woltz, Wertheim
- Xella Fermacell, Calbe/Saale

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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

- 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 the area of Kaiserslautern

HIGH PERFORMANCE CENTER SIMULATION AND SOFTWARE-BASED INNOVATION

The Fraunhofer-Gesellschaft concept of High Performance Centers supports the goal of sustainable site development. The Fraunhofer concept builds on existing cooperation with other actors in the scientific community and the regional business networks. In this way, all dimensions are included: research and academia, promotion of young talente, comprehensive infrastructures, innovation, and knowledge transfer to SMEs as well as to major companies. The concept may be understood as an instrument for innovation and ensuring sales oriented excellence in key areas for selected regions. The intensive exchange between the Fraunhofer Institutes with both universities in Kaiserslautern and good relations with the local economy have been institutionalized in a High Performance Center since January 2016: The name "Simulation and Software-Based Innovation" already expresses the scientific excellence that has emerged in Kaiserslautern over the past two decades. The official opening event in March was attended by many representatives from government, science, and business.

The High Performance Center is divided into R&D labs and application centers, which differ in focus and industry orientation. The research and development labs tend to focus on methods. They develop concepts and algorithms in various fields with different priority research subjects. These, in turn, become the basic technologies available to the three application centers. The centers reflect the expertise of this research center in the area of simulation. The cooperation between the Innovation Cluster for Digital Commercial Vehicle Technologies and the Commercial Vehicle Alliance is a good example. Technical processes and products are simulated using MSO-based process engineering at the application center for "Modeling, Simulation, and Optimization," which applies mathematical optimization methods on the basis of physical and data based modeling. And, at "Smart Ecosystems" research focuses on new methods and techniques of software engineering in specific application scenarios. Currently, the priority subjects are medical science and green energy grids.

In the first two years, the High Performance Center receives start-up funding of five million euros from State of Rhineland-Palatinate. Over this same period, industrial partners – including BASF, Daimler, John Deere, Liebherr, Procter & Gamble, Robert Bosch, Schmitz Cargobull, and Volvo Construction Equipment – also contribute another five million euros, while the Fraunhofer Institutes provide an additional one million euros.

1 *Inauguration of the High Peformance Center (from left): Dr. Mattias Schmidt (Procter & Gamble), Dr. Christoph Großmann (BASF), the spokesman of the center Prof. Dr. Dieter Prätzel-Wolters (Fraunhofer ITWM), Prof. Dr. Arnd Poetzsch-Heffter (TU Kaiserslautern), Prof. Dr. Peter Liggesmeyer (Fraunhofer IESE) and the Fraunhofer President Prof. Dr.-Ing. Reimund Neugebauer*

HIGH PERFORMANCE CENTER
SIMULATION- AND SOFTWARE-BASED INNOVATION

FRAUNHOFER-CHALMERS RESEARCH CENTRE FOR INDUSTRIAL MATHEMATICS FCC

One of the most important international partners of Fraunhofer ITWM is Fraunhofer-Chalmers Research Center for Industrial Mathematics (FCC), founded by the Fraunhofer-Gesellschaft and Chalmers University in Göteborg in 2001. Its mission is very similar to that of Fraunhofer ITWM and the center works most closely with our Mathematical Methods in Dynamics and Durability department as well as the Optimization and System Analysis, Prognosis and Control departments. In 2015, an international committee evaluated the scientific and business development as well as the future strategy of FCC. The successful rating confirms the Institute is an outstanding research facility that has become a center for industrial mathematics in Sweden. Its portfolio covers contract research, service, algorithms and software, all based on modern mathematical methods in the area of modeling, simulation, and optimization (MSO) that flow into industrial innovations for products and production systems. Areas of application include mechanical engineering, life sciences, paper and packing industry, electronics, and information and communication technologies (ICT).

The Fraunhofer-Chalmers Research Center for Industrial Mathematics is structured in three departments:

- "Geometry and Movement Planning" works in close cooperation with Chalmers Wingquist Laboratory to develop simulations for automated path planning, sealants, flexible materials (e. g., cables and hoses) and human movement models. This last area is important for the ergonomic design of assembly processes.

- "Computational Engineering and Design" works on innovative numerical methods, fast algorithms, and engineering support tools for virtual product and process development. Applications include fluid dynamics, structural dynamics, and electromagnetism.

- "System and Data Analysis" supplies expertise in dynamic systems, forecasting and controls, image and video analysis, statistics, and quality engineering, in addition to technical, biological and biomedical applications.

The FCC currently has a staff of 45 employees and a budget of five million euros in 2016.

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.

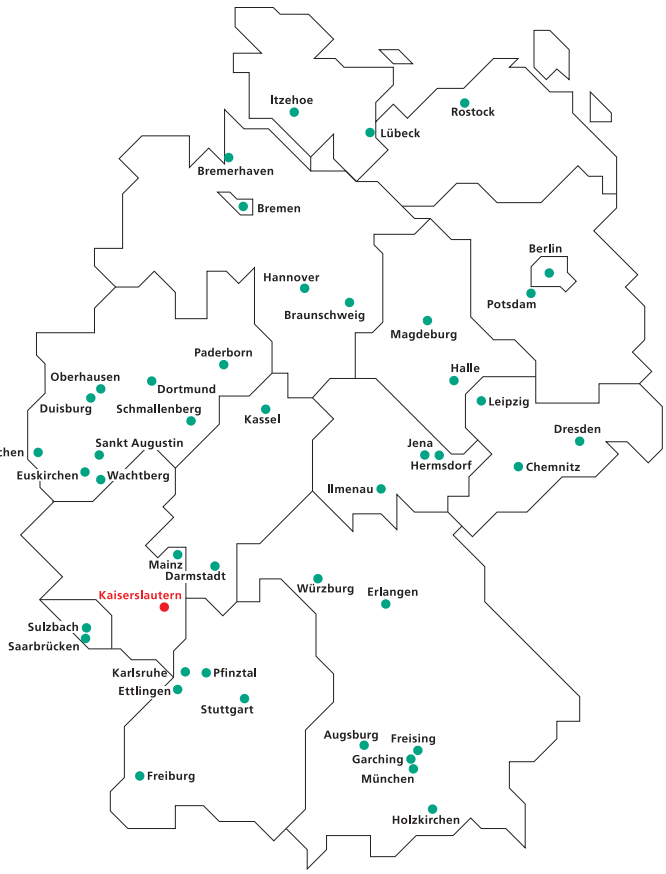
At present, the Fraunhofer-Gesellschaft maintains 69 institutes and research units. The majority of the 24,500 staff are qualified scientists and engineers, who work with an annual research budget of 2.1 billion euros. Of this sum, 1.9 billion euros is generated through contract research. More than 70 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 state 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.



FAREWELL CEREMONY FOR DR. MARION SCHULZ-REESE

1 *"Can't stop me now" – with much warmth and a touch of sadness, the administrative director says farewell to her Institute.*

Dr. Marion Schulz-Reese, administrative director at ITWM, retired after a long career mid-way through 2016 and was given an official send-off – attended by many friends and guests who contributed anecdotes, photos, films, and music. This participation ensured a very entertaining evening under the motto: "Farewells are the doors to new worlds."

Marion Schulz-Reese reminisced about the key stations in her long professional career together with institute founder Professor Helmut Neunzert and other colleagues. The current Finance Minister of Rhineland-Palatinate, Doris Ahnen, was among the long-time supporters of ITWM; first as a state minister and later as the Education and Science Minister. She spoke about the successful support programs in the state of Rhineland-Palatinate, and of course, the successful women in various positions who have had the occasion to meet over the course of the years – for example, as a government minister and an administrative director.

Dr. Dietmar Albrecht, head of human resource development strategy at Volkswagen, first learned to appreciate industrial mathematics at the end of the 1980s. He sent a sincere video message from Beijing in which he remembered the early days of applied mathematics in Kaiserslautern. The topic of knowledge transfer was of most interest to him and he described Marion Schulz-Reese as the "epicenter" of this field. Checking in from India was Professor Subbiah Sundar, one of the original alumni ambassadors of Kaiserslautern, who paid homage with his song "Marion means success." Other speakers included Prof. Vincenzo Capasso, who organized the first European Consortium for Mathematics in Industry Workshop in 1988 – effectively making industrial math a topic in Europe; and, Dr. Winfried Eschmann from the mathematics department at TU Kaiserslautern, who co-founded the mathematical modeling week for students and teachers. Professor Jens Struckmeier reminded the audience of the days from 1995 to 2000 when ITWM was a state institute; during this period, the institute demonstrated its performance abilities and was eventually admitted into the Fraunhofer-Gesellschaft.

After thanking the speakers, Elisabeth Ewen, Corporate Director of Personnel, had another small surprise to present: the "Fraunhofer Taler", made of porcelain. With this symbol, Fraunhofer-Gesellschaft recognizes deserving employees for their outstanding service to the society. The event came to an emotional close when the children of Kita Klammeräffchen (company child-care service) bid farewell in song to their mentor. The existence of the Kita at the Fraunhofer Center is, to a large extent, because of the persistent efforts of Marion Schulz-Reese, who managed to persuade the city, state, and Fraunhofer-Gesellschaft of the necessity and practicality of workplace oriented day care.

FESTIVE COLLOQUIUM FOR INSTITUTE FOUNDER, PROFESSOR HELMUT NEUNZERT

On the occasion of institute founder Helmut Neunzert's 80th birthday, ITWM organized an official celebration at the Fraunhofer Center at the end of September. Alongside friends and colleagues, were many of the doctoral students who earned PhDs under the supervision of Helmut Neunzert during his professional career. Among them was Prof. Jens Struckmeier, who in his "Stories of Happy People" traced Neunzert's career in three parts: The happy years before industrial mathematics – the arrival of mathematical modeling at TU Kaiserslautern – and the new millennium. The last phase bore witness to significant events like the admission into the Fraunhofer-Gesellschaft, the State's Mathematics Initiative, the establishment of the Felix Klein Center for Mathematics, and many individual honors such as the award of the Fraunhofer Medal and the Order of Merit from the State of Rhineland-Palatinate.

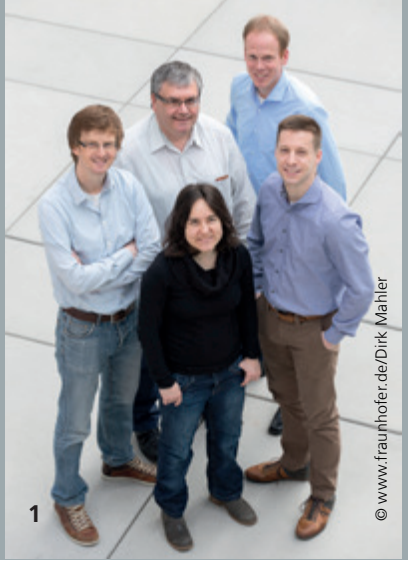
He offered a quote as his motto for the coming years "There is nothing against which an old man should be so much on his guard as the urge to give in to casualness and inaction," as he promised to remain a distant, but interested observer of ITWM.

1 *The "Neunzert-Doctorates Choir" singing the favorite song of Helmut and Renate Neunzert: "Die Gedanken sind frei"*

2 *Process engineers from scientific and business communities joined the workshop at the end of September.*

INTERNATIONAL WORKSHOP: MATHEMATICAL METHODS IN PROCESS ENGINEERING

The High Performance Center Simulation and Software-Based Innovation organized an international workshop at Fraunhofer ITWM – wholly in line with the Fraunhofer strategy of promoting excellence through the bundling of existing expertise in science, applied research, and industry. The subject of the 2-day event held in mid-September was "Mathematical methods in process engineering" and it was attended by approximately 100 invited speakers and guests from various universities and industry. Modeling, simulation, and optimization are key technologies in the design and control of production processes to improve productivity and flexibility to the needs of the global marketplace. The workshop was intentionally designed to focus on the areas of process optimization and process simulation; the application-oriented topics were "Granular flows," "Filtration," and "Fibers and nonwoven fabrics." A summary of participant comments reads: "The workshop is an outstanding opportunity that facilitates exchange between mathematicians, engineers, and scientists working in the field of process engineering and should be repeated on a two-year cycle with changing focus topics."



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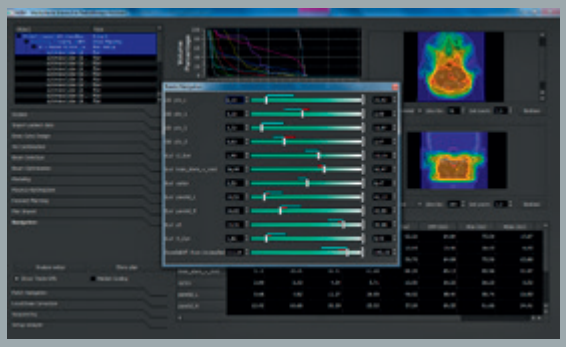

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PRESTIGIOUS AWARD FOR CUSTOM RADIATION THERAPY

1 *The prizewinners: Philipp Süss, Karl-Heinz Küfer, Katrin Teichert, Alexander Scherrer and Michael Bortz*

2 *Screen shot of the user interface: With the techniques developed at ITWM, all aspects of a therapy plan can be directly influenced.*

The Stifterverband Science Prize is awarded for scientific excellence in applied research projects conducted by Fraunhofer Institutes in collaboration with industry and/or other research organizations. In 2016 this prize was given to a group of researchers from Fraunhofer ITWM, together with colleagues from Cancer Research Center, University Hospital Heidelberg, and Harvard Medical School/Mass General Hospital. In close cooperation with their partners from the medical application the ITWM researchers developed a software for the more efficient design of radiation therapy planning for tumor patients.

The result was an interactive and easy-to-operate software product. It shortens the duration of radiation therapy planning, makes finding a good balance between therapy potentials and possible side-effects easier and ultimately increases the patient's chances of recovery. The jury specifically recognized the broad viability of the method in treating the wide-spread illness of cancer as well as the relevance to international markets.

The objective of the therapy is to kill tumor cells while protecting healthy tissue. In the past the physician formulated his wishes and the radiation physicist turned these demands into a therapy plan. If the physician wasn't satisfied with the results, the physicist did follow-up work. Gradually the optimum solution was found. The new thing about the mathematical approach is that from the very beginning a variety of solutions is calculated; the physician can then choose the best solution for the patient. In order to improve the process, ITWM researchers Karl-Heinz Küfer, Michael Bortz, Alexander Scherrer, Philipp Süss and Katrin Teichert considered therapy planning as a multi-criteria optimization task, in this case a balanced compromise involving around ten to fifteen in part contradictory planning goals. The principle of the Pareto solution is a better concept here than the previous trial-and-error strategy. With the new planning system the tumor can be better brought under control, since it could be irradiated with a higher dose. This means the probability of permanently eradicating the tumor is also higher.

By the end of 2015 vendor RaySearch Laboratories had sold several hundred systems all over the world. With additional licensing through world market leader Varian Medical Systems since 2016, the technology will be available at over 20,000 therapy planning stations around the world.

1 *The section of the building occupied by the Center Materials Characterization and Testing*

INTEGRATION OF THE CENTER MATERIALS CHARACTERIZATION AND TESTING

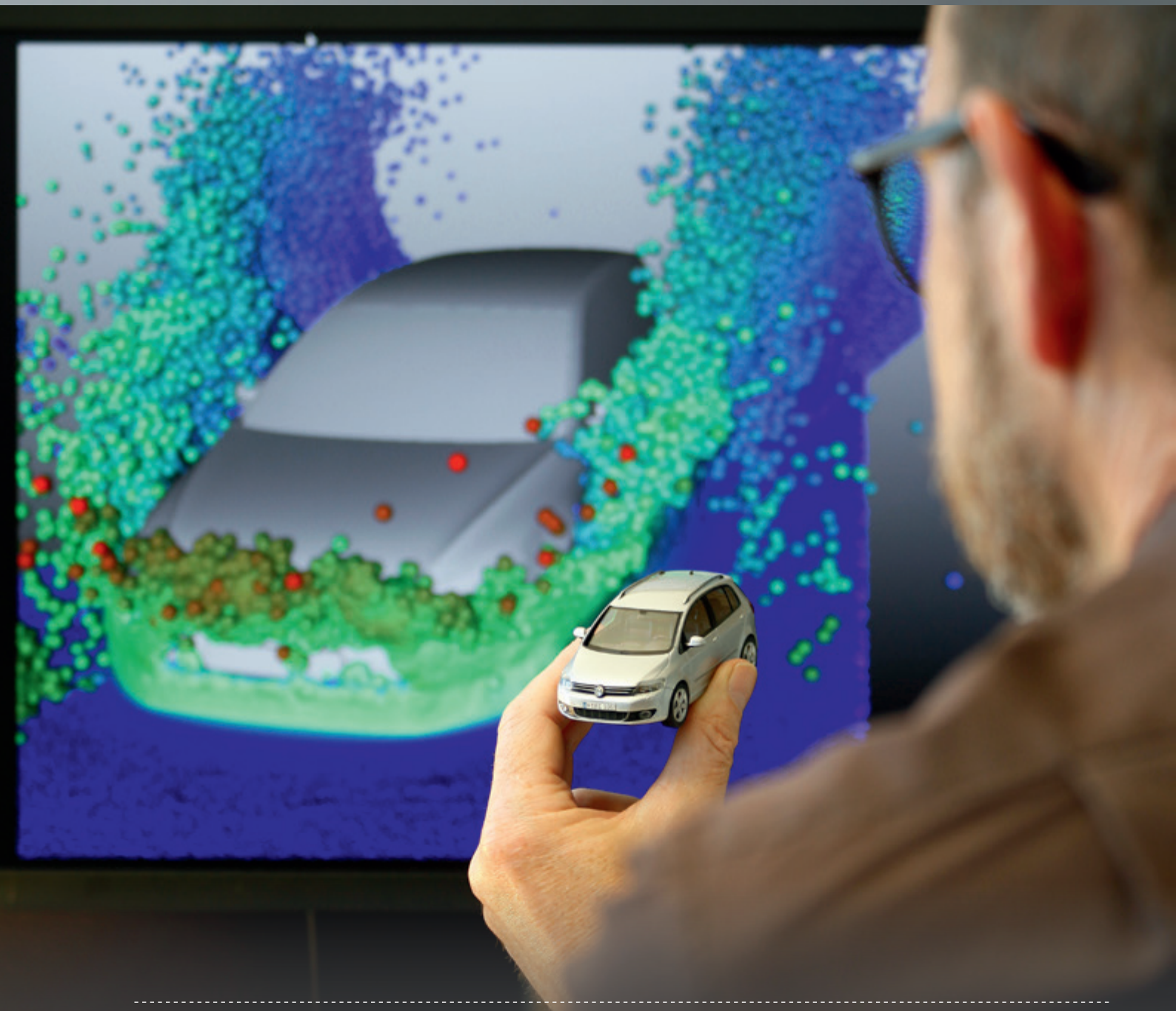
Measuring technologies and mathematics got even closer connected at Fraunhofer ITWM at the beginning of 2017, when the Center Materials Characterization and Testing was reorganized from Freiburg's Fraunhofer Institute for Physical Measuring Techniques to the mathematics institute in Kaiserslautern. Spatially, the physicists were already present in Kaiserslautern as they occupied an expansion of the Fraunhofer Center in 2015. Now, the 20-plus employees are also organizationally assigned to Fraunhofer ITWM. The expansion provided a total additional floor space of 1400 square meters. The new construction houses high frequency measuring systems, spectroscopic systems, metal and electronics workshops, a chemical lab, and a robot work station.

In partnership with Kaiserslautern Technical University, the project group "TeraTec" of Fraunhofer IPM began to exploit terahertz radiation for use in industrial applications in 2005. In 2010, the TeraTec Application Center was established to provide customers a one-stop access to the benefits of terahertz measuring technology. The successful cooperation in the field of industrial terahertz measuring systems provided the justification for the establishment of the new Center Materials Characterization and Testing. Over the past decade, under the umbrella of the Fraunhofer IPM, the material characterization and testing department developed the terahertz technology to maturity for use in the industrial sector. In particular, the development of the non-contact measurement of coating thickness opened a field of application where success is determined in large part by the physical modeling and parallel numerical evaluation of the measured data.

The clever combination of precise measurement with highly capable evaluation algorithms enabled this technological breakthrough. Non-contact, non-destructive material testing facilitates the detection of defects in ceramics, plastics, or even fiber reinforced composites. There is also special interest in coating thickness measurement, for example, for use with painting processes. Terahertz radiation and millimeter wave measuring technologies, in particular, are an alternative to ultrasonic measurement in cases where mechanical contact is not desired or not possible, and even x-ray radiation where the ionization poses a problem.

The state of Rhineland-Palatinate, Fraunhofer-Gesellschaft, and Fraunhofer IPM are supporting the integration process over the next three years with a funding in the amount of 1.6 million euros.

TRANSPORT PROCESSES



Many industrial processes can be simulated using numerical methods, especially, in the area of fluid mechanics. One particularly efficient meshfree solver is the Finite Pointset Method, which was developed by the department and is constantly being expanded. The selected application was prepared with our main cooperation partners and shows a simulation of vehicle passing through water.

DR. DIETMAR HIETEL
DR. RAIMUND WEGENER
HEAD OF DEPARTMENT

The core competence of the department is the mathematical modeling of complex industrial problems and the development of efficient algorithms for their numerical simulations. The specific problems mainly occur in the context of the technical-natural sciences (fluid dynamics, radiative transport, optics, structural mechanics, etc.) and, after modeling, result in differential equations that can be generally characterized as transport algorithms. The biggest issues, in the eyes of our industry customers, typically concern product optimization or the design of production processes. The portfolio of the department includes collaborative research and development projects with our industrial partners, studies that include design and optimization recommendations as well as software programming of modules or complete tools. The year 2016 was a very successful one for the department, both scientifically and economically. The introduction of a double-head in the department significantly strengthened and focused the group organization. The following pages provide a review of the methodical developments in the four working groups that play a role in various applications. The range of industries we support includes: technical textiles, automobile manufacturing and automotive suppliers, mechanical and plant engineering, process engineering as well as the medical technology and energy sectors. The problems tackled may fall under the areas of fluid dynamics, fluid-structure interaction, fiber dynamics, thermodynamics, and energy distribution.

MAIN TOPICS

- Flexible structures
- Meshfree methods
- Fluid dynamics in process design
- Energy grids and model reduction

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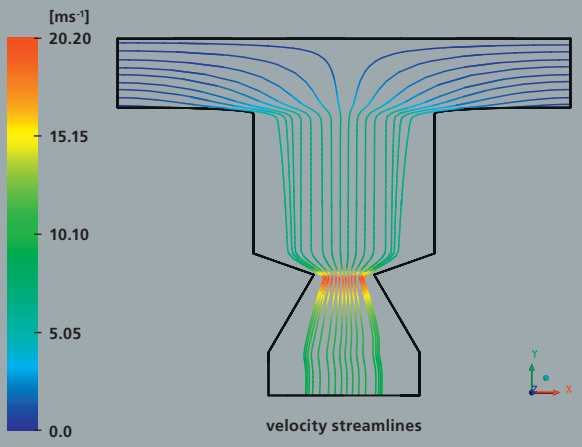

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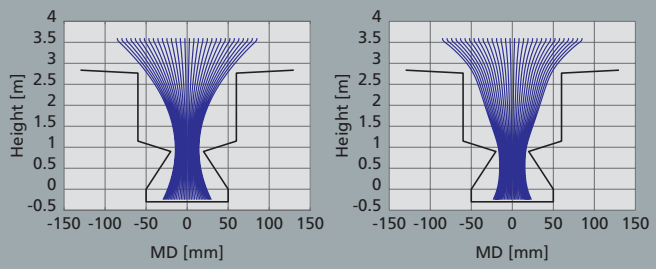

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MODELING AND SIMULATION: VISCOELASTIC MELT SPINNING PROCESSES

1 *Aerodynamic acceleration area in a spinning process; with color-coded streamlines of the velocity magnitude*

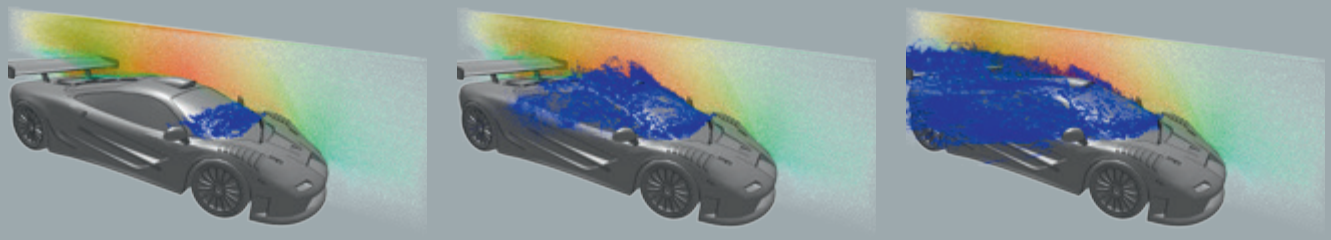
2 *Fiber dynamics model with viscous (left) and viscoelastic (right) materials*

In spinning processes a hot liquid jet is extruded from a nozzle and mechanically or aerodynamically stretched. By cooling down it solidifies and forms an elastic inextensible thin fiber. Process simulation and design require an appropriate material modeling that covers the full range from the viscous jet behavior at the nozzle to the elastic behavior of the final fiber.

Over the past years, Fraunhofer ITWM has developed a new viscoelastic material law for Cosserat rod models and achieved a major advance in the realistic simulation of the spinning process. The Cosserat rod models are based on an one-dimensional balance of mass, linear and angular momentum, and energy along the fiber curve. Conventional simulations using a viscous material model provide an incorrect dynamic for the cooled fibers as they do not account for bending characteristics. The new viscoelastic model, however, overcomes this limitation and provides realistic results throughout the entire process. As desired, the model shows viscous material behavior at the higher temperature boundaries and flexible elastic behavior for the lower temperatures.

The importance of viscoelastic material modeling can be seen from a simple, two-dimensional example: A fiber bundle leaves the spinning pack so the fibers can be cooled and drawn by the air coming from both sides. The machine geometry has a constriction where the velocity of the air flow increases and the fiber jets are pulled through. The fiber simulation results are shown for viscous and viscoelastic material laws, respectively. After just a short running time in the case of viscous material behavior, the fiber curvature is no longer flexible and cannot change because of the cooling. In contrast, the viscoelastic model captures the bending of the cooled fibers and allows the actual overall dynamics to be simulated.

Fraunhofer ITWM successfully implements the new model in combination with a library of flow-interaction models to support the design of modern fiber production plants and further optimize existing processes.



1

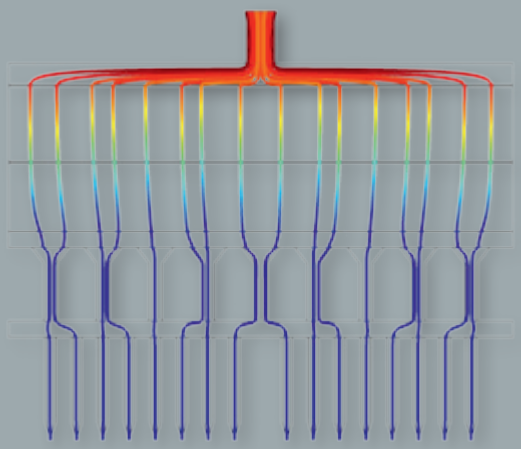
MESHFREE SIMULATION OF FLUID DYNAMICS AND CONTINUUM MECHANICS

Meshfree numerical methods are increasingly used to simulate various industrial processes and operations, in particular, for problems in fluid dynamics or continuum mechanics. The Transport Process department has been developing the Finite Pointset Method (FPM) as its own meshfree simulation tool since the year 2000. FPM is based on a non-meshed cloud of numerical points that represent the continuum and move at the material velocity (Lagrangian method). In effect, FPM is able to very simply and naturally model processes with free surfaces, phase boundaries, and moving geometry parts.

Since 2002, the main focus has been on developing an implicit FPM variant, which enables numerical simulations of incompressible or slightly compressible processes (low Mach numbers). In 2014, the Fraunhofer-internal cooperation project MESHFREE was started together with Fraunhofer SCAI, with the aim of coupling the algebraic multigrid method (SAMG) with FPM. For this purpose, SAMG is being adapted specifically to the meshfree characteristics of FPM. The large sparse systems of equations resulting from implicit formulations can be solved more robustly and much faster using the FPM-SAMG variant. In fact, the simulations for some industrial applications have only become possible as a result of this cooperation.

Industrial projects have already been successfully completed using the coupled approach in 2016. In addition to the FPM-SAMG coupling, the illustrated application couples two independently running FPM simulations. One of the simulations calculates the air flow around a vehicle, while the other simulation models the flow of rain or spray water. Information is exchanged between both simulations: the spray water simulation requires data from the air phase, mainly speed and pressure, while the air flow simulation requires input about the current location, size, and number of spray water droplets. Each simulation uses the integrated SAMG method. Such processes are difficult to reproduce using traditional mesh based simulation methods. The MESHFREE simulation tool opens a whole new range of possibilities for the design of vehicles and components.

1 *Interaction of air and spray flows around a vehicle at various simulation times*



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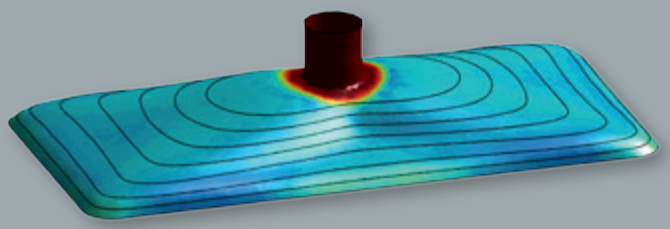


2

ANALYSIS AND OPTIMIZATION OF POLYMER SPIN PACKS

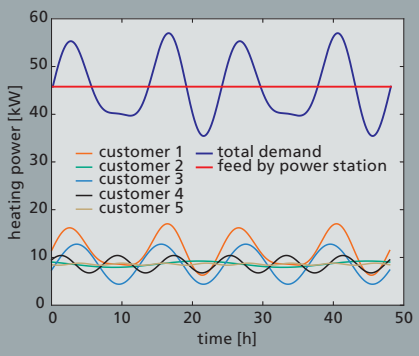
1 *Paths of the polymer particles through a typical spin pack*

2 *Optimized distributor cavity between input pipe and filter*

Spin packs are used in the production of synthetic fibers. Typically, melted polymer is disbursed in the spin pack under pressure, passing through multiple filter layers, before it is then pressed through fine capillaries in the spinning plate to be spun into fibers. Depending on the process parameters, the polymer being used, and the specifications of the finished product, different problems can be encountered: Excessive residence times under temperature or high shear rates can degrade the polymers and high pressure drops can hinder the process and reduce the potential output.

ITWM uses flow simulations in combination with in-house developed analysis tools to identify weak points in the design of spin packs. ANSYS Fluent is the standard tool used for the flow simulations. Models for the shear and temperature-dependent viscosity describe the non-Newtonian polymer rheology. But the key aspect is the interpretation of simulation results. Therefore, a representative number of movement paths of the polymer particles are tracked through the entire pack. Relevant variables like residence time, pressure, temperature, or shear rate are evaluated along these paths. This is performed for the pack a whole as well as for the individual components so, in the end, a causative component is identified for each problem. For example, excessive residence times leading to a degradation of the polymers may often occur in the distributor cavity located at the transition between the inlet tube and the filters. Using the geometry optimization methods developed at ITWM, such cavities can be given a flow optimized design, free of harmful dead zones. In contrast, high pressure drops can occur in the fine feed channels required for bi-component spin packs. The simulation-supported analysis permits targeted design improvements, which eliminate the need for costly trial-and-error attempts.

ITWM has accumulated broad experience and competence in this area. They include the analysis and optimization of existing designs as well as design support for new packs. In addition to single component and bi-component packs, other polymer extrusion systems can be studied, for example, polymer filters. These evaluations include detecting the typical sources of error as well as targeted searches for application-specific problems. Generic optimization tools can be extended to customized solutions.



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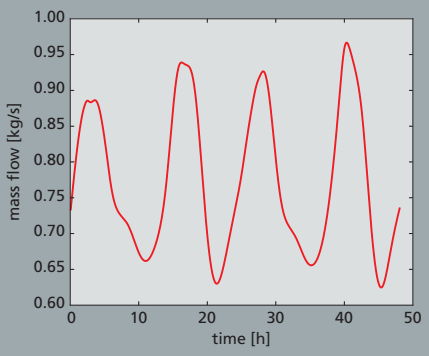

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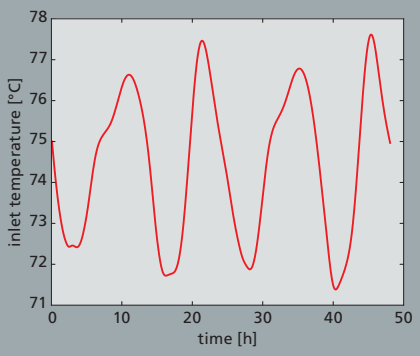

3

DYNAMIC NETWORK SIMULATION FOR INCREASING EFFICIENCY IN DISTRICT HEATING POWER SYSTEMS

District heating power stations (DHP) are mainly used to supply heat and warm water. However, suppliers also generate a good part of their revenues from selling electricity from cogeneration of heat and power. When district heating networks are integrated and dynamically controlled as energy storage units, turbine operations can be made more efficient and firing additional boilers may be avoided. The optimization of operational processes at the power station requires all components to be mathematically represented as accurately as possible. In terms of the district heating network, this means not just the static states, but also the full dynamics must be considered over time. Current software products to support DHP operations are either focused on the optimal use of local resources (where the district heating network is treated as an unstructured sink) or on supplying safely all customers (where consideration is given to detailed, locally resolved hydrothermal models of the power grid). These packages do not include an overall optimization with variable operating conditions. Sponsored by the Federal Ministry for Economic Affairs and Energy (BMWi), this ITWM project is implemented in cooperation with GEF (a German engineering company) and TWL (Technische Werke Ludwigshafen) with the aim of achieving the integration of a dynamic network model into the optimization of power station operations. A dynamic simulation of the district heating power grid is itself of measurable benefit to the operator. For example, the inlet temperatures at the power station and mass flow fed into the network can be controlled as a function of the variable customer demand for heat over time in such a way that the output supplied by the plant remains constant and reliable – even at times of peak usage. The integration of costly gas turbines for the additional heat generation can be minimized or even completely avoided.

The district heating model now in use still has too many degrees of freedom for a comprehensive optimization of operations. To forecast pressures and temperatures, it must be substantially compressed without any significant loss in accuracy. Here, we rely on the use of mathematical methods of parametric model reduction. The optimization challenges are characterized by the limiting conditions of the forecasts for stochastic fluctuations in usage and prices. To improve the forecasting model, we perform simulations for historical time series. A software wizard is being developed to perform potential analyses for the TWL power stations and to present the added value of this new approach to the entire sector.

Coverage of periodically variable demand with constant power feed through by combined regulation of mass flow and input temperature:

1 *Variable customer demand and constant power feed*

2 *Control of mass flow*

3 *Control of inlet temperature*

FLOW AND MATERIAL SIMULATION

A device for dynamic-mechanical thermo-analysis (DMTA) provides the precise in-house characterization of material parameters necessary for the micro structure simulation of porous media and composites. Measurements can be taken in a wide range of temperatures and humidity using nitrogen cooling and humidity generators. Ultimately, the device is used to validate simulation results.

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. The simulation challenge of the mutual influences of manufacturing processes and restrictions with the multifunctional, local material properties of complete composites under dynamic strain is typical. 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. The department cuts into two larger fields of competence: 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. There is a strong demand for our highly efficient, micromechanical methods for the material design of fibre reinforced composites and technical textiles. The "simulation-assisted design of complex flow processes" works on the corresponding manufacturing processes such as mixing, dispersing, injection, filtration, coating and segregation. Focusses of the industrial application are processes of filtration and segregation and the product design of filter systems or of other process machines. The projects of application in the area of electrochemistry concern diverse aspects for the design of material of battery cells or fuel cells as well as for their production e. g. the filling of battery cells.

MAIN TOPICS

- Virtual Material Design and Microstructure Simulation
- Complex Fluid Dynamics and Multiphase Flows
- Technical Textiles and Nonwovens
- Lightweight and Insulation Materials
- Filtration and Separation
- Electrochemistry and Batteries

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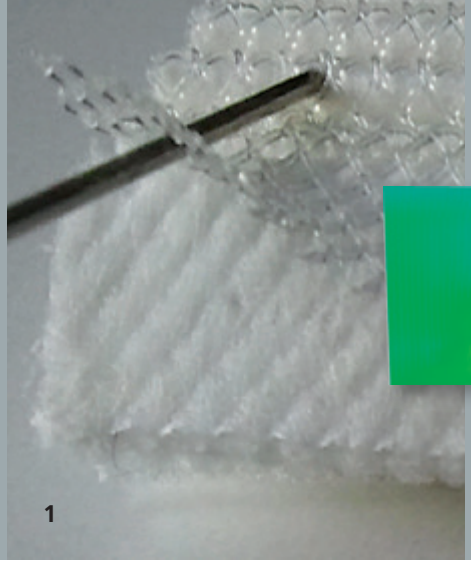

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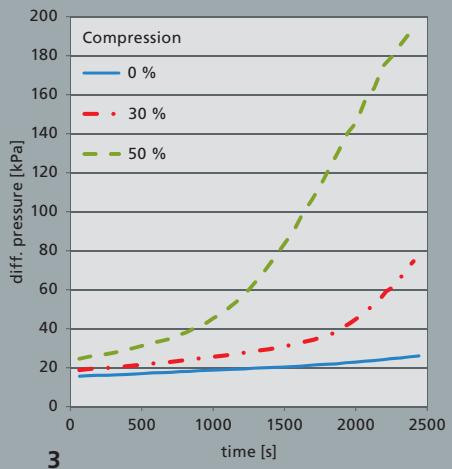

3

MODELING AND SIMULATION FOR THE OPTIMIZATION OF MULTI-LAYERED FILTERED FILTER MEDIA

1 *Imprints of the supporting mesh in the filter material due to the pleating procedure*

2 *Simulation of the compaction of the filter material and the corresponding effects. Left: Flow speed, Center: Shape of the nonwoven, right: Pressure distribution in the flow*

3 *Time evolution of the differential pressure caused by the loading of the filter material for different mechanical compression levels*

Specialized simulation tools have proven to be very useful for the innovation and optimization of filter media and filter element designs. In order to produce reliable and predictive results, material parameters such as the fiber volume fraction (porosity), flow resistance (permeability) and mechanical properties are of paramount importance.

The design of filter materials with high dirt holding capacity and filtration efficiency, while featuring a low pressure loss, is a challenging task. Therefore, homogenous filter media usually cannot fulfill all these requirements. In many cases, the filter medium consists of several layers, combining filtering nonwovens with supporting meshes in order to provide mechanical stability even for high volumetric flow rates. During manufacturing of the multilayered medium (e. g. pleating), mechanical compression leads to imprints of the mesh in the softer nonwoven layers, causing tremendous local compaction of the materials, leading to corresponding changes in flow resistance filtration properties. A purely empirical approach to identify suitable material combinations, optimal layer thicknesses and manufacturing process is extremely time-consuming and costly.

The goal of the project "Virtual workbench for the optimization of filter media" (ViWOFiM) is the development of models and algorithms that are able to accelerate the design phase for such filter materials. This is based on the coupling of the software packages FeelMath and FiltEST, developed at the Department of Flow and Material Simulation. Using known mechanical properties of the starting materials and prescribing a compression for the multilayered medium, FeelMath computes the local deformations in the individual components. The obtained local material compactions are translated to a permeability distribution by utilizing suitable models. This is used by the flow simulation module of the software FiltEST for the computation of velocity and pressure distribution in the medium, such that an effective flow resistance of the compressed multi-layered medium. In a similar way, the local filtration properties can be deduced from the corresponding compressions. Subsequent simulation of filtration processes allow for the computation of an effective filter efficiency of the multi-layered structure after the processing.

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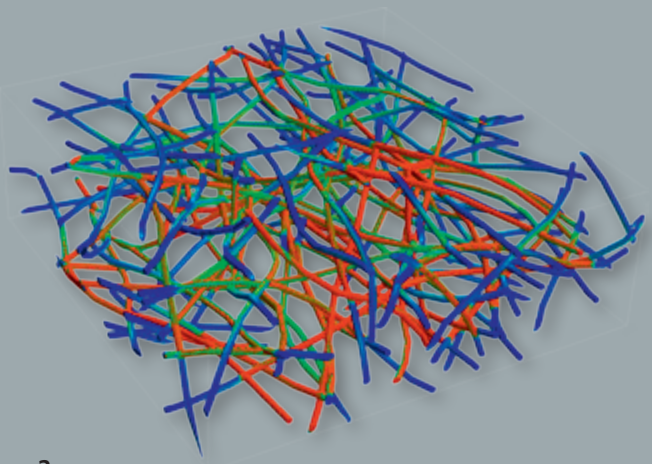


2

MICROMECHANICAL SIMULATION OF THE RESILIENCE OF NONWOVENS

Nonwovens are an important component of different products of several uses, e. g. transport of humidity in sanitary products, insulation materials or filters. Nonwovens are usually produced on large engineering facilities. For this, experimental studies of design with regard to the optimization of these nonwoven-structures prove to be very difficult. There are so many parameters of design, as for example fiber properties, surface weight or type of nonwoven bonding and finishing that are affecting the properties of nonwovens. For the change of one single parameter, e. g. the material of fiber, it is necessary to adapt the whole process of fabrication from the spinning of the fibers via their stacking to the nonwoven hardening. Following the production of such a prototype a time consuming and cost-intensive characterization of the properties of nonwovens carried out experimentally has to be done. For this reason detailed studies considering several parameters of design are uneconomic.

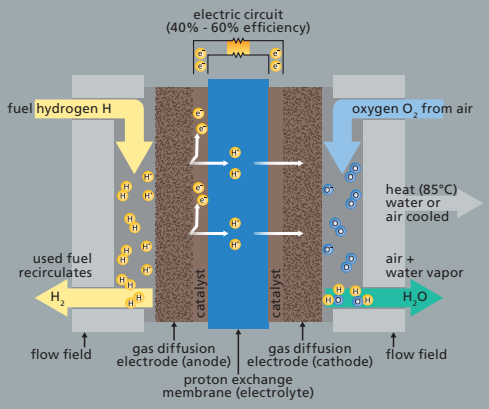
Thus, micromechanical models of simulation are developed at Fraunhofer ITWM in cooperation with Procter & Gamble Service GmbH (P&G). By means of these models it is possible to forecast numerically the effective properties of nonwovens for diverse parameters of design. To virtually modify and optimize individual parameters in this connection it is only necessary to adapt the corresponding inputs of the computer model.

In this case, the focus of the numerical predictions is primarily lying on the time-dependent behavior of the nonwovens. The dynamic properties can be determined by means of numerical simulation of cyclic measurements. In doing so, a good correspondence of simulation and measurements is obtained. Compared to experiments the required computational time for the simulation in case of low frequencies does not change. Therefore, we can obtain rapid forecasts for the long-term behavior (month till years) and the corresponding resilience of nonwovens using numerical models. A lot of material variants can be simulated and studied within a few hours. The fact that not only effective (macroscopic) properties of nonwovens can be computed, but also local physical values such as distribution of tensile stresses in binding agents and fibres is a further advantage of this micromechanical approach. So, the simulation contributes to a better understanding of the properties of nonwovens.

Future designs deal with an extension of the models with regard to simulation of the production processes. By this, a fully digitalized layout design of nonwovens from the manufacturing process till the optimization of functionality is possible.

1 *Microstructure model of a nonwoven with a typical anisotropic distribution of fiber directions, generated at the computer*

2 *Computed local stresses in the fibers (red: high stresses, blue: low stresses), of the compressed nonwoven; these stresses are essentially influencing the properties of nonwoven.*



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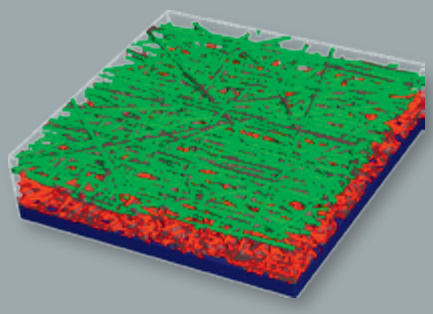

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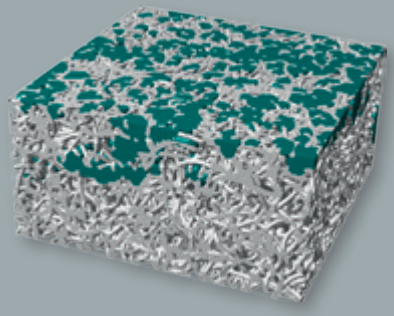


3

OPTIMIZATION OF THE GAS DIFFUSION LAYER TO BE USED WITH PEM-FUEL CELLS

1 *PEM fuel cells*

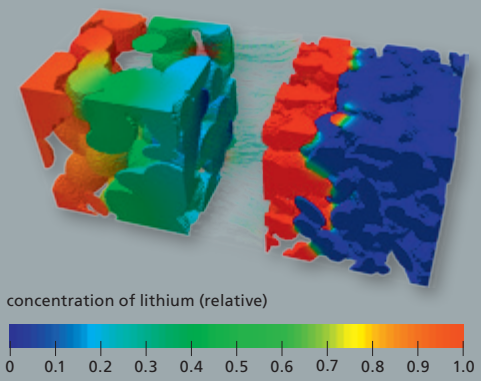
2 *Model of a gas diffusion layer and micro-porous layer*

3 *Porosimetry – simulation of water imbibition*

Hydrogen as an alternative energy source will play an important role in the future due to the decentralization of energy supply systems and declining oil reserves. The stored energy in hydrogen can be transformed into utilizable electric energy by fuel cells. Generally speaking, a fuel cell works as follows: molecular hydrogen, which is led to the anode, splits by disposal of two electrons into H^+-ions. While electrons are used by an external electric circuit in order to produce energy, H^+-protons diffuse to the cathode through an electrolytic membrane. At the cathode, the protons and the recirculating electrons react with oxygen from the air yielding water.

In order to guarantee optimal supply of oxygen to the cathode and removal of emerging water, a so called gas diffusion layer is installed between the cathode and the air supply channel. Usually, this layer is a nonwoven made of carbon fibers and a micro-porous layer made of carbon black. To enable water removal, the layer is made hydrophobic. Within the research cooperation 'OPTIGAA 2' supported by the BMBF, the Fraunhofer ITWM works on modelling of gas diffusion layers using the software GeoDict and computing material properties like flow resistance and effective diffusion. Change of material properties subject to varying water saturations of the diffusion layer are of special interest. Saturation dependent material parameters can be identified in an easy and efficient way by the pore morphology method.

The goal of the research cooperation is to establish the computer-aided design of fuel cells. Therefore, methods are developed in cooperation with research partners, which allow a scale transition between microstructure, fuel cell and fuel cell stacks. Consequently, material parameters of different gas diffusion layers, which are calculated at the ITWM, can be used in CFD-simulations of the fuel cell. Hence, it is possible to study the influence of different component designs on the whole cell stack.



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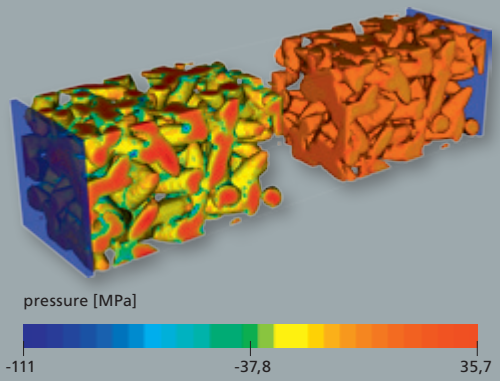


2

ELECTROCHEMICAL SIMULATION OF LITHIUM ION BATTERIES: VOLUME-CHANGING AND PHASE-SEPARATING ELECTRODE MATERIALS

The strong increase of electromobility demands the continued development and improvement of the key component of an electric car: the lithium ion battery as electrochemical energy storage system. To improve its life-time and reliability is a key issue which requires a profound understanding of the limiting degradation mechanisms. One major degradation effect is due to volume change by certain anode materials during intercalation of lithium ions: Silicon, for instance, which is a promising new anode material due to its high gravimetric energy density, changes its volume by 300 percent. The resulting mechanical stresses can lead to cracks within electrode material and eventually to a capacity loss.

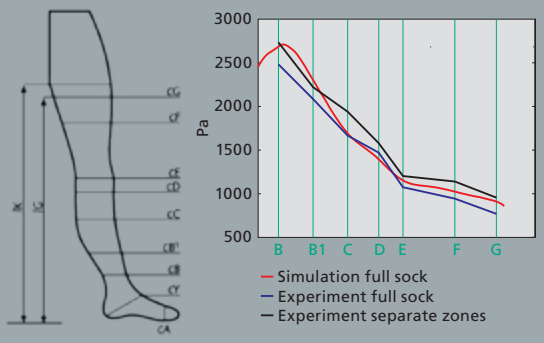
It was the main goal of the AiF project ALIB (Expansion of lithium ion battery cells) to be able to asses these effects reliably. The electrochemical simulation models that are available in our software BEST (Battery and Electrochemistry Simulation Tool) were extended to capture the effects of volume change. It is the main purpose of BEST to compute ion and charge transport within a battery in order to make predictive statements on the battery behavior. The simulations can be performed within the 3d electrode microstructure as obtained, for instance, from imaging techniques. In a collaboration with colleagues from Helmholtz-Institute Ulm the models have been extended such that it is possible to describe the lithium-concentration-dependent change in volume as well as the build-up of mechanical stresses. Additionally the influence of the inhomogeneous stress distribution on ion transport and intercalation reaction is considered. The electrochemical-mechanical system is solved numerically by coupling the battery solver BEST to our structural mechanics solver FeelMath, which solves the mechanical equations using a highly efficient Fourier method.

Besides that, certain electrode materials display a phase-separation behavior into a lithium-rich and a lithium-poor phase for certain states-of-charge. It is believed that this enhances the effect of mechanical degradation. By adding a phase-field model we could simulate electrochemistry, mechanics and phase-separation including electrolyte and electrode microstructure in a fully coupled way. Hence it is possible to predict the mechanics-affected battery performance as well as to estimate the risk for mechanical degradation.

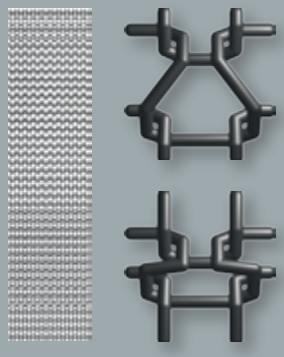
1 *Simulated concentration distribution within the electrode material. While ions in the left electrode move by pure diffusion, they show a phase-separation behavior in the right electrode into clearly separated lithium-rich (red) and lithium-poor (blue) phases.*

2 *Simulated distribution of pressure within the electrode matrix due to inhomogenous lithium ion distribution.*

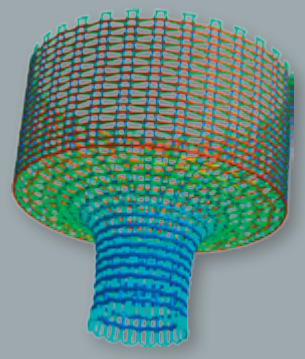
BEST



input (leg size (lenght, circumference), pressure profile)



design optimization of the knitted textile



back transformation in the machine control parameters

1

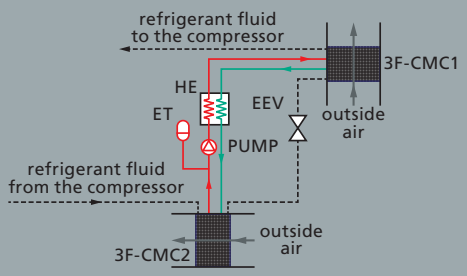
MODELLING, SIMULATION AND OPTIMIZATION OF KNITTED COMPRESSIBLE STOCKINGS

1 *Optimization of the knitting machine parameters for patient specific compressible stockings*

The company BSN medical is manufacturing different products from diverse knitted fabrics, among others tubular knitted compression stockings. The fact that despite of the same basic design diverse models can be developed from the same material is the particular characteristic of these compression stockings. An important characteristic of design of all compression stockings is that in addition to the yarn of the construction another yarn is added; only through the interaction of both yarns the final properties come into being.

The aim of BSN Medical is to standardize and automatize the process of development that is strongly controlled by experience today. It should be possible for example that a specific compression stocking made from a newly-created material is designed virtually so that for the novel product the original characteristics of compression can be kept. Furthermore, machine parameters can be determined, to modify the compression at defined positions in case of unchanged material. Finally the possibility to design patient-specific stockings at the computer should be created. For this aim, ITWM developed special algorithms and implemented them into the own calculation tool TexMath. The numerical methods are based on the finite-element-method with non-linear truss-elements that is extended to frictional contact between yarns in this tool. The friction force is modelled by means of the Euler-Eytelwein law and the non linear problems are solved by two separate Newton procedures, for the elastic deformation and the sliding under friction force. By means of this computation programme the procedure of virtual knitting of a compression stocking is simulated and presented visually using different threads and parameters of the machine during the production. The virtual stockings resulting hereof are extended again in another simulation in order to get force-strain curves for a knitted sample. The simulated force-strain curve coincides well with the measured one. Furthermore the stocking, knitted virtually, is put on a virtual leg. This is done by means of seven measurements at seven zones of the leg along the leg's axis. Usually, on each line between every two zones, a value of the pressure on the leg is prescribed in the norms. So, for each given leg with known diameter at each of seven zones, the stocking can be verified in advance by means of the created pressure profile onto the leg.

The aim of this project is to reach a prescribed pressure profile for a deformed knitted fabric. At this, in case of indicated yarn characteristics, optimal machine parameters are searched for each zone in order to minimize the deviation of tension of the stocking with regard to the targeted pressure profile. It is a two-step procedure. In the first step, the virtual stocking is knitted and virtually put on the given leg. In the next step, the mesh size is optimized for each row in a gradient procedure, to minimize the deviation of the computed pressure profile to the wished one. The end result is a parameter set for an optimal stocking pattern.



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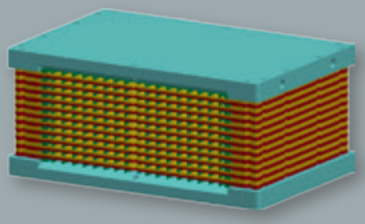

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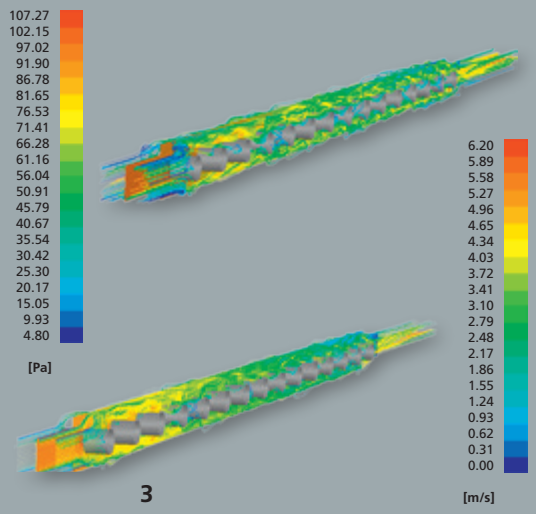


3

XERIC: INNOVATIVE CLIMATE-CONTROL SYSTEM FOR ELECTRIC VEHICLES

The project XERIC is funded within the Horizon 2020 EU program and aimed at developing a new climate-control system able to increase Battery Electric Vehicles (BEV) autonomy thanks to its better energy efficiency in comparison with traditional air conditioning systems. The climate-control system should be able to grant passengers' comfort in all weather conditions. The core of the system are innovative 3-Fluid-Combined Membrane Contactors (3F-CMCs) which simultaneously are crossed by air (to be sent to passengers vane), an aqueous desiccant solution (to dehumidify air) and a refrigerant (to control the desiccant temperature and partly to cool the air). Sensible and latent heat transfers between the air and the desiccant take place through a hydrophobic membrane which is permeable only to the vapour phase of water, while the refrigerant undergoes phase changes. The project partners work in close collaboration to achieve considerable power savings up to 35–40 %.

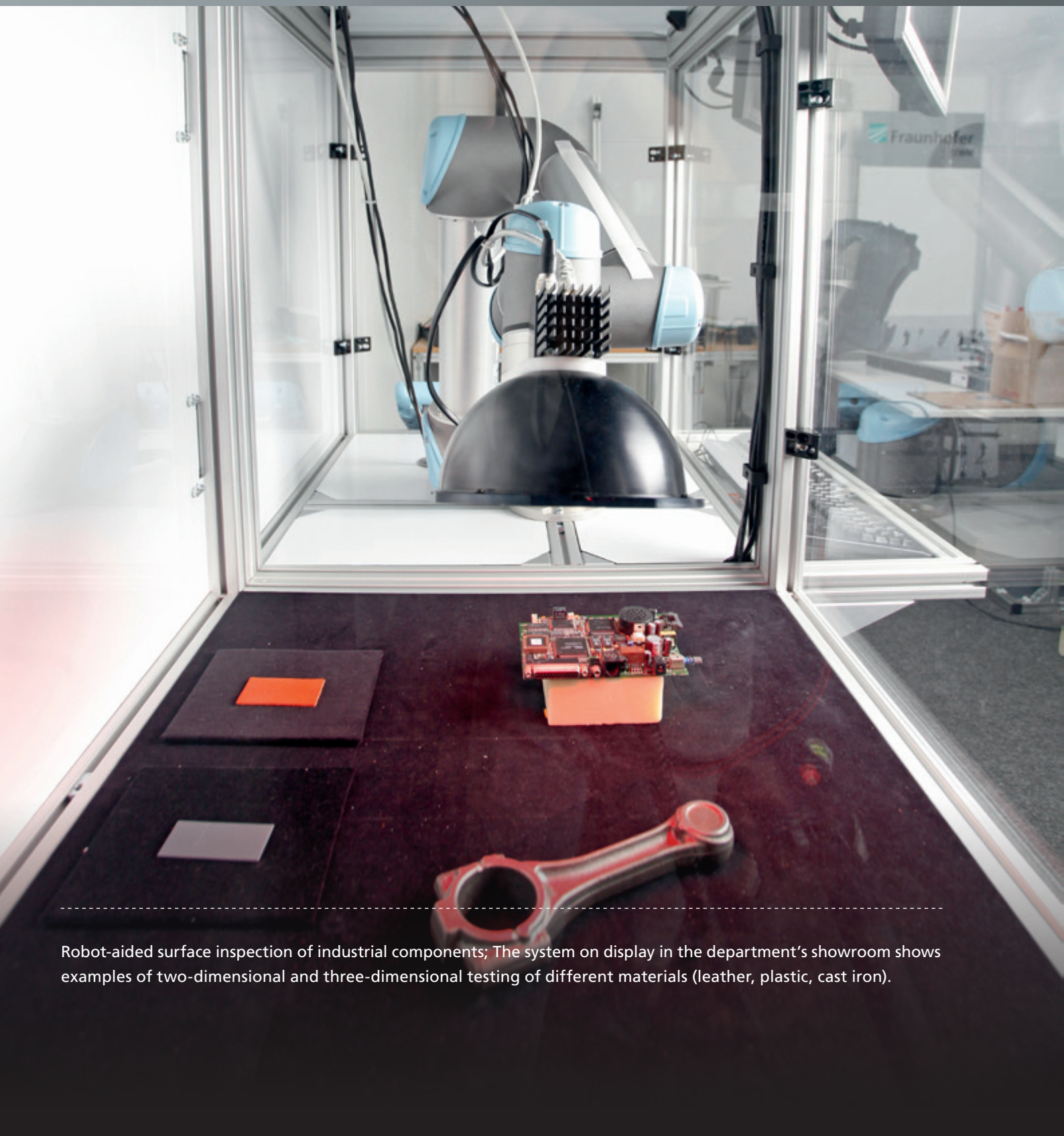
Within the project mathematical modeling and computer simulations tasks are assigned to Fraunhofer ITWM. The simulation results are used at different stages of the developments, aiming at optimizing the design and the performance of the 3F-CMC which consists of a stack of thin frames. High mechanical pressures occur due to the usage of the desiccant. High temperature gradients appear during the operation. Therefore, the first task of ITWM was to support proper sizing of the frames so that they mechanically sustain the pressures and the mechanical loads due to temperature gradients. Various studies on the mechanical stability were carried out in connection with this. Furthermore, the membranes separating air and desiccant are very thin and special spacers are used to support them in order to avoid deflection. These spacers, however, induce pressure losses in the air channel which need to be optimized also with respect to air resistance. Furthermore, simulations of heat and mass transfer processes are carried out to better understand the vapor concentration dynamics. The final task assigned to ITWM is the modeling of the frost formation. The new air conditioning system should work at a wide range of temperatures and humidity. Therefore, undesirable effects like frost formation should be studied in advance, and care should be taken to prevent them.

1 *Architecture of the air conditioning system with two 3F-CMCs*

2 *CAD design of the 3F-CMC prototype*

3 *Air pressure (top) and velocity distributions (bottom) for spacer geometry*

IMAGE PROCESSING



Robot-aided surface inspection of industrial components; The system on display in the department's showroom shows examples of two-dimensional and three-dimensional testing of different materials (leather, plastic, cast iron).

MARKUS RAUHUT
HEAD OF DEPARTMENT

Image processing has become an important element of industrial production. Inspection systems have been part of production line planning in recent years, as opposed to the after-the-fact retrofitting of the past. One of the most important quality assurance measures today, is the surface inspection or the evaluation of the optical appearance of a product. The faults may be either functional or aesthetic, but an aesthetic "fault," being a subjective feeling, is especially difficult to represent as a mathematical model. One specific aim of the department is the development of mathematical models and algorithms for image analysis, primarily for industry software and use in production environments. The application range includes challenging surface inspection and the analysis of micro-structures. The micro and nano structures of modern materials are substantially determined by their macroscopic material characteristics. Analyzing the spatial geometry and relationships of the structural features of a material allows the optimization of the material characteristics by means of virtual material design. The department also develops algorithms for the characterization and stochastic modeling of such materials.

The overall goal of the Image Processing Department is to develop, in close cooperation with partners in industry and research, custom solutions in the field of image and signal processing.

MAIN TOPICS

- Quality Assurance and Optimization
- Surface and Material Characterization
- Image Understanding and Scene Analysis

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1

CEILING PANEL INSPECTION – MODEL-BASED LEARNING FOR SURFACE CONTROL

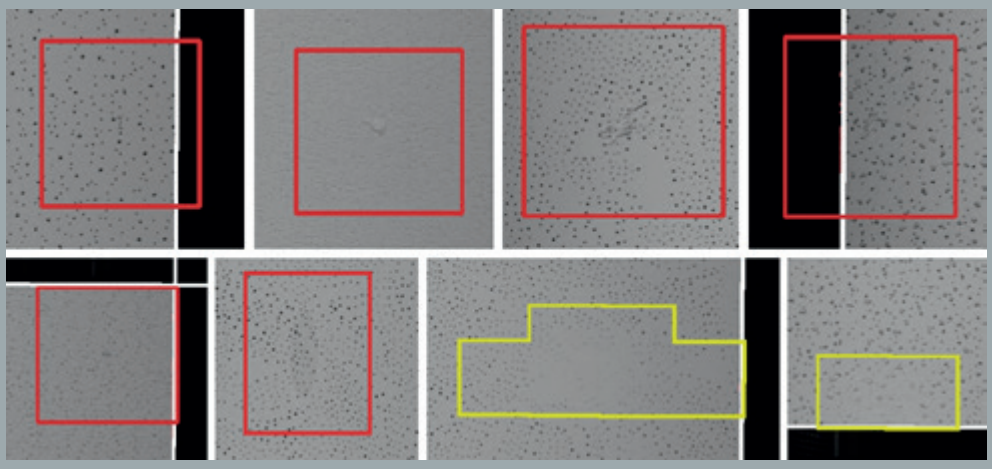
1 *Inspection system "MASC Stex 2"*

Industrial image processing is used for quality control in many production environments. First, every effort must be made to create optimal image acquisition conditions. The images are mathematically transformed by means of image processing algorithms in various ways to find the potential defect regions and, subsequently, to classify the product. Generally, finding such regions consists of a combination of traditional image processing methods like smoothing, segmentation, edge detection, morphological operations etc. However, the recent advances in Machine Learning, especially, in the area of Deep Learning, have intensified the wish to automate this aspect of industrial image processing and reduce the elaborate adaptation effort – the manual parameterization of large algorithmic chains. As a illustration of how the Image Processing Department is driving this automation and what limitations are encountered, we will use the surface inspection of mineral fiber panels.

The aim of the surface inspection of mineral fiber panels is to find defects in various design pattern. Typically, for many manufactured products, it is not possible to use a fully automated machine learning method for fault detection because of the infrequent occurrences of defects and because manual marking is time intense and expensive. Consequently, our approach assumes that the rejection rate is very low in good production systems. It follows that the majority of the panels produced can be classified as "good." In contrast to learning and representing all classes of fault, we learn the "good" products. This is one-class classification or, so called PU learning (positive and unlabeled data). If a new design or pattern must be learned under this method, the largest possible sample of the current production design is taken and it is assumed that this is a representative average. Using a sample of 20 to 200 panels, the one-class classifier can be trained.

At this point, it is essential to introduce prior knowledge of meaningful features – in other words: modeling of characteristics. Because of very different features in the ceiling panel illustration, we select two features to manage algorithmically and apply a binary classification learning method.

The first feature is the needling with its typical form, structure, and composition. The needling of a ceiling panel is rich in contrast and is well suited for fast segmentation. This is why we do not select pixels or generic regions as the calculation basis, but rather the segmented pinpricks. Because the pinpricks are stamped (i. e., applied mechanically), they should be geometrically similar in the "good" cases and more conspicuous in the bad/defective cases. We then calculate the appropriate features to include area, roundness, axial ratios, and average gray tone.



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The second feature is the large-scale appearance of the panel, i. e., color application, the structural homogeneity, the existence or lack of pinpricks, the distribution, etc. In this case, local points or segmented regions are not used as the calculation basis, but the entire panel is divided into overlapping windows of a representative, but fixed size. The software calculates a feature histogram for each of these windows, which among other things, contains the gray value distribution and the ratio of pinpricks to background.

Using this training data, a one-class classifier for each of the feature classes is trained. For this purpose, a representation of the data is created by means of the so called k-Means-Cluster centers. Since different features are present in normal or good cases, an overrepresentation of the data is selected, that is, the specified number of cluster centers is intentionally too high. In the process, clusters with fewer representatives are deleted and a so called pruning takes place. While this method prevents so called over-fitting, it is noted that the random samples do not exclusively contain representatives of the normal or good parts, but they may also contain bad parts.

In the illustration, the actual classification is achieved by calculating the nearest-neighbor distance. Different distance functions are used because there are different feature types. The Euclidian distance is appropriate for geometric features of the needling, whereas for histogram distances the Mahalanobis distance is preferred. The focus of the inspection systems is set using threshold values for the described distances and can be adjusted during production. The surface and design faults that are detected in production with the method presented include discoloration, color blotches, and deviations in the pattern.

2 *Examples of surface and design faults in the production of ceiling panels*

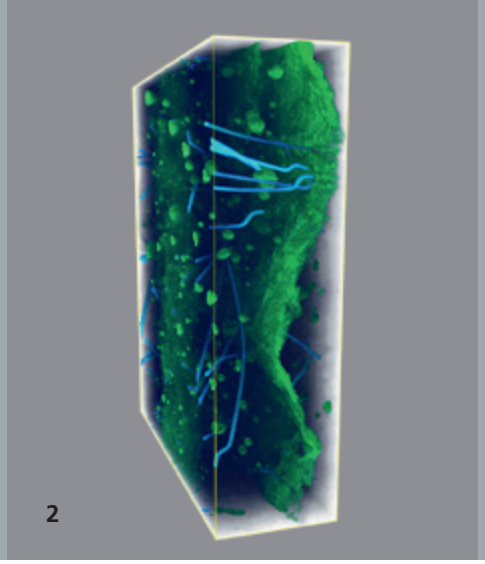


IMAGE ANALYSIS OF STEEL FIBERS IN CONCRETE

1 *The crack extracted from a conrete sample after testing (three-point bending test)*

2 *Volume rendering of a reconstructed tomography image*

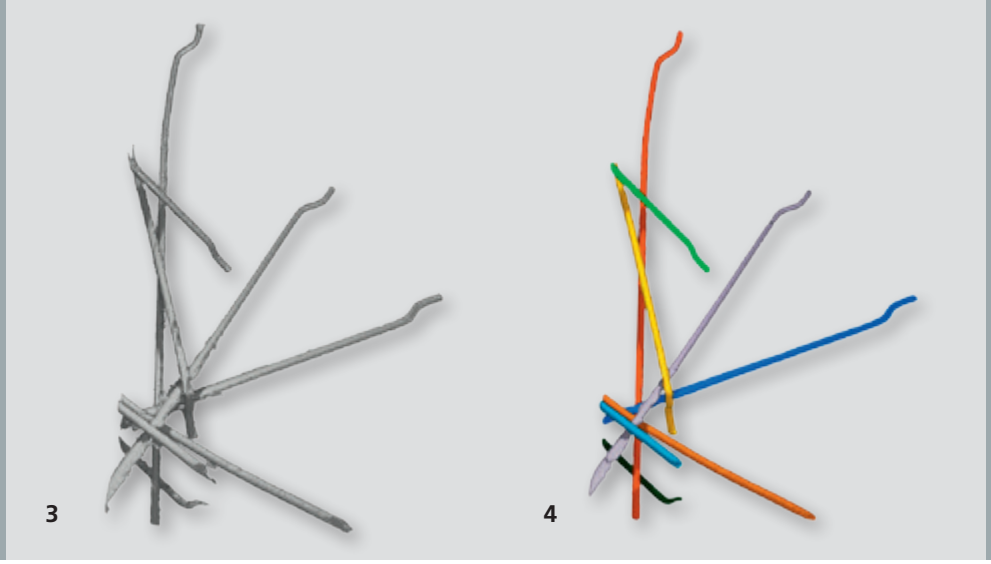
Steel fiber reinforced concrete is a composite material made of concrete and steel fibers, which are mixed in the liquid state. The features of the hardened material vary depending on the shape and dosing of the fibers. Some absorb forces better and some have a stabilizing effect on possible fractures in the event of cracking. Mathematicians from the Image Processing department are working in close cooperation with civil engineers at TU Kaiserslautern to better understand the effects of the admixture of steel fibers. Of major interest are how concrete behaves after a crack has formed and what role the addition of fibers plays. In simple terms, the fibers crack-crossing determine the post-cracking behavior of steel fiber reinforced concrete. Consequently, it is necessary to look at both the crack and the fibers for a proper analysis.

Previous methods for analyzing fiber orientation and quantity require the cracked area of the sample to be broken open or sawed, making an undisturbed analysis of the fibers impossible. However, analysis of the material using 3D imaging by computed tomography (CT scans) allows to inspect the cracked area. At the same time, this prevents biasing of results due to pulling out fibers when breaking the sample.

A special challenge in evaluating 3D images of steel fiber reinforced concrete is caused by the size of the analysis sample. The sample size is limited by the size restrictions of modern µCT technology and, in some cases, does not support a clear separation of fibers that are in contact with one another. Since individual fibers are required for the analysis, Fraunhofer ITWM has responded by developing an algorithm that separates aggregated fibers, so called fiber clusters, into individual objects. This allows the filtering of the crack-crossing fibers that are involved in the transmission of force, which in turn enables the subsequent determination of parameters such as fiber length, orientation, and bond length along the crack.

The algorithm for detecting and separating fiber clusters was developed with ToolIP (Tool for Image Processing), a software for creating image processing and analysis solutions. First, to locate all aggregations, the following method is performed: The distance between the two most distant points in every object is computed in the 3D image, whereby distances are measured only within the objects. The algorithm is based on a simplified model that assumes single fibers to have a cylindrical shape, whose length is the measured distance.

The model yields an estimated volume that is then compared to the measured volume of the object in the image. In the case of a fiber cluster, the volume is significantly larger than the one determined on the basis of the cylinder model. On the other hand, if the volumes are nearly



the same, the algorithm classifies the object as a single fiber. If the 3D image being inspected is very noisy, a manual analysis of the borderline cases is necessary.

The separation of the aggregated fibers is then accomplished as follows: First, the algorithm reduces the surface noise by highlighting the fibers. For this purpose a decision is made for each surface location as to whether it is shaped cylinder-like. If yes, it is amplified and if not, it is attenuated. Finally, the algorithm estimates the location of the axis of the fiber by looking for points that are furthest away from the fiber surface. Along the thus located axes, the algorithm joins fiber segments by assigning the remaining points to the closest axis. Due to noise, sometimes over-segmentation (fibers consisting of several pieces) can occur and some pieces may even be missing. To close any resulting gaps, the algorithm enlarges all pieces found within the fiber's surface area. Using an interactive tool, the user assigns the few remaining segments to different individual fibers.

The method described above supports the analysis of steel fiber reinforced concrete by automating parts of the evaluation of this material. The engineer is not required to have expert knowledge of image processing.

3 *Example of a fiber cluster: Multiple single fibers in contact in an arbitrary spatial alignment.*

4 *Example of a segmented fiber cluster: Single fibers are recognized as different objects enabling their individual evaluation.*

SYSTEM ANALYSIS, PROGNOSIS AND CONTROL

In the department's lab, plant and machine models are coupled with controls in a real-time capable hardware-in-the-loop simulation. Control algorithms can be implemented on the department's own control units or integrated with the original client system. A comprehensively equipped HIL platform enables the data capture and generation of many different signal types in addition to error simulations.

DR. ANDREAS WIRSEN
HEAD OF DEPARTMENT

The complexity of the dynamic behavior of many technical or biological systems is often the result of a combination of various sub-systems and structures, each equipped with specific sensors and actuator configurations. In many cases, it must be assumed that the information acquired from measurements of the system or structural behavior is distorted by interference from overlapping sensor data. Usually, this situation is additionally compounded by incomplete system and structural descriptions.

The System Analysis, Prognosis and Control department typically works on the issue of identifying dynamic system parameters as well as providing real-time capable simulation models. This is the foundation for development of the forecasting systems needed to monitor, control, or validate the behavior of electronic control devices with "hardware-in-the-loop" methods. The department draws on its core competencies in the field of systems and control theory – with special skills at model reduction for solving differential algebraic equations of switched systems. Sequential Monte-Carlo approaches (particle filter methods) are used for the simulation and state estimation of stochastic processes. Furthermore, the department uses machine learning methods such as deep learning, probabilistic graphic models, and clustering algorithms in high dimensional data spaces.

MAIN TOPICS

- Plant and machine controls
- Energy generation and distribution
- Biosignal processing
- Machine learning in medicine and technology
- Software tools for process and innovation management

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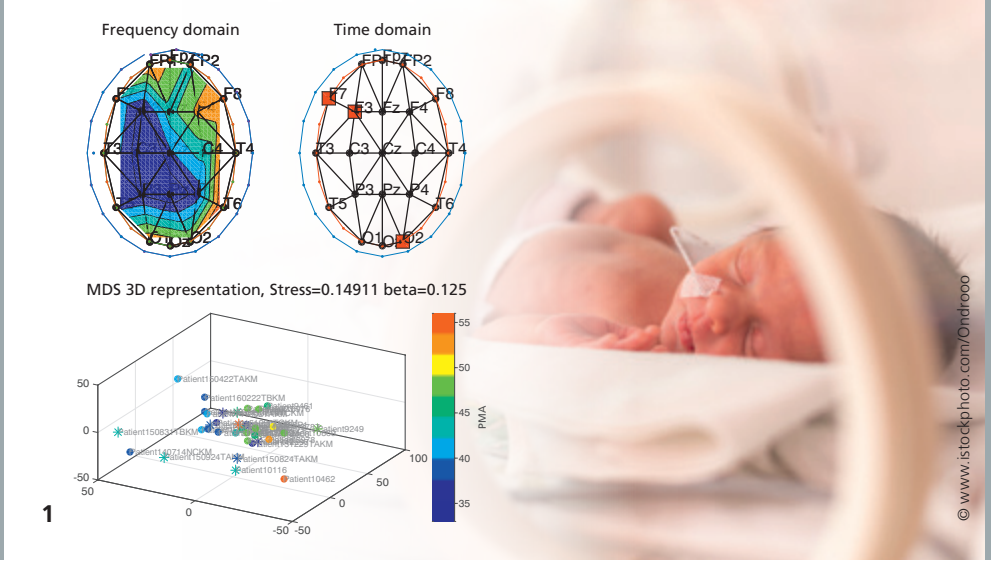

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DIAGNOSTIC SUPPORT SYSTEMS FOR THE BRAIN MATURATION PROCESS IN PREMATURE INFANTS

1 *EEG analysis tool: Analyses in frequency and time range (top)*

Positioning of the premature baby with regard to the similarity to the findings and the age of the patient from the database of the hospital information system (bottom)

The aim of neonatal intensive therapy is to support the functioning of the immature organs of extremely premature infants in a way that the development may proceed as if taking place in the mother's womb. The regular development of the brain, especially of the cerebral cortex, is of primary importance. Possible threats to the development process can arise if the oxygen supply of the brain is compromised. Monitoring systems are available, that can detect any restriction in the oxygen supply throughout the entire organism. However, the relevance of a single event for the cortical oxygen supply is, in many cases, vague. During the cortical maturation process neurons are connecting with each other. This process can be disturbed by harmful incidents like oxygen deficiency on the one hand. On the other hand, it is conceivable that the normal cortical development can be effected solely by non-physiological conditions outside of the mother's womb. The cortical maturation process can be studied using the electric discharges of the cortical nerve cells, which are recorded via an EEG.

The System Analysis, Prognosis and Control department is developing an analytical software tool as an integral component of a multifunctional monitoring system for premature infants brains in the sub-project "Diagnostic support system for the maturation process of the brain in premature infants," as part of the Federal Ministry of Education and Research´s Tenecor project. In the final version, this system should be able to help doctors facilitate evaluations of the health status and the maturation process of infantile brains. This is achieved by means of machine learning algorithms through the synergetic examination of five signal sources (NADH, fb-EEG, aEEG, DCEEG, Impedance).

Currently, the diagnostic software disassembles the 12 channels of the neonatal EEGs into time dependent frequency bands; the energies are determined for the separate channels in defined frequency bands, and sorted into an ordinal scale. Next, the paired dependencies between energies in the different channels and frequency bands are determined using mutual information. These are then used to generate a probabilistic network for each patient. The resulting distances between the networks are embedded in a three-dimensional Euclidean space and the formed point clouds are clustered. First tests with EEG's of premature infants have shown that the cluster centers are correlated with pathologies, i. e. preterm infants with similar pathologies are close to each other in Euclidean space. Furthermore, correlations between the distances and the postmenstrual age of the premature infants without serious pathologies were also detected.

1

CONTROL CONCEPTS FOR THE ENERGY GRIDS OF TOMORROW

1 *Sub-station with wiring and transformers*

The current focus of the energy revolution is mainly on power generation, transportation networks and electric mobility. However, in terms of creating a CO_2-neutral energy supply, perspectives must be broadened because the energy cycle includes generation, conversion, transport, storage, and consumption in electricity, gas, and thermal grids. Regardless of the energy medium, information technology and mathematics encounter a number of basic recurring problems in the modeling, simulation, and control of hierarchical energy grids with stochastic production and consumption. In the project MathEnergy, funded by the Federal Economics Ministry, the solutions to these problems are to be found in the development of new mathematical methods, collected in a software library, and demonstrated in the fields of gas and electricity and even in a coupling of the two. The project is divided in the following segments: overall grid modeling, model order reduction, scenario analysis, state estimation and control, overall system integration, and demonstrators.

In particular, the System Analysis, Prognosis and Control department is working on model-based monitoring and control methods for the synchronous planning and operation of the electricity transport and distribution grid.

The estimation of the current system states of the underlying mathematical model based on the measured data is the starting point for model-based, optimal control of the supply and consumption of electricity or gas. Taking into account the observability of the model and an error analysis of the predicted input to the power grid from alternative energy sources, methods will be developed for the optimal positioning of additional sensors required for the dynamic state estimation. The technical (sampling rates, signal propagation times, errors, etc.) and economic limiting conditions must also be considered. Extended Kalman filters and particle filter methods developed in the department are used for dynamic state estimation. The latter approach can be used for state estimation of systems with stochastic behavior, with physical limitations, and at the same time, non-equidistant sampled measurements. The real-time tools developed for estimating the state and the scenario analysis methods are then used in a control approach for multi-grid coordination by means of model predictive control (MPC). Hierarchical or distributed MPC methods with reduced dynamic models are required to enable the data exchange among the different controller.

OPTIMIZATION

Production plant for colored gemstones in the Optimization department: Colored gemstones are produced in a highly individual process, which considers aesthetic principles while working with absolute precisions of 10 – 15 micrometers even at maximal production volume. The design is modular and scalable.

PROF. DR. KARL-HEINZ KÜFER
HEAD OF DEPARTMENT

Working in close cooperation with partners in research and industry, the department's main focus is to develop custom solutions for planning and decision making problems encountered in the logistic, engineering, and life science sectors. The work is characterized by a methodical approach to 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 optimization of the quality and cost. The division's core competencies include the development and implementation of application and customer-specific optimization methods to calculate the best possible process and product designs. In the development and implementation of interactive decision support tools, we give special consideration to multiple criteria approaches and to the integration of simulation and optimization algorithms. In general, optimization is viewed not so much as a mathematical problem to be solved, but rather as a continuous process supported by the department's development of suitable tools. Our cooperation with customers in various industrial sectors ranges from consulting projects to the restructuring of decision making processes, but may also include the development of custom software for the optimization of complex processes and the creation of unique features.

MAIN TOPICS

- Medical therapy planning
- Arrangement and cutting problems
- Production planning and resource efficiency
- Process engineering
- Model learning and smart data
- Supply Chain Networks

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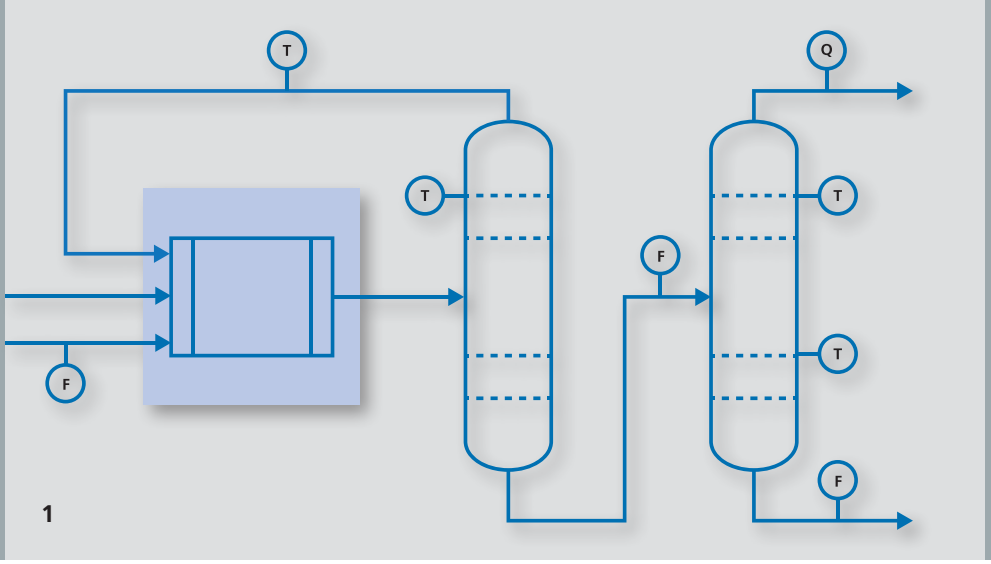

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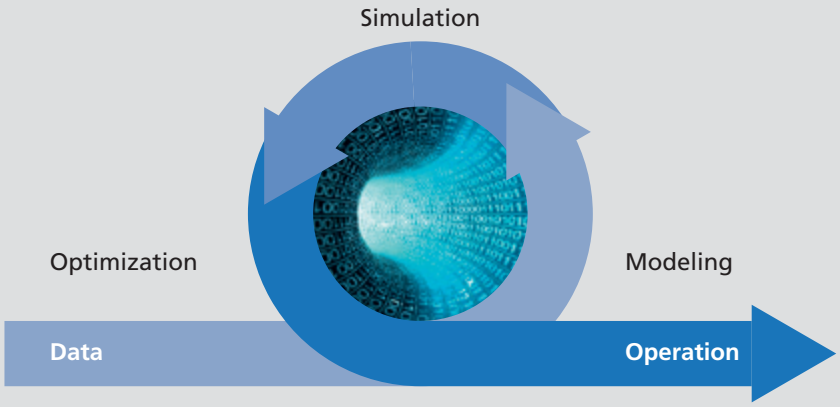
GREY BOX MODEL FOR COMPLETE PROCESS OPTIMIZATION

1 *Schematic shows a flowsheet with a reaction unit for material transformation and two distillation columns for purification; the circles symbolize measuring points (T: Temperature reading, F: Flow measurement, Q: Measured cooling capacity)*

The virtualization of chemical manufacturing plants in a model and the subsequent, model-based optimization are key steps towards innovation, as well as for efficiency and quality improvements. The success of this approach crucially depends on the reliability of the models. ITWM and BASF SE are developing, in a bilateral cooperation project, hybrid modeling methods that integrate physical-chemical know-how ("white") with data-driven approaches ("black"). The methods are used at the BASF flowsheet simulator so as to be available for the everyday work of the process engineers.

A typical chemical production process includes a chemical reactor for material transformations, with the educt from the reaction being fed into a purification process, for example, distillation. To model this process in a flowsheet simulator, not only is knowledge of the chemical reactions required, but also the thermodynamics to describe the distillation must be known. The situation where knowledge of the stoichiometries and reaction constants is incomplete is quite typical in industrial practice, whereas the distillation processes are well known. Besides this physical White Box knowledge, historical process data is available for a variety of measured operating points. The goal of the project is to generate information from the process data that can be used to close the gaps of the physical models. To this end, the first step is to replace the reactor with a simplified short-cut model, which contains – together with the purification model – all existing physical equations. The reconciliation performed using the model enable predictions that are as close as possible to the observed measurements for the real plant. A reconciliation consists of the minimization of a sum of squares, where the squared difference between model predictions and observed measurement points is as low as possible. Each term is weighted with the inverse variance of the measurement point. Since the variances are often vague and the adjustments to the various measurement variables are conflicting, this step includes not just one, but a set of reconciliation problems with optional user interaction. The result of this step is reliable soft sensor data about the inputs and outputs of the reactor. The second step consists of the identification of a model for the insufficiently modeled apparatus – in this case, the reactor – on the basis of the soft sensor data. Various methods are available, for example, regression methods with predefined functions, but also artificial neural networks with back propagation training. Quantitative statements about the confidence intervals and prediction errors are possible using statistical methods. In addition, the parameters for which only unreliable estimates exist can be separated from those that are identifiable with high accuracy. In a third step, the data-driven model from step 2 is inserted in the flowsheet to generate a complete model of the process. This is by no means a trivial step for several reasons: Besides ensuring the solvability of the whole system, the extrapolability for a complete process



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optimization must also be assured. This is carried out using optimization processes that not only account for the multi-criteria nature of the problem, but are also able to deal with uncertainties. These methods include robust and stochastic optimization.

The generally continuous uncertainty of the model parameters is described by a discrete selection of scenarios. The selection of the scenarios ensures the greatest possible representation of the uncertainties; strategies for statistical experimental design are available as are randomized approaches. The impact of these scenarios on the target function is calculated and quantified by means of sensitivity measures. The aim of robust optimization is the best possible design of the worst possible scenario. This optimization strategy is performed on a multi-criteria basis, taking into account the many competing objectives. Furthermore, the above mentioned sensitivity measures can be defined as target functions – in addition to those already provided – and minimized (for minimized sensitivity to uncertainties) or maximized (for maximized sensitivity, for example, when experimental design is important). In this way, it is possible to study the cost of a more or less sensitive process design relative to other business targets. Practical experience shows, in many cases, a relatively small adjustment to the process design is sufficient to achieve a significant improvement in robustness. If the uncertainty in the model's predictions is still too great after preparing the Grey Box model, a model-based, multi-criteria experimental design is developed where the data generated from the experiment is maximized while meeting other business targets to the fullest extent possible. An important next step is the fine tuning of the data-based methods to facilitate the integration of limiting conditions such as balance equations. This effects, for example, the topology of the artificial neural network being used. It is also interesting to see to what extent the White Box environment can ensure the reduction of confidence intervals that result from the data-driven model identification. This is especially important for process optimization under uncertain model parameters.

2 *Learning from data: Typical workflow with modeling, simulation, optimization, including data for near reality models*

1

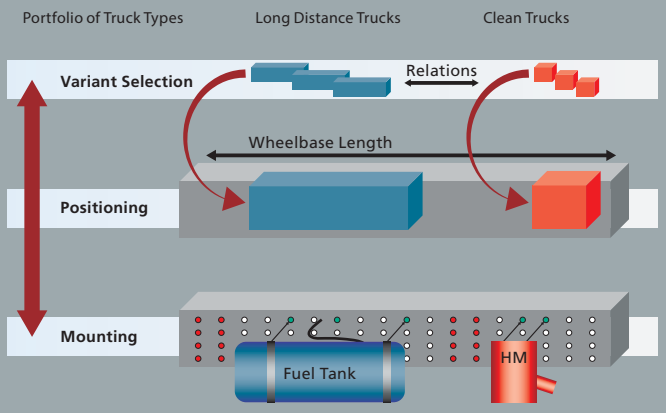
INTERACTIVE SURGICAL OP PLANNING ASSISTANCE

1 *Optimal schedules with subsequent corrections possible*

Modern operating rooms are a key factor, perhaps the dominant factor, in the cost calculation of a surgical intervention because of the increasingly expensive technical equipment. To economically operate a hospital with its own OR equipment, the goal is to maximize the utilization of the OR. From this perspective, a plan should be filled in with scheduled OPs in such a way that they span the whole day without any break inbetween.

On the other hand, OP planners face conditions and dependencies that make planning significantly more complicated. Surgeries may require special equipment that may not be available in every OR or is available only in limited quantities. Surgeons, nurses, and the patients themselves are limited by other appointments, vacations, or shift schedules, medical considerations may restrict the time of day, and after each surgery there has to be a free bed for the patient. One special challenge is the variation in the duration of surgeries: Even when an appendix operation is normally completed in 10 minutes, it can take much longer in case of unexpected complications. When planning on the basis of simple average values, substantial waiting times may occur, in the worst case operations may even be postponed to the next day.

As part of a European Fund for Regional Development project, the Optimization department is developing a software component for interactive assistance in operation scheduleplanning in cooperation with the software company Imilia from Berlin, which offers in its portfolio the software "Timerbee," a planning and schedulingsoftware for the healthcare sector. The "OP Planner" toolcalculates smart planning suggestions for long term planning and the allocation of individual patient appointments, as well as a detailed schedule for the next day that takes into account all of the dependencies mentioned above, in addition to addressing the risk of delay by means of optimized sequences and a clever distribution of high risk surgeries to different operating rooms. An appointment request made in the OP Planner software is sent directly to the planning component developed at ITWM, which creates a mathematical model of the planning problem using the master data supplied by Timerbee. By Constraint Programming the solution space is explored and a manageable number of optimized and structurally different suggestions are presented to the user for selection and further interactive adjustment. Fast data connections and efficient implementation of the constraint search ensure user friendly behavior without any significant delays in the software.



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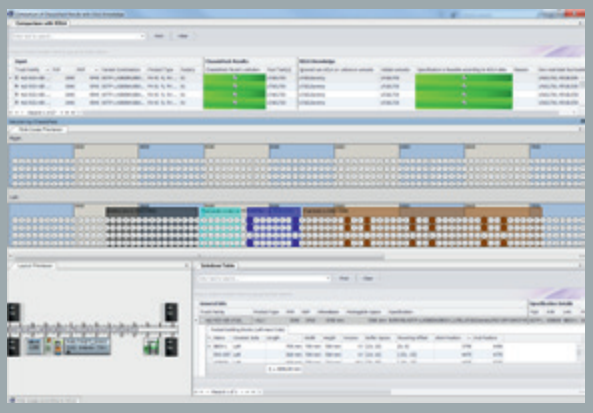

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VOLVO GTT CHASSISPACK: COMPLEXITY REDUCTION IN TRUCK CHASSIS PACKAGING

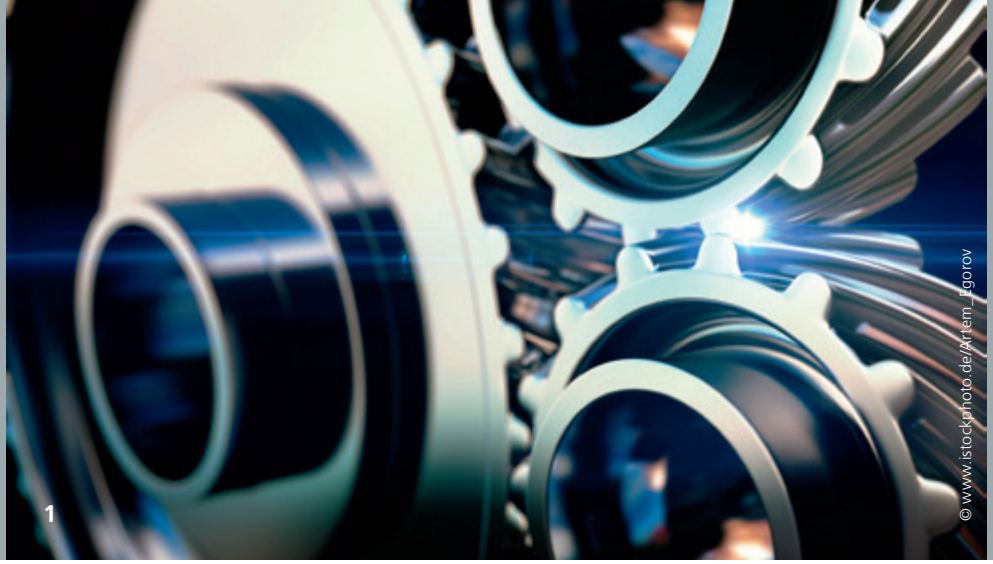
Volvo Group Trucks Technology (GTT) offer their customers tailor-made trucks specified by a combination of numerous truck design features (called variants) from which the customer can choose. All possible product configurations can potentially be manufactured, unless there is a documented reason explicitly forbidding it. On the one hand, this enables Volvo to offer trucks for varying customer needs; on the other hand, it results in a very large amount of potential truck configurations that has to be maintained.

Many combinations of variants that are not allowed together are documented explicitly with so-called restrictions in an engineering knowledge database. However, much of the knowledge required by engineers is documented only implicitly in the database, particularly since the set of explicit restrictions leads to new hidden rules. This makes it difficult to solve numerous truck design problems occurring frequently in practice. Whenever there is a change in the product, for example when a new technology has to be included, the engineers are responsible for ensuring that the change is valid for all of the implicitly defined truck configurations. To find engineering solutions to all possible, highly varying truck specifications at the same time makes this a complicated and tedious task. In the long-lasting cooperation between Volvo GTT and the department Optimization, a lot of case studies have been done yielding a suite of algorithms and Software tools for facilitating the work of the engineers. Currently, the algorithms are being developed as services that will be integrated into numerous tools used by engineers routinely.

For example, the latest service is designed for automatically inferring knowledge from Volvo's database that is hard to gain without the help of advanced algorithms. Hidden rules make it hard to find appropriate solutions if engineers can only rely on their experience. This algorithm is successfully used in the ChassisPack Hole Explorer that helps engineers to understand, which mounting holes on the chassis are used by which items. In one case study the tool made it easier to find vacant holes for an additional ground stud that was needed in a certain area of the chassis for new electrical function. A large portion of the total complexity of the truck development is related to the chassis. Therefore, several case studies resulted in a tool called ChassisPack Analyzer focusing on the chassis. This tool helps to conduct what-if-studies, for example for finding a reduced variant selection that approximates the "ideal" Pareto set of truck layouts. The chassis packaging is modeled as a 1.5D packing problem that uses a constraint programming solver for generating non-overlapping positions for truck items and maximizes fuel volume by choosing the largest feasible fuel tank variant.

1 *Parameterization of the truck chassis on different levels*

2 *Analyzing truck layouts with ChassisPack Analyzer*



1 *Gearbox components: The heat generated at the surfaces from friction, in combination with a strong temperature dependent properties of thin, tribologically active films on these surfaces leads to a complex interaction of load spectra and material properties, which can hardly be analyzed using conventional experimental methods.*

TRIDEFF: SIMULATION OF TRIBOLOGIC PROPERTIES OF COMPOSITE MATERIALS

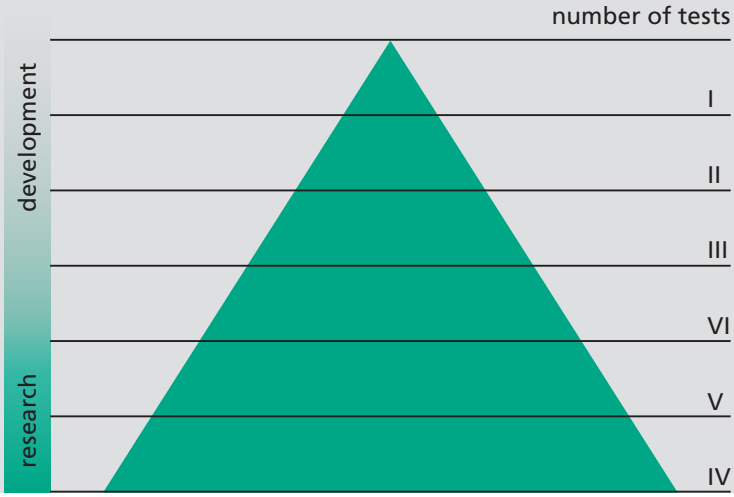
The energy transition and the constant price increases for raw materials create challenges for sustainable R&D focusing more and more on energy and raw material efficiency . This is especially true for components that are subject to friction and wear. For example, a typical vehicle experiences an energy loss of up to 35 percent because of friction. The branch of science that studies such systems is called Tribology.

Tribologic properties are generally system properties as load spectra and thermal balances of components are of critical importance. Generally, a large number of parameters can affect the behavior of tribologic systems. In material and component development, this makes it all the more challenging to draw conclusions about the actual behavior of the real tribological system based on tribological lab tests using standard component geometries.

The current practice, based on simple test setups like “pin-on-disc” or “block-on-ring,” is to choose a material or preselected materials and, in the further course of development, refine the test setup in six categories, becoming ever more practice-focused down to field testing. At the same time, the selection of materials is further restricted and the number of required experiments is reduced, category by category.

TriDeff is a DFG sponsored project being carried out in cooperation with the Chair of Composite Engineering at TU Kaiserslautern. ITWM develops new optimization methods for a faster, targeted selection of friction reducing composite materials. The material class being studied is based on a polymer matrix material (PEEK), applied as a thin coating to the component surface. Dispersed throughout such matrix materials are fibers (for example, carbon or fiberglass), as well as micro- and nano particles. Since these inclusions are very small, the overall external surface of the material has homogeneous properties, which are strongly dependent on the distribution and orientation of the film and, correspondingly, the coating process. This is the reason why a model of the properties of the new composite must first be prepared so they can be characterized more quickly and their behavior under tribological stress can be predicted from their composition. The main focus is initially on mechanical strength (durability), thermal properties (conductivity and expansion) and other tribological characteristics.

In many cases, a targeted optimization of material properties is possible for specific application scenarios because of the high degree of flexibility in the composition and properties of the composite materials. However, in spite of this great flexibility, this optimization potential can hardly be explored by purely experimental methods. This is all the more true when the starting

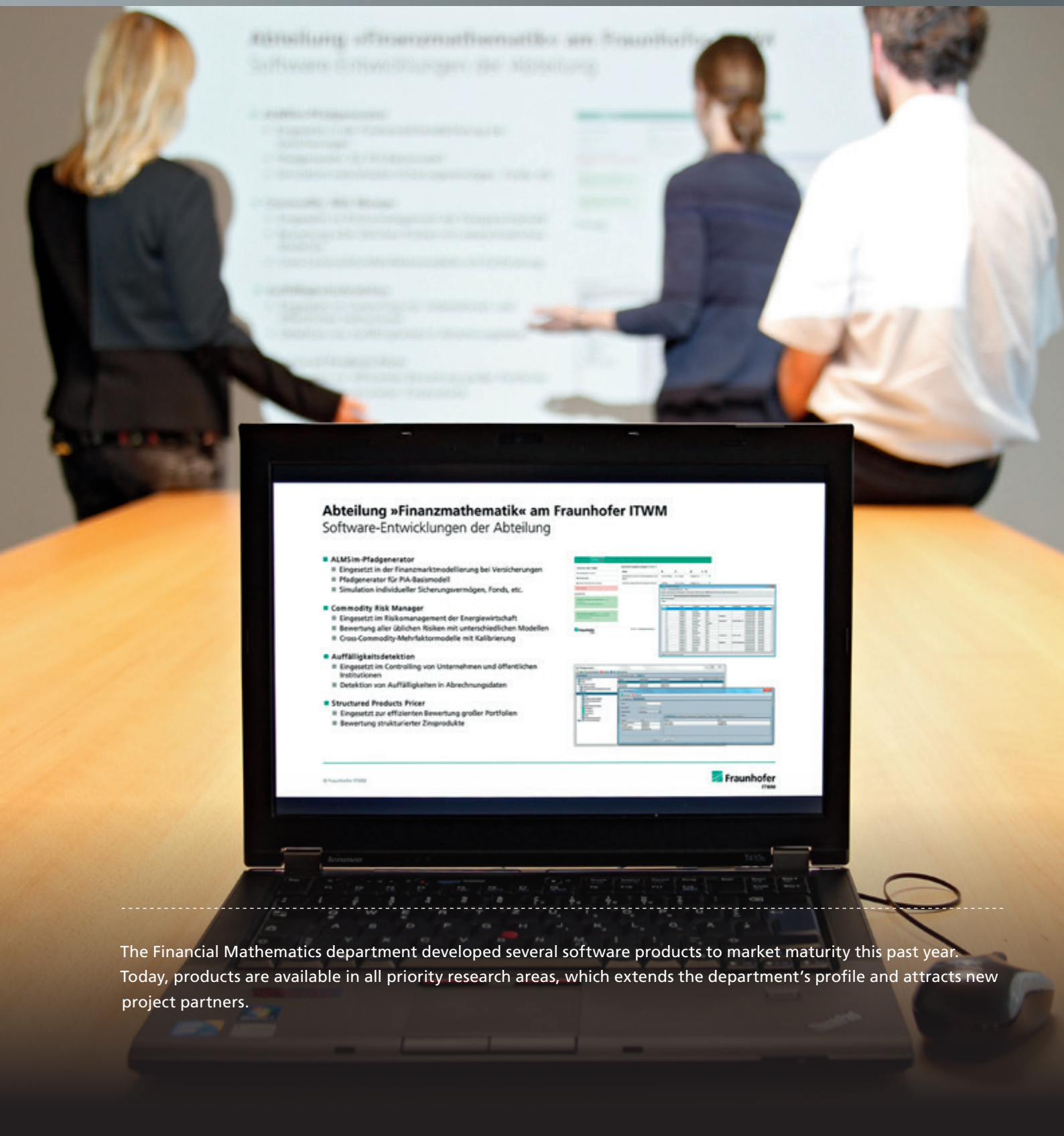


material itself is complicated. The plastic (PEEK) used as the basic material in this project exhibits very strong temperature dependent properties, so the temperature balance in the overall system – being one of the key system properties – must be described with great accuracy.

One of the main aims of the ongoing development at ITWM in the TriDeff project is to "virtualize" the selection of the composition of a composite by means of the mathematical theory of homogenization, whereby combining the simple properties of all the individual materials that are aggregated in the composite can be used to predict the more complex behavior of possible variants of the composite material and optimize them for application-specific purpose. The overriding scientific objective of the project is a full description of the correlation between different categories of tribological testing with particular attention on the thermal balance, specifically, the relationships between Categories VI and V (Fig. 2). Finally, an FE model will be developed as a sort of digital demonstrator for Category V and experimentally validated at TU Kaiserslautern.

2 *Reducing the number of possible variants of a tribosystem by test category: Field testing on real systems, for example, long term studies in the automobile sector are used in Category I. Categories II, III, and IV (test bench with complete system, component, assembly) systematically applies requirements to Category I for the parts being tested. The actual material development takes place in Categories IV, V, and VI in the lab with simulated component surfaces or using simple test specimens.*

FINANCIAL MATHEMATICS



The Financial Mathematics department developed several software products to market maturity this past year. Today, products are available in all priority research areas, which extends the department's profile and attracts new project partners.

DR. ANDREAS WAGNER
HEAD OF DEPARTMENT

The Department of Financial Mathematics has accomplished a successful year 2016. The change in the head of the department at the end of 2015 has proven effective and four new research fellows have been employed to cope with all the research and industrial projects. In the long-term project for the "Produktinformationsstelle Altersvorsorge gGmbH" (PIA), which started in 2015, the department modelled, simulated, and classified state-subsidized pension tariffs ("Basisrente", "Riesterrente") with their specific properties for exemplary customers. Since 1st of January 2017 this classification is a necessary condition for each state-subsidized pension tariff in Germany. The department was successful in simulating all requested tariffs before the end of the year.

Beyond that a first project for the energy industry has been finished. The developed risk management software evaluates different types of risk indicators for a medium-sized energy supplier using factor models for electricity, gas and CO_2, which all have been developed in-house. Furthermore, a method for the calculation of a "guaranteed claim" used in loss projection in the public health sector has been established.

MAIN TOPICS

- Mathematics for the Financial Industry: asset-liability management, chance-risk classification, …
- Mathematics for the Energy Industry: risk management, model development, …
- Data Science for the Controlling: loss projection with statistical methods, fraud detection, rating, …
- Development of individual software solutions in the named fields

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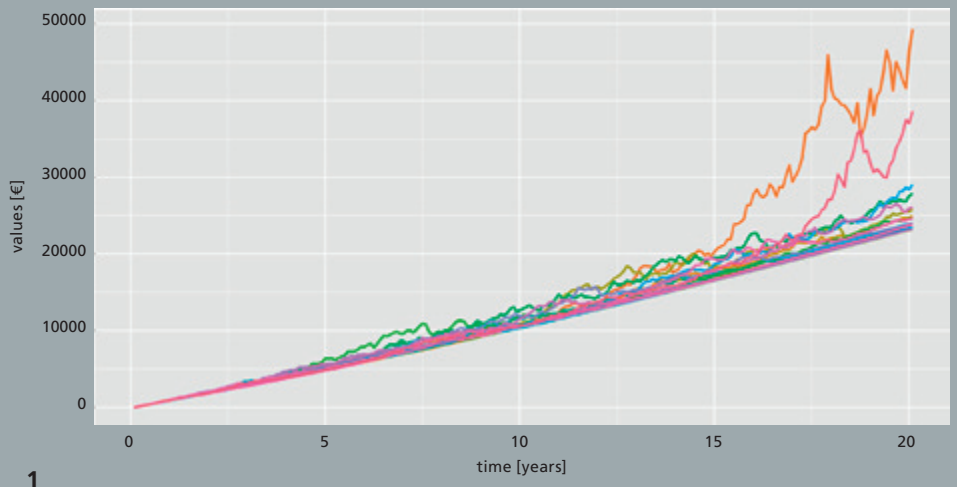

1

CLASSIFICATION OF PRIVATE PENSION PRODUCTS FOR THE PIA

1 *Development of wealth of a 20 years contract under different scenarios*

Since 2002, private pension products are supported by state subsidies in Germany. Two common forms of these payments are the Riester and Rürup pension schemes. Since 2017, according to the law for improvement of old age provision (AltvVerbG), all state subsidized private pension products in Germany must be classified according to their return risk profile. For every single product, a key information document must be provided, that contains this return risk class. The German Federal Ministry of Finance (BMF) assigned the task of determining this classification to the Produktinformationsstelle Altersvorsorge gGmbH (PIA). This organization fulfills administrative and official duties entrusted by the Federal Ministry of Finance and engaged the Department of Financial Mathematics in 2016 to classify approximately 600 private pension products.

For the classification, we simulate 10 000 possible market scenarios for the entire period of the annuity payments based on a market model, i. e. a model for the interest rates and stock prices. In each scenario we calculate the individual wealth of the contract at the end of the saving period. The wealth distribution defines the classification into one of five return risk classes. The simulation takes into account the type of contract (classical life insurance, bank savings plan, fund savings plan, static or dynamic hybrid products with several assets), investment decisions of the management (rebalancing between assets with different risk profiles), and included costs. Complex hedging strategies and options are also taken into account. For the classification the law requires four prototypical customers, each investing 100 € per month over 12, 20, 30, and 40 years.

The heart of the market model is a Hull-White interest rate model with two stochastic factors. This model allows to adequately portray recent phenomena of the interest rate development, such as negative interest rates and decorrelation of long- and short-term interest rates. A further stochastic factor models the stock market using a Black-Scholes model with stochastic interest rate. In order to keep simulation times small, we generate the scenarios on a monthly basis, which also corresponds to the frequency of the contributions of the policyholder. However, to simulate e. g. hedging by daily rebalancing, the monthly simulation requires the development of approximate trading strategies.

Since January 1st, 2017, every state subsidized pension product comes with a product information sheet which shows an return risk class determined by ITWM. Currently, more than 600 pension products have been classified. In the future, the return risk classes will be reviewed annually on the basis of latest market data.

1

RISK MANAGEMENT FOR ENERGY UTILITIES

1 *Risk assessment for the power industry*

Energy utilities are subject to a manifold of risks. For the management, it is essential to be able to control them. Depending on the risks, their assessment and reporting occur either automatically or manually.

Often the risk management decisions are based on complex and confusing calculations in spreadsheets. Even if standardized solutions for risk management are available on the market, they are usually unlikely to fulfill specific and individual demands. They also require a transition to the format of the risk controlling software. In general, these products come at high integration costs. The Financial Mathematics department of Fraunhofer ITWM has developed an individual software package for risk management for a medium-sized energy supplier. Due to its architecture, it can be run independently of the portfolio management (PFM) system and has low integration costs.

The software is able to assess complex and business-specific risks. Furthermore, it is neither for the model selection nor for the calibration bound to the restrictions of spreadsheet risks analysis. At this point, the software profits from the rich experience and expertise in financial mathematical modelling of Fraunhofer ITWM. Depending on the risk category, standard approaches are often insufficient or are based on heuristics.

Depending on the commodity (electricity, gas, CO_2…) different models are used to evaluate the market risk. The software can also take correlation between the commodities into consideration. The market data is daily updated and the parameters are automatically calibrated. According to the risk, the software provides different methods.

Apart from calculating Value-at-Risk, Profit-at-Risk and the Mark-to-Market, it is also possible to monitor hedging strategies. Every method allows a scenario-based valuation, such that the software is compatible with simulation methods from third parties. (e. g. consumption forecasts). Sometimes, it is not possible to get a closed solution with the chosen risk method. In this case, the evaluations are based on Monte-Carlo simulations.

MATHEMATICAL METHODS IN DYNAMICS AND DURABILITY

Interactive simulator RODOS® with attached passenger car cabin: The simulation scenario in use is based on 3D laser scanner data, recorded with REDAR. The attachment is used for the development and testing of assistance and automated solutions for passenger vehicles. Test drivers experience a highly immersive virtual environment where they can also perform high risk maneuvers. Compared with field testing, reproducibility in the simulator is excellent.

DR. KLAUS DRESSLER
HEAD OF DEPARTMENT

In our department, we are dealing with modelling and simulation of usage variability, durability, energy efficiency and real-driving-emission of vehicles. For such 'transient' attributes a good model of the vehicle is not sufficient, however, the simulation of the boundary conditions i. e. "the interaction with the rest of the world" is needed as well - in particular, good models for the road network, topography, road conditions, traffic, tires and driver's behavior. Most important, validation processes for such vehicle properties require statistically qualified test and simulation scenarios, which capture the real usage variability of loads, consumption and emission. Fraunhofer ITWM is working on these topics systematically in the framework of the Fraunhofer Innovation Cluster Vehicle-Environment-Driver Interaction.

Furthermore, we are developing simulation methods and software for the optimization and validation of engineering and production. In cooperation with Fraunhofer-Chalmers Center (FCC), we are working on IPS Cable Simulation, the leading software for the engineering of wiring harness, cables and hoses, and on solutions for the ergonomic analysis of human workers in the production process.

MAIN TOPICS

- Modelling and simulation of usage variability in vehicle engineering (VMC®/U·Sim)
- Simulation of the vehicle-environment-human interaction
  - Tire and full vehicle simulation (CDTire)
  - Interactive simulation/simulator RODOS®
- Simulation of cables and hoses (IPS Cable Simulation)
- Dynamic simulation of human motion: MAVO project "Ergo-dynamic Moving Manikin with Cognitive Control"

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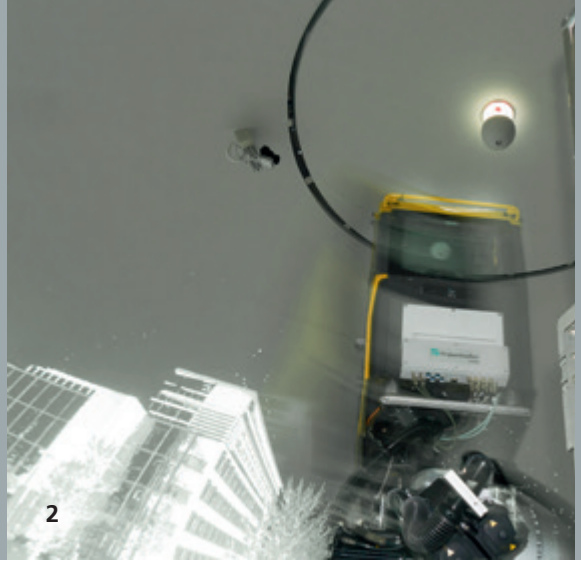
1 *Automatically generated route for a commuter. Direct connection lines between origin, destination and one stopover are colored in red. Real route on road network calculated by VMC® is colored in blue.*

USAGE MODELING OF VEHICLES USING VMC®

One of the main research topics in the department "Mathematical Methods in Dynamics and Durability" (MDF) at Fraunhofer ITWM in Kaiserslautern is about usage modeling of vehicles taking geo-referenced data into account. In cooperation with five big truck companies the software package "Virtual Measurement Campaign" (VMC®) has been developed. For vehicle manufacturers not only the acquisition and evaluation of real measurement data is important, furthermore a deeper knowledge and understanding of the vehicle's usage becomes more and more a major topic. Those aspects have to be taken into account to extrapolate data for different customer groups to the whole lifetime of a vehicle. Besides other applications, VMC® offers important contributions in designing and evaluating measurement campaigns. The following example gives a brief overview about the mathematical methods and software tools, which have been applied during a project conducted together with Volkswagen Nutzfahrzeuge.

Using the software module "VMC® GeoStatistics", a measurement campaign was planned in detail for a desired target region. In this process, relevant topographical factors like road type, slope or curviness were taken into consideration. Our aim was the determination of a route for the campaign reflecting well all characteristics of the targeted region. All important topographical factors and relevant driving conditions have been sufficiently included, allowing statistical evaluations of the data collected during the measurement campaign. In parallel, the vehicle usage was also considered. Depending on the vehicle type, different industrial sectors and fields of application with their differing operational profiles are of importance. These include, amongst others, parcel service distributors or craftsmen. The latter for instance mostly travels from his premises to his diverse customers, but in addition, he also has to buy consumables as needed. Visualizing his daily travelled routes inside his area of operation shows some star-shaped pattern. In contrast to that, a typical tour of parcel services and distributors looks more like a circuit. Typical tours include more stopovers than the trips of craftsmen. In order to generate representative routes for different customer groups, spatial information and potential single targets are needed. Those have been extracted from the VMC® database. For each customer group several thousand routes have been generated. The obtained results are verified with generally accessible statistics including for example typical driven distances of commuters as well as specific measurement data. Digital map data allows the determination of the topographical conditions on the roads travelled and the composition of trip types. Finally, these parameters were used during extrapolation of measured data to expected load distributions. In particular, sensitivity studies and comparisons between different customer groups have been conducted. These allow customized configurations of vehicles and an overall customer oriented design and development.



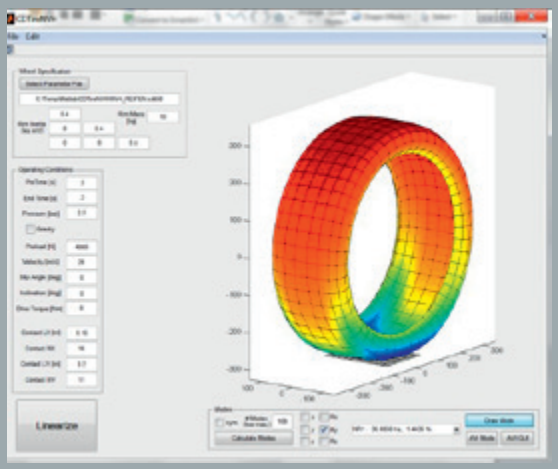
INTERACTIVE DRIVING AND OPERATING SIMULATION WITH RODOS®

In the simulation-based testing of new vehicle concepts, all relevant influences on the vehicle model have to be correctly displayed in very early project phases. The environment as well as the human-vehicle interaction is particularly challenging. With the rapidly increasing complexity of vehicles, which not only support the driver in a multitude of decisions, but also increasingly take over the actual driving partly or completely, new requirements arise for the simulation chain in the development process. The number and nature of the interactions between the vehicle, the environment and the human (driver), which have to be taken into account in vehicle development, has increased considerably in the recent past.

Traditionally, the focus of a simulation has been to compute the physical characteristics of the vehicle, taking into account a few partial aspects of the environment (e. g., the road surface) and the driver (e. g., as a controller). Also for the coupling of these input variables less complex approaches have so far generally led to meaningful results. Aspects such as automated and autonomous driving have to be approached with new global methods and developed iteratively during the simulation. With increasing intelligence of the vehicle and the resulting more active role of the vehicle, a relatively simple modeling of the driver's behavior is no longer sufficient. The reactions and feelings of the driver are now very strongly dependent on the 'decisions' of the vehicle itself. The subjective feeling of driving no longer results solely from the physical characteristics of the vehicle but also from its 'intelligent' behavior (active intervention in the process of driving) as well as the (partially autonomous) behavior of other vehicles. Furthermore, the necessary degree of detail of the environment increases as the built-in sensors detect with a high degree of accuracy and, for example, a description of the road surface as an input variable in the model is by no means sufficient. In particular, the human being, whose immersion experience is strongly influenced by visual and vestibular impressions, reacts significantly to different degrees of complexity and realism in the simulated environment. To this end, the ITWM developed a new tool chain that starts with a highly accurate laser-based 3D (REDAR) recording of the environment and ultimately integrates the driver into the simulation environment using a robot-based driving simulator (RODOS®) with an extraordinarily high degree of immersion. The vehicle simulation itself, in addition to the driver interaction, also uses the environmental data – e. g. via a specially developed terrain server for the tire models – as input. Despite the immense amounts of data, the environmental representation based on point clouds is realizable on the basis of new 'out-of-core' approaches.

1 *Simulation scenario based on measured 3D point clouds (Trippstadter Straße in Kaiserslautern)*

2 *Excavator simulation in a point cloud-based scenario*



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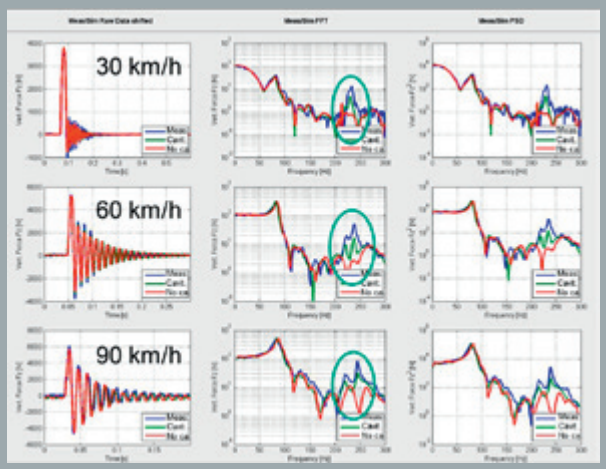


2

INFLUENCE OF THE DYNAMICS OF THE INFLATION GAS ON THE OPERATING CONDITIONS OF A TIRE

1 *CDTire/NVH: Linearization of the rotating tire*

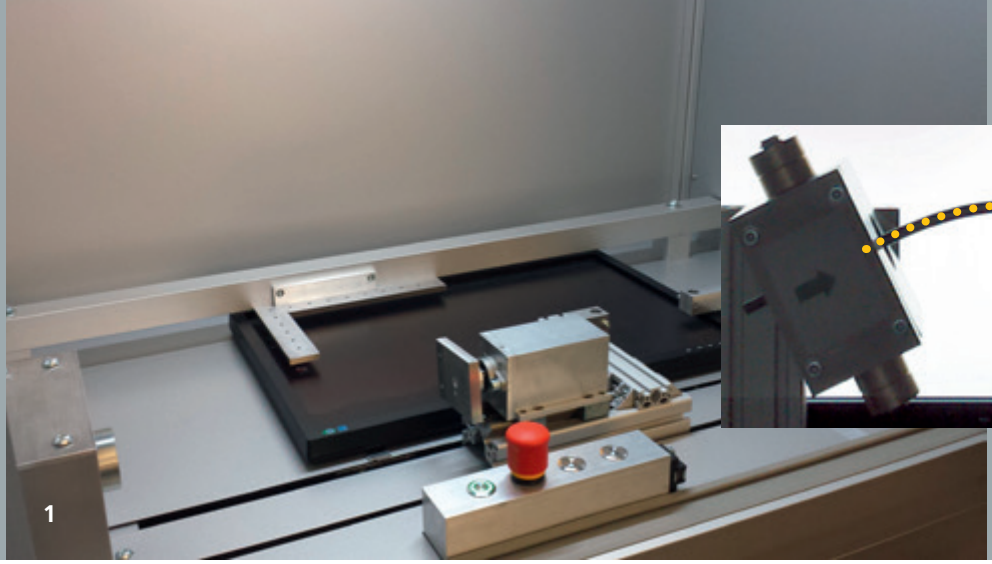
2 *Vertical spindle force comparison for cleat runs: measurement (blue) vs. simulation with (green) and without (red) dynamics of the inflation gas*

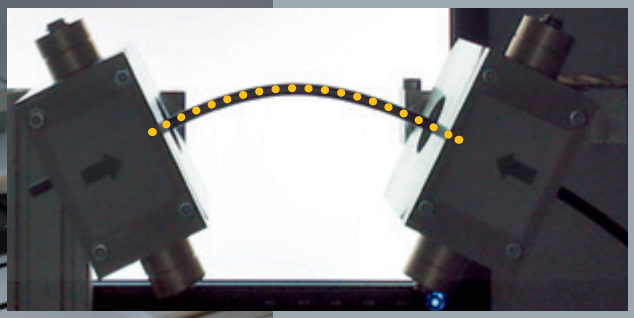
The ITWM developed the tire model CDTire/3D, a shell-based bead-to-bead model with materialized modeling of sidewalls and belt. All functional layers of a tire (inner liner, carcass, belt and cap plies and the tread) are modeled as separate entities accessible in pre-processing and condensed into one geometric shell representation. The structural properties of each layer can be parameterized separately and may vary with local cross section position. This modeling yields an optimal compromise between computational effort and solution accuracy, allowing for full vehicle simulation scenarios for all typical application attributes to assess and optimize vehicle suspension, structure and dynamics with more than reasonable simulation times.

CDTire/3D models the tire from bead to bead, including the sidewalls. As such, the inflation pressure can applied correctly onto the innermost layer (innerliner) of the tire. For many applications, it is feasible to model the inflation pressure as a prescribed value, provided as a function of time. This modelling already allows for complex application scenarios such as sudden total pressure loss simulations in safety-critical virtual developments of vehicle control systems.

However, there are applications where it is needed to model the inflation gas dynamically and the tire's dynamic interaction with it. Such an example is the extension of the frequency range of NVH (noise, vibration, harshness) applications up to and beyond 250 Hz. For typical passenger car tires, the first resonance of the inflation gas (air) – the so-called cavity mode – lies at around 220 Hz. In this frequency range, the dynamics of the inflation gas (air) couples with the tire structure, generating significant peaks in the spindle forces acting on the rim.

In order to feature these applications, CDTire/3D now has the capability to model the inflation gas as an isotropic compressible Euler equation with time-varying cross section area. With this modeling, sudden changes in cross section area (as experienced e. g. in cleat runs) yield local changes in the pressure that propagate with the velocity of sound in both circumferential directions of the tire's cavity. This modeling also takes into account that the inflation gas within the tire is rotating with the tire. Within the rotating inflation gas, the pressure variations still propagate with the speed of sound in both directions, but a non-rotating observer will register two different frequencies relative to a non-rotating frame. This velocity-dependent split in the frequency of the cavity mode is also visible in measurements.





IDENTIFICATION OF MODEL PARAMETERS FOR IPS CABLE SIMULATION WITH MESOMICS

The numerical simulation of highly flexible components like cables and hoses is an important aspect of modern virtual product development. The software IPS Cable Simulation, developed from FCC and ITWM, allows an interactive and at the same time accurate simulation for design and assembly situations.

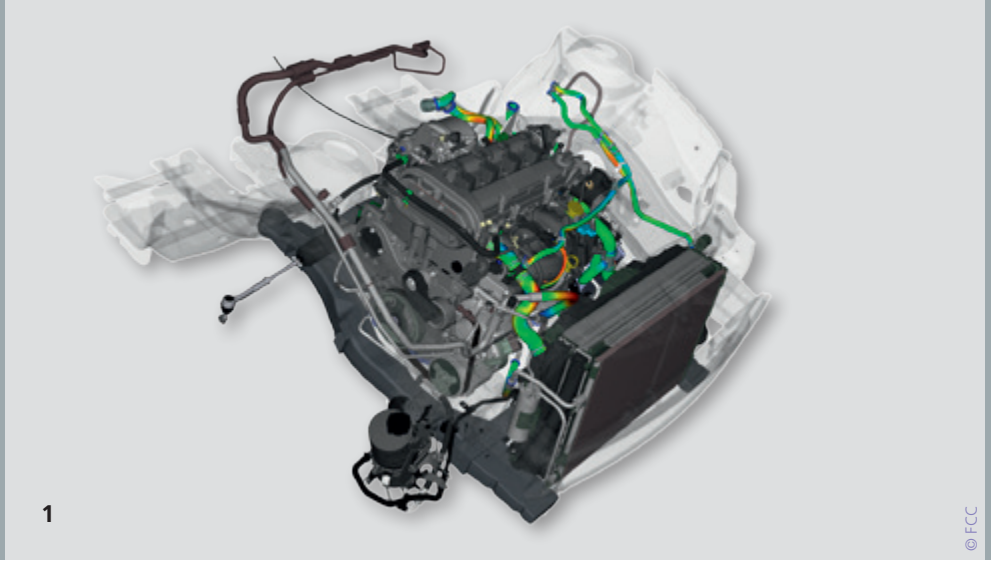
For a physical correct prediction in the digital mock-up of cables and hoses, their mechanical properties are an essential model input. Therefore, recently a highly automated measurement system (MeSOMICS) was developed, constructed and registered for patent. MeSOMICS stands for "Measurement System for the Optically Monitored Identification of Cable Stiffnesses." Besides classical measurement quantities like forces and moments, it provides an optical detection of the cable bending line. This optical detection is used to monitor the measurement process.

The measurement system is especially tailored for a comfortable handling and automated evaluation of parameters. For instance, the assembling of specimens is very easy, the subsequent measurement performs automatically and the relevant model parameters for IPS Cable Simulation are derived immediately after the measurement. Moreover, the innovative concept for the bending test allows practically relevant radii of curvature, which is not the case for the standard 3-point bending test. Thus, the scope of validity is significantly increased.

Based on nonlinear beam theory, an elaborate evaluation algorithm identifies the stiffness parameters from the measured data. By using all recorded quantities – forces, moments, displacements und the mentioned camera images – the algorithm is very robust. In particular, the identified bending stiffness is directly verified by a theoretical solution of the corresponding bending line. Finally, MeSOMICS provides a complete set of cable stiffnesses for the numerical simulation with IPS Cable Simulation.

1 *MeSOMICS sample chamber*

2 *Optical monitoring of the bending test with theoretically identified bending centerline*



1

DYNAMIC SIMULATION OF CABLES AND HOSES

1 *Complex cable harness in an engine compartment*

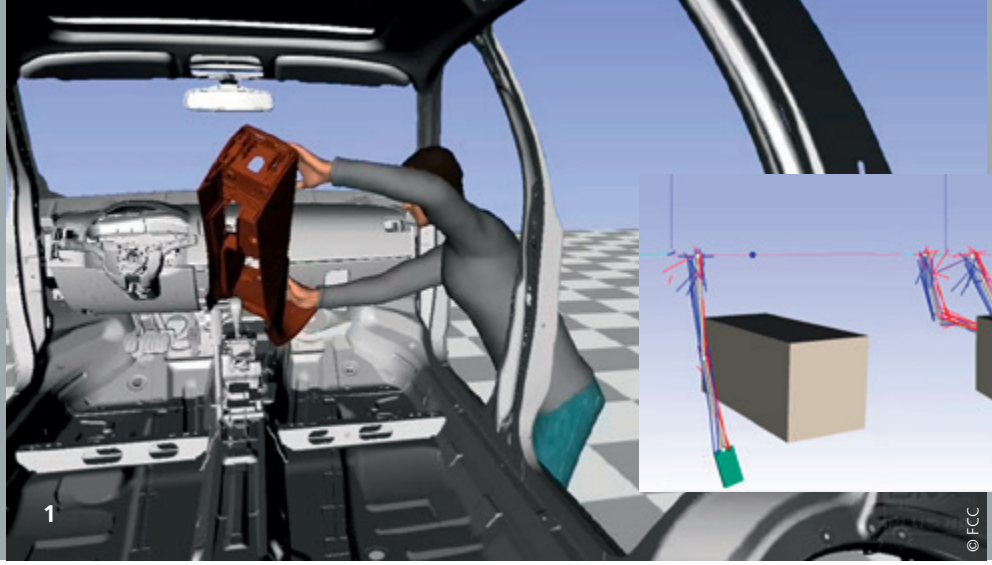
Numerical simulation has become an important aspect of modern production processes in vehicle industry. Very early in the process chain – even before the first prototypes are built – simulation is used for digital mock-up in order to discover possible problems and to improve certain components and their assembling.

Especially challenging is the simulation of highly flexible components like cables and hoses, for which high loads and contacts with high friction should be avoided. Considering slow or quasi-static motions, our software IPS Cable Simulation already enables an interactive, but at the same time highly accurate, simulation of assembly processes of flexible components. It was developed by the FCC in Gothenburg together with the ITWM and is widely used by leading car manufacturers. The software is distributed by the spin-off fleXstructures GmbH.

Nevertheless, when it comes to fast excitations with high frequencies, inertia effects cannot be neglected and dynamic simulation of cables is indispensable. To achieve fast and accurate results with the computational more expensive dynamic simulation, the cable is formulated as geometrically exact Cosserat rod. In combination with modern approaches from discrete differential geometry, this model allows for rather rough discretization, thus short computational time, and still leads to robust and realistic results.

Currently, we integrate the dynamic cable simulation in IPS Cable Simulation. Thus, experienced users can generate flexible cables as before, assemble them digitally and easily compare variations. In contrast to quasi-static simulation, they only need to add some further information: dynamic excitations and damping characteristics of the cable.

An essential tool for the assessment of assembly configurations are accumulated damage values, which are computed in the fatigue analysis after the simulation. In this context, we distinguish two approaches. On the one hand, we already provide a so-called comparative load data analysis (LDA). This method computes pseudo-damage values on the cable surface, which do not predict the absolute lifetime of a component, but allow to compare several configurations to find the best one in the sense of damage. On the other hand, there is a strong interest in absolute lifetime predictions. Algorithmically, we can proceed similar to the comparative LDA but have to use component specific Wöhler curves, which provide the number of acceptable load cycles at certain amplitudes. The assessment of this process is part of our ongoing research.



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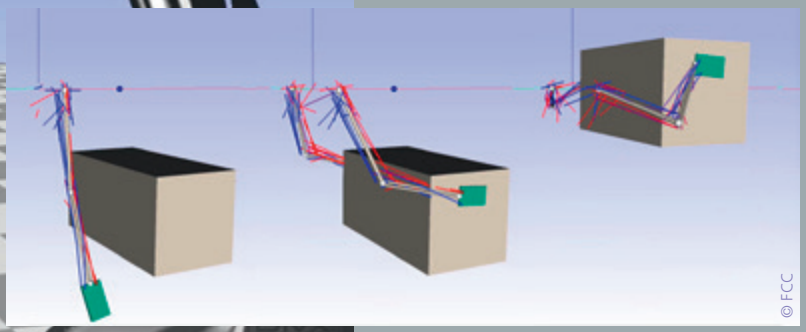


2

DIGITAL HUMAN MODELING FOR VIRTUAL ASSEMBLY PLANNING AND ERGONOMIC WORKPLACE DESIGN

The modeling and efficient simulation of human motions for applications in the fields of ergonomics, medicine and computer graphics is a big challenge. The objective of the project "Ergodynamic Moving Manikin with Cognitive Control" (abbrev. EMMA-CC) is the development of an enhanced digital human model for ergonomic assessment of dynamic motions by validated simulation to support the design of healthier and safer workplaces in future product development and product planning processes. Six Fraunhofer Institutes are collaborating in this project: FCC, IAO, IGD, IPA, IPK, and ITWM.

The digital human model IPS IMMA – developed by FCC department "Geometry and motion planning" – therefore provides a basic tool, which we want to enhance by combining it with our research fields in biomechanics and optimal control (ITWM), biomechanical 3D muscle modeling and validation (IPA), hybrid parallelization of biomechanical simulations (IGD), ergonomy methods (IAO), and cognitive control modeling (IPK) in order to achieve our ambitious objectives.

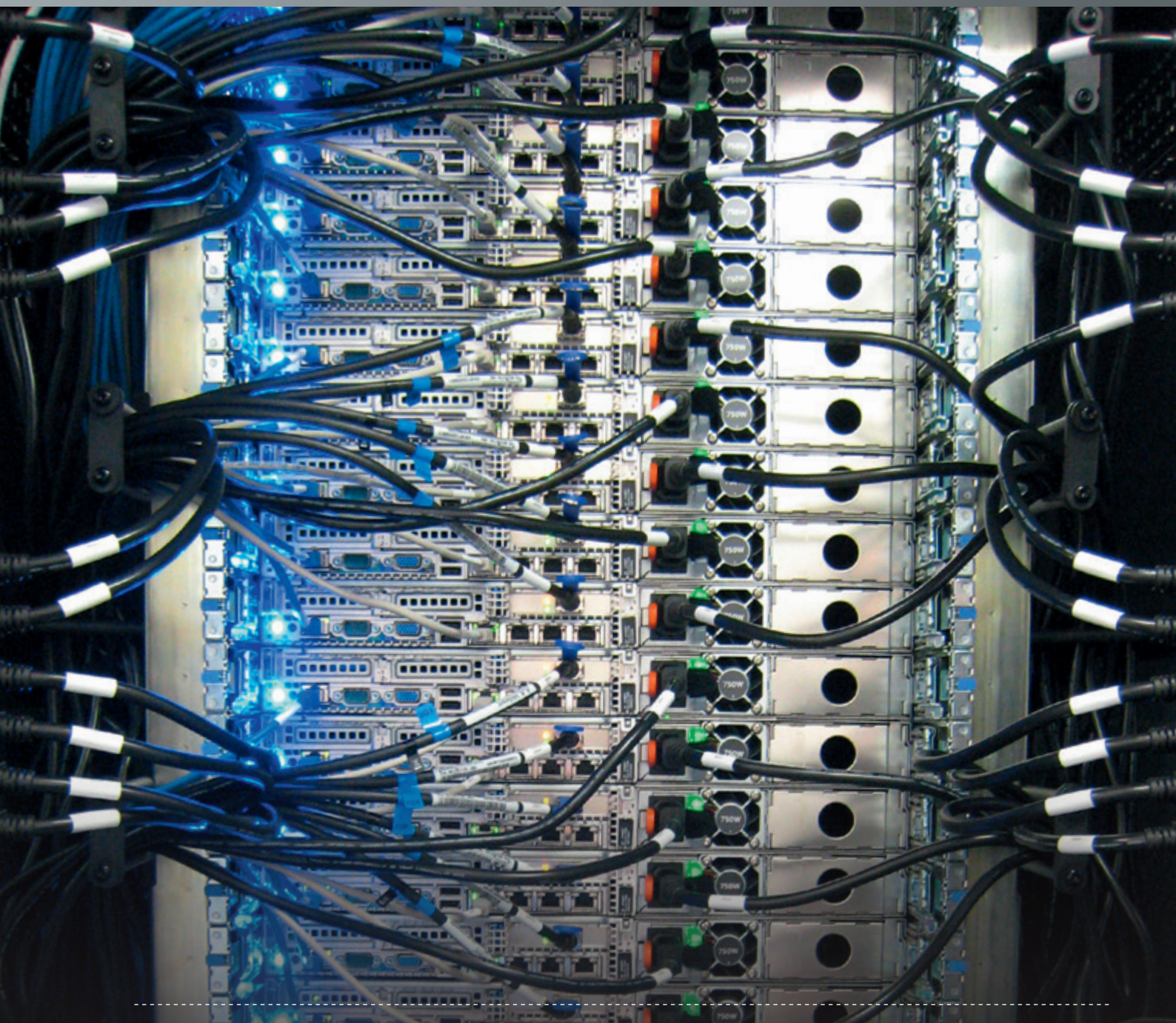
ITWM and FCC are collaborating closely on biomechanics and optimal control, with the goal to generate realistic human-like motions of the DHM from generic working instructions like for example "move a box from A to B." Such a model would enable the engineers to take into account physical workloads and reachability issues in virtual assembly planning. The digital human is modeled as a biomechanical multibody system with muscles as actuators. The motions of the DHM for specific working instructions are predicted with the help of optimal control, where an objective function accounting for physiological quantities that are relevant for humans is minimized. This new approach enables the user to make quantitative statements about muscle forces and joint loads during assembly, which are important indicators for ergonomic assessment.

With the model developed in the project EMMA-CC it will be possible to develop new ergonomic guidelines for dynamic motions. These provides the basis for an ergonomically favorable assembly planning accounting for dynamical effects, as well as a personalized ergonomic workplace design. Due to fast and robust numerical algorithms the model is running nearly in real time on a modern personal computer, which allows for the productive use in optimizing virtual assembly. The practical relevance of the simulation tool is validated by numerous ongoing experiments conducted by Fraunhofer IPA, and its practical utility for application engineers is demonstrated in a virtual reality environment developed by Fraunhofer IPK.

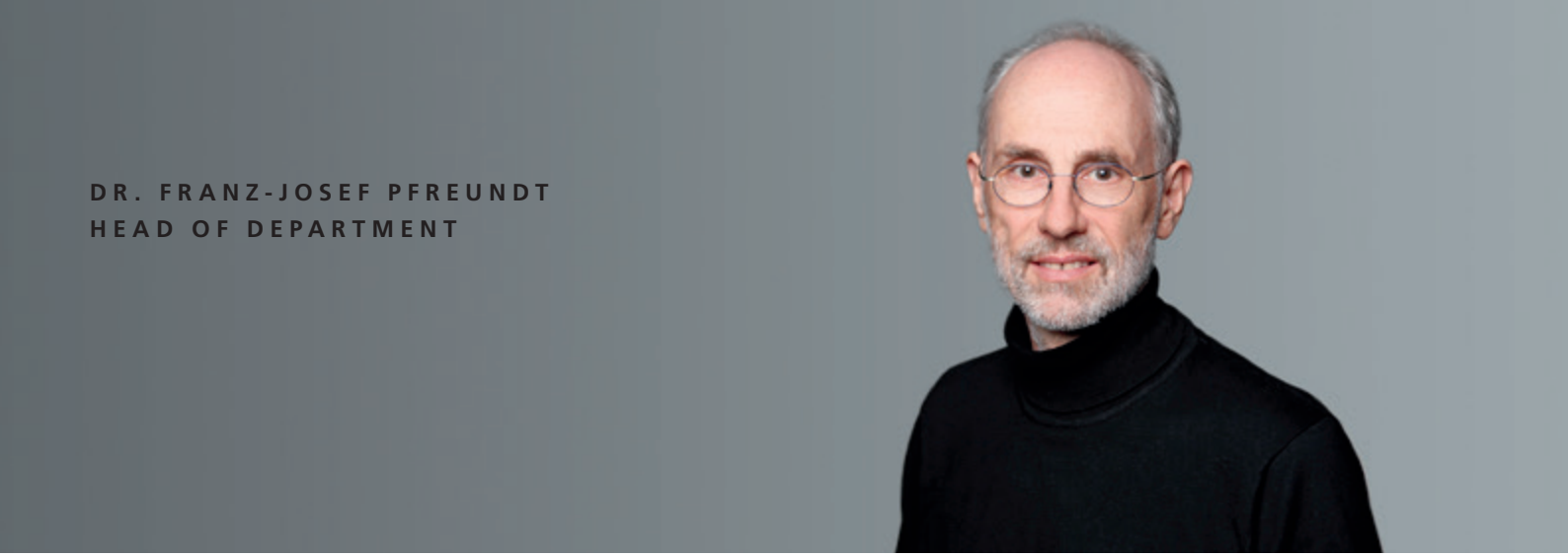
1 *Simulation of the assembly of the center console of a passenger car in IPS IMMA*

2 *Lifting of a box, simulated with a biomechanical digital human model actuated by muscles*

COMPETENCE CENTER HIGH PERFORMANCE COMPUTING



Back side of the computer racks: Separate data arrays are stacked in such “cabinets” and connected to each other in fast networks, for example, Infiniband. The close packing and linking of several such racks creates a mainframe computer that provides modern data centers with the computing power required for future-oriented HPC applications – like Deep Learning or other types of simulation.



DR. FRANZ-JOSEF PFREUNDT
HEAD OF DEPARTMENT

High Performance Computing (HPC) is indispensable for research and economic competitiveness. Basic research in the fields of energy, the material and life sciences and climate research is unthinkable today without sophisticated simulations. The same applies to key sectors of the German economy. Deep learning and machine learning methods are poised to significantly change our society.

The European Union has declared HPC a key strategic issue for Europe and is making a substantial investment in the field. One major element in all of this is the convergence of HPC and Big Data. The department contributes in this environment by participating in the key EU projects and was nominated for the EU Innovation Radar Prize for creating the GPI programming model. In 2016, the ecosystem of myPowergrid technology was significantly expanded to support the management of distributed power storage systems and our priority research topic Deep Learning established international status with algorithmic concepts and deep analyses.

MAIN TOPICS

- HPC System Software and Applications
- Deep Learning and Big Data
- ICT and Renewable Energies
- Parallel File Systems – BeeGFS and BeeOND
- Simulation and Data Analysis in Seismology

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1

2

TWO NEW PROJECTS BASED ON THE MYPOWERGRID TECHNOLOGY

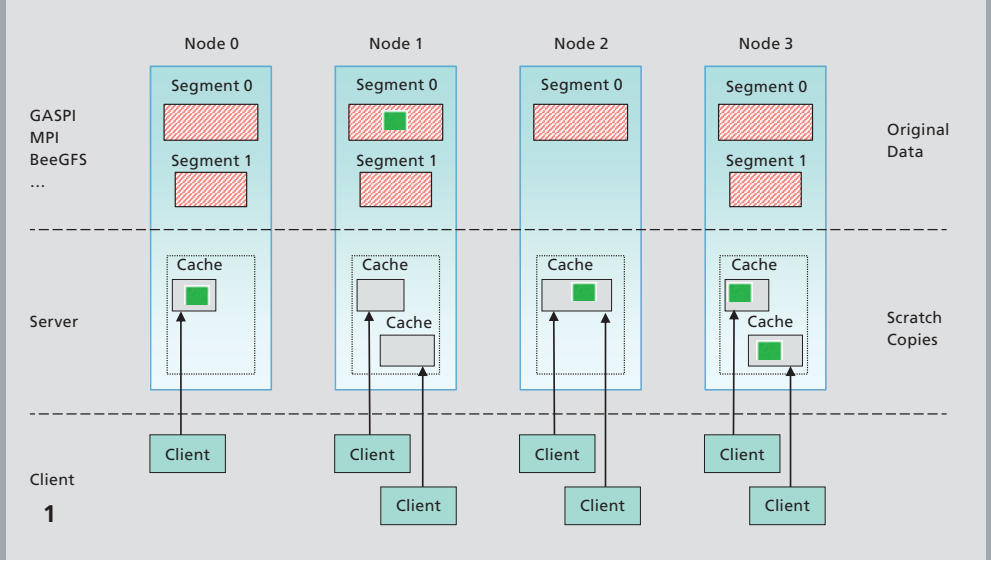
1 *Schoonschip Community in Amsterdam Noord*

2 *Realised peak shaver for load reduction of industrial consumers with load profile metering; the battery supports a maximum power of 60 kW and has a capacity of 60 kWh.*

The integration of alternative energy from sources like photovoltaic plants and wind turbines poses a great challenge for the power grids. The group "Green by IT" is dedicated to creating a reliable, cost efficient, safe and future-oriented energy supply by developing intelligent IT systems and innovative algorithms to enable the transition and deal with the fluctuating production from renewable sources. The year 2016 marked the launch of two new research projects: GreenPowerGrid and Grid-Friends, each with a project term of three years. Both of these projects use the technological foundation provided by the successfully completed myPowerGrid project.

GreenPowerGrid is sponsored by the state of Rhineland-Palatinate and the European Fund for Regional Development (EFRE) to pursue the goal, in cooperation with Stadtwerken Speyer, of enabling a regional green energy supply. The myPowerGrid technology serves as the basis for the development of decentralized PV storage power plant. The goal is to build more than 100 PV storage systems within the city limits of Speyer and provide a local power supply directly to customers using reliable alternative energies. The project has already produced a metering concept and an innovative billing/accounting system. The power supply for 250 households for an entire year has been simulated to a resolution computed every second and shows a positive local self-supply rate by the PV power storage station and, after the initial assessment, a positive new business model for the public utility. A German-Dutch business consortium is developing and evaluating a coordination mechanism between individual power consumers and producers in the Grid-Friends project, which is sponsored by ERA-Net Smart Grids Plus and the German Federal Ministry for Economic Affairs and Energy (BMWi). ITWM's part of the Grid-Friends project is to develop a comprehensive energy management platform for micro-grids and energy communities. In addition to the controls for the storage batteries, the institute is orchestrating a merger of two sectors: that is, the flexible control of heat accumulators in combination with heat pumps and charging stations for electric drive vehicles with respect to the availability of local photovoltaic power supplies. The resulting energy management platform is to be deployed in a demonstrator with 35 floating apartment buildings on a canal in Amsterdam and a residential neighborhood in Cologne-Widdersdorf, Germany. The two demonstrators pursue different objectives: maximum self-supply in Amsterdam and maximum cost efficiency in Widdersdorf.

In addition to these research projects, an agreement with a leading grid operator was signed for consulting and demonstration project: ITWM is planning the installation and follow-on operations for two high-performance battery storage systems for load reduction in industrial operations with load profile metering. The optimized control of the batteries is based on the local energy management system adopted from the myPowerGrid technology.



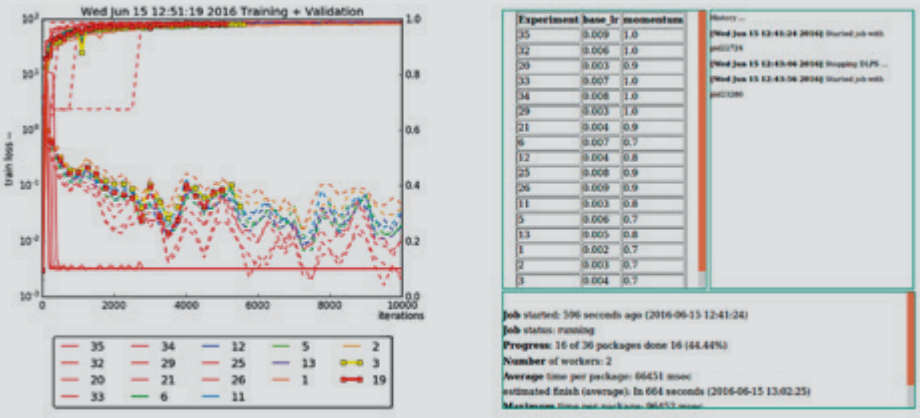
HIGH PERFORMANCE COMPUTING FOR EUROPE

1 *INTERWinE's Directory Cache Client-Server-Architektur*

The CC HPC has been involved in the European funding programs for several years. We are currently involved in six ongoing projects in HPC and transport. We present two highlights of the ongoing projects.

Fraunhofer ITWM's Communication Model GPI (Global Address Space Programming Interface), a key technology in the HPC, is fostered within the scope of the EU-funded INTERWinE project. INTERTWinE promotes the interoperability of communication models available on the HPC market. Communication models are used to communicate data between compute nodes and compute cores. This is important for parallel programs that efficiently utilize the computing power of large computer clusters. GPI allows for asynchronous, multi-threaded communication, avoiding intermediate copies of data. As a result, the computation time can be optimally overlapped with the time required for the communication of the required data. Interoperability between GPI and other communication models allows users to mix already developed code with GPI-based code and to take advantage of the benefits of GPI. In the scope of the INTERWinE project, Fraunhofer ITWM is developing a tool that allows applications that use task-based programming models, which often run on one node, to be scaled on many nodes.

Our distributed runtime environment GPI-Space forms the basis of the IT infrastructure in the EU-funded SafeClouds project. SafeClouds will revolutionize air traffic management. Air traffic will continue to grow in the coming years. In order to improve the security standards cost-neutrally, it is necessary that data is exchanged and intelligent algorithms are applied. This is the only way to quickly identify risk factors from the massive data volumes and initiate counter-measures. GPI-Space forms the basis for the data exchange. The components of GPI-Space enable a division between the algorithmic expertise of the domain experts and the parallelization of the programs for an efficient execution on computer clusters. The runtime environment of GPI-Space is responsible for distributing and executing the program on the available resources (also via geographically distributed systems). The workflow is defined using the runtime environment and executed dynamically and concurrently using GPI. For us the SafeClouds project is exciting as we use our software GPI-Space in a completely new application area. In the next two years, we will accompany the SafeCloud project and analyze its results.



1

SCALABLE DEEP LEARNING BASED ON HPC TECHNOLOGY

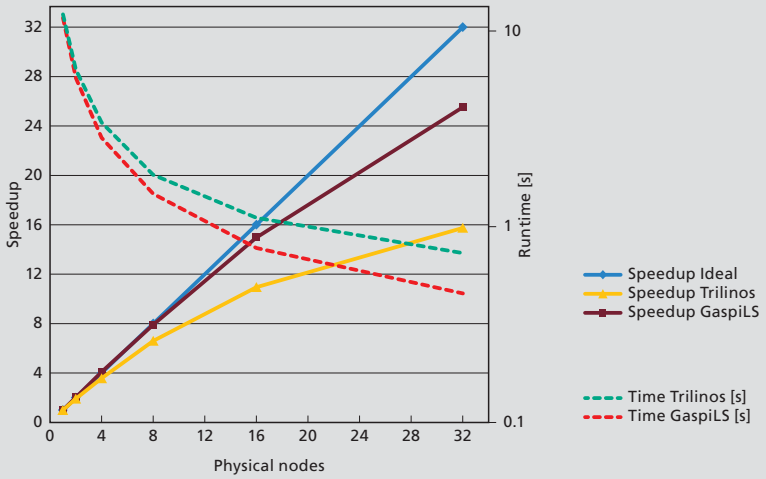
1 *DLPS system automates meta-parameter optimization of deep neuronal networks in the cloud.*

In recent years, huge advances have been made in the field of machine learning and its many application areas – from voice recognition to automatic image analysis to autonomous cars to computers that play Go at the World Championship level. Behind all of these achievements are the so-called Deep Learning algorithms. This learning method models the learning problem using very large, complex, artificial neuronal networks. Training such networks requires not only very large data volumes, but also enormous computing power. In terms of the mathematics, the training process corresponds to a non-convex and non-linear optimization problem in the high-dimensional space. Such challenging problems claim days to weeks of calculation time before producing a practical model using the usual optimization methods.

According to the literature, the previously attained acceleration of the training process through parallelization has been rather modest because of the sequential nature of established optimization processes. CC HPC, based on experience in high-performance computing and HPC tools like GPI, GPI space, and BeeGFS, has been able to advance the development of new algorithms in this area to the point of being able to introduce the first scalable solutions.

CaffeGPI was created on the basis of the widely used Caffe open source software and enables – via multiple computing nodes – the distributed training of Deep Learning models on HPC clusters. Thanks to the use of a new optimization algorithm and the GPI-library, CaffeGPI achieves a significantly better scalability than other distributed approaches.

Deep Learning in the Cloud (DLPS): The DLPS system, based on GPI space, enables the automatic and redundant optimization of the meta-parameters of a deep learning model. Adapting these parameters to a specific problem is usually a time consuming and data computing intensive process. DLPS, however, can automate and cost efficiently "outsource" it to the cloud.



1

GaspiLS – SCALABLE LINEAR SOLVER LIBRARY

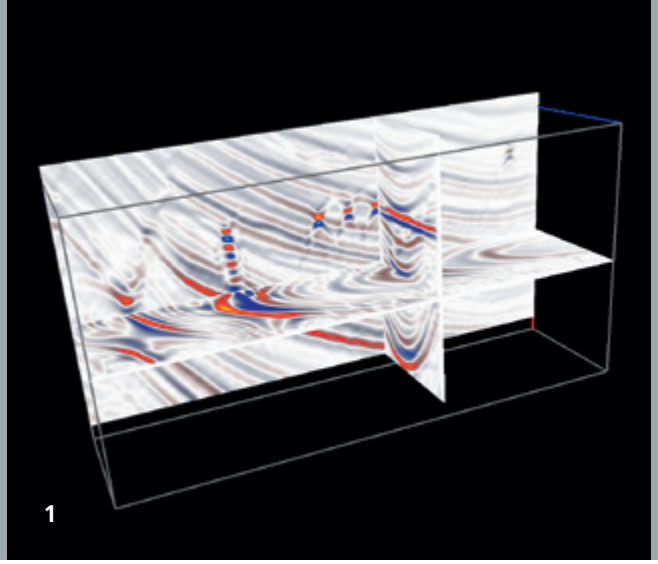
Nowadays, in a lot of research fields, simulations form the third pillar of science beside the traditional ones represented by theory and experiment. Computational models are supposed to create a virtual image of nature. In most of the cases, these simulations are based on the discretization of a differential equation. Ultimately, this yields a big system of algebraic equations which are solved e. g. by an iterative solver. The solution of these systems of equations is extremely compute intensive and the effort usually increases with a higher level of detail in the underlying model. The demand for more and more compute power is obvious.

1 *Scalability and absolute runtime of GaspiLS in comparison to Trilinos for a CG based reservoir simulation (Intel Haswell, 256 GB RAM, two sockets per node, six threads per socket)*

However, the CPU clock rate has reached an upper limit on the hardware side. In order to gain more compute power, one is increasing the parallelism on the compute units instead. For example, the amount of floating point numbers which can be simultaneously processed by a single arithmetic operation is raised. On the other hand, the number of compute cores is increased on a single CPU. On top of this, several CPUs are arranged in parallel in a network to form a single big unit. On modern systems, there are up to 20 cores per CPU. This implies that the dual socket systems, which are generally used in the HPC sector, provide up to 40 cores per compute node. One has a huge amount of hardware provided parallelism on a single device which also needs to be reflected in the software layer. The so called accelerator architectures which host up to 72 cores are even more extreme within that respect.

If one wants to exploit the increasing parallelism provided by modern hardware for the simulations, software with good scalability features is required. Here, scalability is a measure which quantifies the additional benefit which is generated by adding additional hardware resources. That means, software which optimally scales exploits the hardware provided resources to 100 %. This has to be the ultimate goal in order to use the hardware efficiently.

GaspiLS is a numerical solver library for iterative methods, which has been designed right from the beginning to provide a good scalability. It is based on the GPI-2 programming model and implements an asynchronous data dependency driven execution model with perfect overlap of communication and computation. It avoids global synchronization points as much as possible. These are the basic principles and necessary conditions to achieve a good scalability. The object oriented design of GaspiLS defines abstract interfaces for matrices, vectors, iterative solvers and preconditioners. As such, it is easy to extend. GaspiLS provides several solvers like (P)CG, BiPCGStab and GMRES. It is also providing preconditioners like e. g. Jacobi, ILU(0) and ILUM(0). GaspiLS is going to be released OpenSource under GPLv3 license. At the moment, GaspiLS is used in two industry projects.



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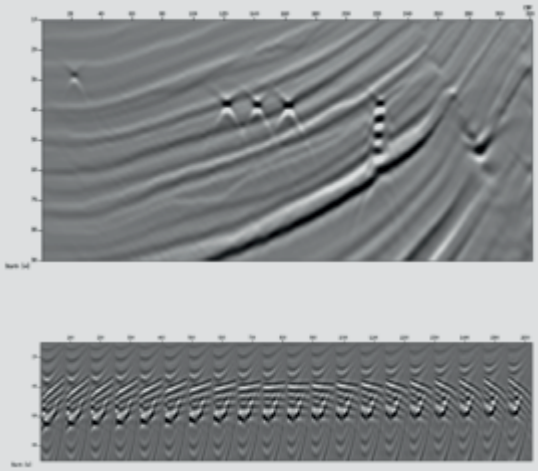


2

USING SEISMIC DATA TO DETECT BOULDERS

1 *Position of underground diffractors as result of GRT migration. GRT interim results shown as fold-outs highlight the linear appearance of the diffractions.*

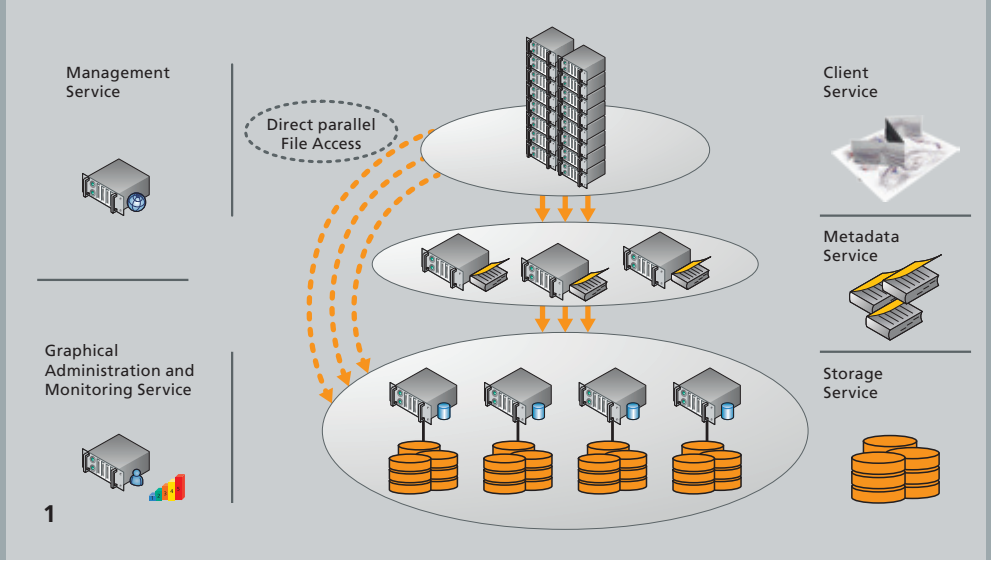
2 *Subsurface image points of diffractions as obtained by GRT migration (upper figure); the linear events with varying dip are an indicator for existing diffraction (lower figure).*

Reflection seismology ranges over a large area of transmitted acoustic wavelengths and is not limited to the frequency bands around 50 Hz so relevant for oil and gas exploration at reservoir depths of several thousand meters. Besides providing structure, stratigraphy, and rock parameter data at such depths, it can also provide detailed, high resolution exploration of the shallow underground.

In this BMWi sponsored project, CC HPC brings many years of experience and competence in developing analysis methods for seismic data and, in cooperation with Fraunhofer IWES, is now working on a process chain to find subsurface boulders having a diameter larger than one meter at subsurface depths up to 100 meters. Energy companies have a great interest in discovering such rock obstacles when planning offshore wind parks and making adjustments for the exact positioning of the turbine towers.

Boulders resting just below the surface or embedded at a shallow depth in the sea bed are easily detected by bathymetric surveys and very high resolution sonar systems. At depths of 10–80 meters below the sea bed, the surveys require the use of deeper penetrating seismologic methods. The idea for the planning of the offshore wind parks is to rely on the seismic acquisition measurements already collected regarding the issues of structural stability. At frequencies around 300 Hz and the resulting wavelengths of 5 meters, boulders of the dimension specified above can be detected using the diffraction response patterns in the seismic data sets.

To separate the diffractions from the comparatively much higher amplitude reflections, CC HPC developed a two-step process, consisting of a multi-focusing technique and our GRT pre-stack depth migration. The reflections are weakened in favor of the diffractions in both steps to produce a limited background image of the diffracting object, which is amplified and inserted in the classic structural migration result to expose the spatial relationships. An interpretation of the results enables conclusions to be drawn about the frequency of occurrence as well as the location of individual objects.



1

BeeGFS – PARALLEL FILE SYSTEM WITH MAXIMUM PERFORMANCE AND HIGH AVAILABILITY

The performance of state of the art processors and network technologies is constantly improving and new possibilities are arising for handling ever more complex problems and for obtaining more realistic and detailed simulation results. However, this also requires the ability to work with very large data sets, often in the terabyte range. To manage these huge amounts of data and ensure optimum computing performance, CC HPC has been working for several years on the BeeGFS parallel file system where parallel read and write function is possible. In this system, individual files are distributed to multiple servers in so called chunks. This method makes it possible to process data sets at speeds many times faster than usual. From the outset, scalability, maximum performance, and flexibility as well as ease of use have been the cornerstones of the development effort and, today, these features are the reasons why the system is increasingly attractive to a wide and global user base.

Last year, BeeGFS was extended by high availability mechanisms, which enables customers to use the software to create a highly reliable global file system. This system requires no other third party software or special high availability hardware. In addition, BeeGFS supplies the BeeOND tool that creates a parallel file system on a defined set of hardware at the push of a button. If required, BeeOND can be used as a dynamic parallel file system directly on the compute nodes. Temporary calculation data can be processed directly, without the need to access a global storage system over the network.

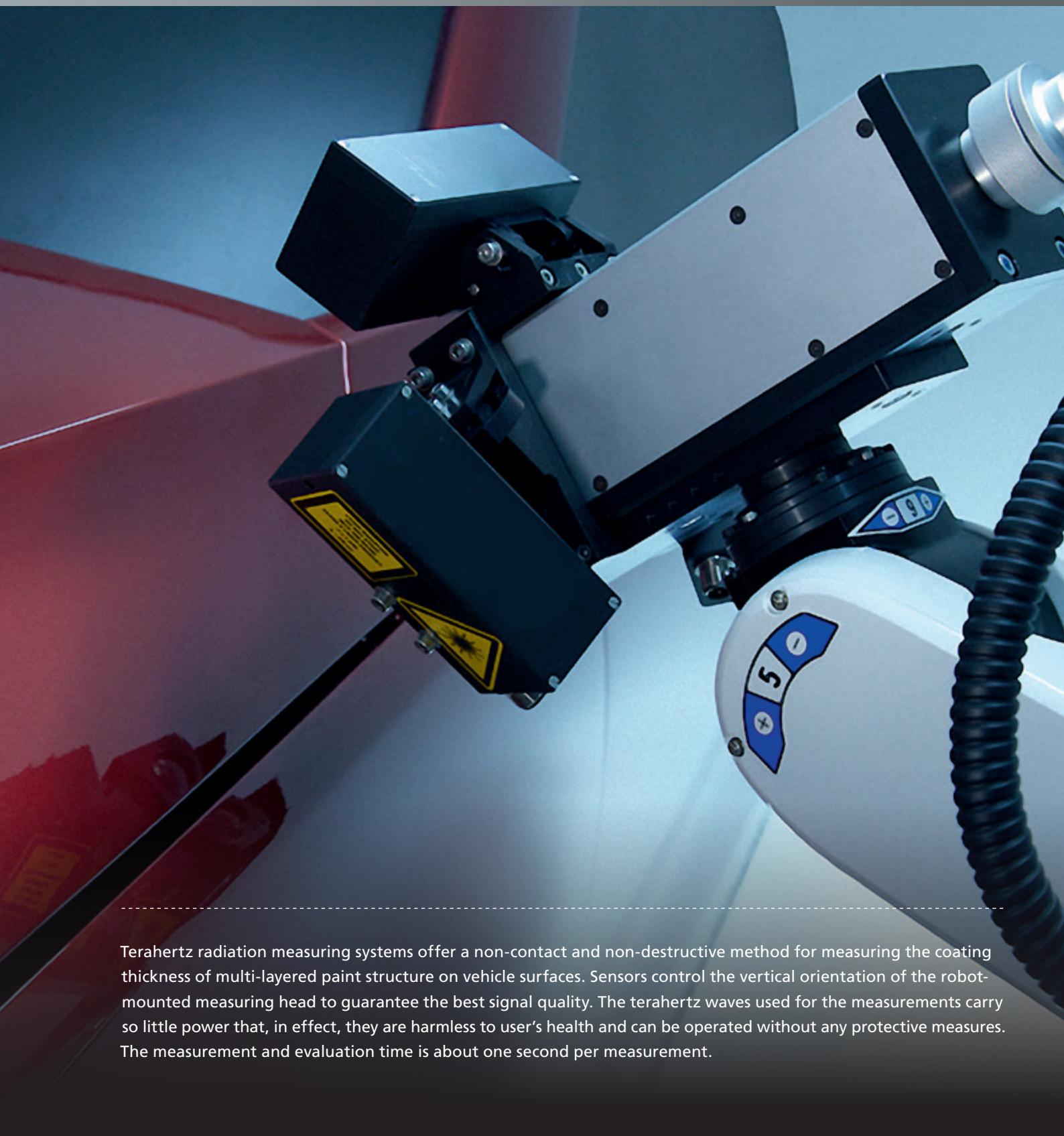
BeeGFS is supplied free of charge at www.beegfs.com. The software is distributed under an open-source license and the source files can be obtained from the website. A Fraunhofer ITWM spin-off company, ThinkparQ, has provided worldwide commercial support for BeeGFS since 2014. Meanwhile, CC HPC continues its development of the software.

The CC HPC development team is also contributing its extensive knowledge to a number of successful EU-sponsored projects. New methods and computer architectures are being developed in cooperation with other project partners, with special attention on exascale computing. When working with such high performance computing units, itneeds to be ensured, that the data to be processed can be provided fast enough. This fact makes BeeGFS one of the key elements of the project.

1 *Overview of BeeGFS architecture: Separate services for metadata and user data enable independent scalability of both functions.*

BeeGFS
developed by Fraunhofer

CENTER MATERIALS CHARACTERIZATION AND TESTING



Terahertz radiation measuring systems offer a non-contact and non-destructive method for measuring the coating thickness of multi-layered paint structure on vehicle surfaces. Sensors control the vertical orientation of the robot-mounted measuring head to guarantee the best signal quality. The terahertz waves used for the measurements carry so little power that, in effect, they are harmless to user's health and can be operated without any protective measures. The measurement and evaluation time is about one second per measurement.

PROF. DR. GEORG VON FREYMANN
HEAD OF DEPARTMENT

In January 2017, the Center for Materials Characterization and Testing became the ninth department of Fraunhofer ITWM at the Fraunhofer-Zentrum in Kaiserslautern, although it was established several years ago as part of Fraunhofer IPM. The work of the Center focuses on the non-destructive and non-contact testing of materials using electro-magnetic waves. The department is a leading international center for the characterization of multi-layer systems, for example, the materials found in the automobile and aviation industries. We use the terahertz range of the electro-magnetic spectrum because most of the materials tested are transparent in this range. Other application areas include testing glass and natural fiber reinforced composites for internal defects and monitoring the wall thickness in the production of plastic pipes and tubing. The Center provides the complete range of consulting services from the optimal measurement methods to special plant constructions for use on the production lines. Sophisticated algorithms evaluate the recorded measurement data and supply clear decision criteria as to whether the tested component meets the quality standards or is rather to be classified as defective. The close cooperation with the Image Processing department and the Competence Center for High Performance Computing enables rapid implementation of challenging solutions.

MAIN TOPICS

- Non-destructive and non-contact thickness measurements on micrometer to centimeter scale
- Defect detection in composite materials
- Wall thickness determination in plastic pipe production
- Terahertz spectroscopy for material identification
- Design and development of special equipment

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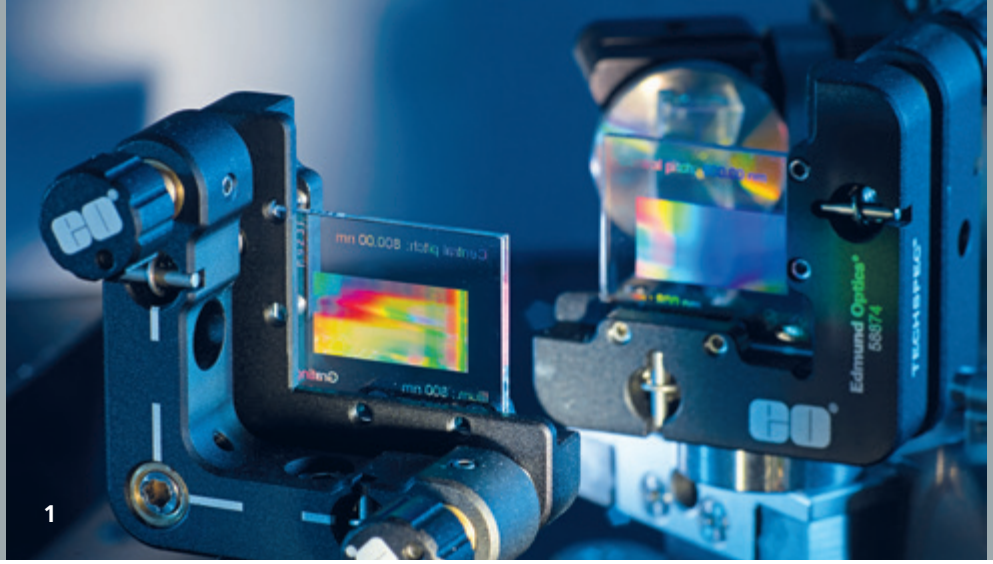


1

OPTICAL TERAHERTZ MEASURING SYSTEMS

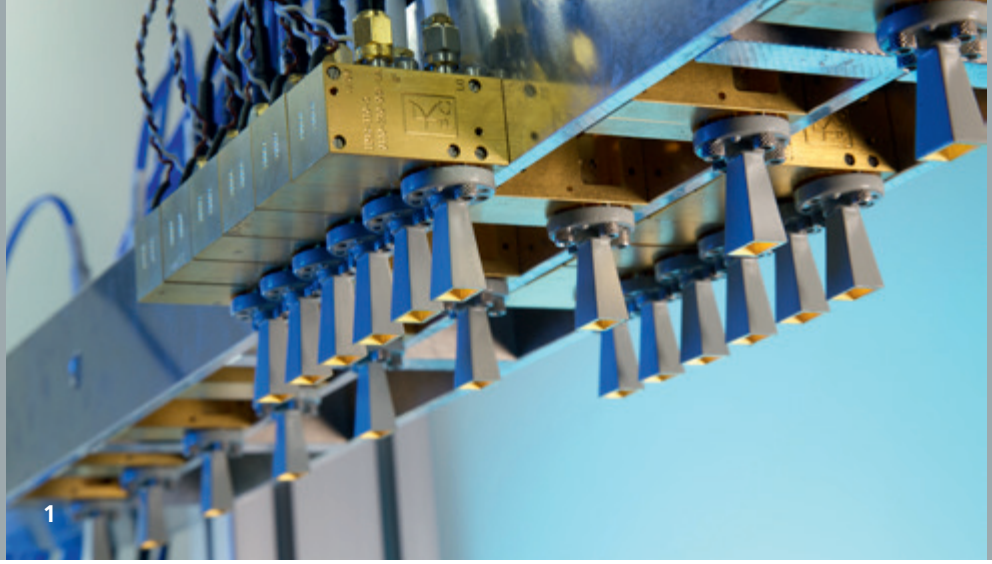
1 *Setup for compensating the dispersion of optical fibers used to transmit ultrashort laser pulses*

The group primarily designs and builds turnkey, terahertz time domain systems for the generation, detection, and analysis of broadband terahertz radiation. The applications range from robot-mounted coating thickness measuring systems and high spatial resolution spectroscopy, to metering systems for ultrafast electronics that combine extremely fast electro-optical converters and ultrafast optics. The group recently added a new branch to work on optical coherence tomography (OCT), which expands the range of layer thickness measurement to below 10 µm.

Terahertz technology is becoming established as the non-contact method for determining thickness, for example, in car paint finishing systems. In contrast to other non-destructive analysis methods, terahertz waves (that are in the range between infrared and microwave) can be used to obtain precise analyses of even the most complex multilayer systems. The reason behind this is that terahertz waves are reflected at every individual boundary at which the refractive index changes. Based on the different propagation times of the reflected partial waves, the layer thicknesses in multilayer systems can be very accurately determined – non-contact/non-destructive – and, this nearly independent of the substrata. The only method currently available to achieve this is the terahertz technology.

The measuring systems based on time domain spectroscopy are useful in the industry relevant range of single and multilayer systems from 10 – 500 µm. Fraunhofer ITWM has already successfully demonstrated this range in cooperation with several industry partners in the automotive industry. One very promising application of the technology is in measuring soft, structured layers, for example, the skins of PVC plastics used for car interiors. The evaluation of the detected terahertz signals is based on a complex evaluation algorithm, which is implemented on a commercially available graphic card and able to reliably determine the thickness distributions of a 4-layer system in less than one second. This determination is performed with an accuracy of up to ±1 µm.

The layer thickness evaluation algorithm is currently being further developed at Fraunhofer ITWM in cooperation with the High Performance Computing department. The aim is to increase robustness and efficiency to allow either an accelerated evaluation or a reduction of the hardware. This effort is in response to inquiries from industry.



ELECTRONIC TERAHERTZ MEASURING SYSTEMS

Another research priority at the Center for Materials Characterization and Testing is electronic terahertz measuring technology. This effort focuses, in particular, on the lower terahertz spectral region between 0.1 THz and 1 THz. In this sub-region of the spectrum, a good penetration depth of measuring signals in dielectrics like ceramics, textiles, plastics, or fiberglass reinforced composites, enables not only accurate determination of thickness in multilayer systems having a total thickness of up to a few decimeters (adjacent to the thickness measuring systems based on optical terahertz technology), but also lends itself very well to imaging in terahertz testing.

Complementary to ultrasound or x-ray testing, terahertz technology enables the visual inspection of dielectrics for internal defects or characteristic features. The non-contact terahertz testing also typically delivers very high-contrast images for soft materials and synthetic composites. Similar to ultrasound methods, tomography-like sectional depth images are produced and, in contrast to x-ray radiation, terahertz waves are not ionizing and do not require any protective measures.

Terahertz imaging systems, which scan the object pixel by pixel by means of a single sensor unit, have already proven their worth in preliminary testing and sample measurements. Meanwhile, the Center for Material Characterization and Testing has continued to significantly expand the portfolio for fast, industrial terahertz wave testing systems: It includes a broad range from hand-held single point sensors and fast scanning systems to in-line capable sensor networks for large area quality control testing.

A particularly interesting application is used for the inspection of the radomes on aircraft, both in the field and in production. Radomes are generally found on the nose of the fuselage and are composed of complex, fiberglass composite structures with functional materials incorporated such as foams or Kevlar. In addition to the structural integrity of the dome, it is also necessary to ensure trouble free operation of the radar system. Terahertz imaging allows these aspects to be addressed during production, enabling early detection of manufacturing defects as well as identifying optimization potential. When deployed in the field, terahertz imaging can be used to check for proper functionality as it makes it possible to detect damage that may not be visible from the outside, for example, due to impact.

1 *New concepts like the MIMO technique are evaluated for faster and more cost-efficient imaging solutions; here a MIMO radar system with 12 transmitters and 12 receivers, which are operating from 75 to 110 GHz.*

TALKS

Andrä, Heiko; Fink, Andreas; Glatt, Erik; Kabel, Matthias; Linden, Sven; Schneider, Matti; Staub, Sarah; Wiegmann, Andreas
Simulation of Elastic Deformations with Damage Effects for External and Pore Pressure
8th International Conference on Porous Media, May, Cincinnati (USA)

Andrä, Heiko; Fink, Andreas; Kabel, Matthias; Staub, Sarah
Pore-scale simulation of damage effects for porous rocks under external and pore pressure
Data-driven modeling and numerical simulation of microstructured materials (GAMM AG DATA), Kick-Off Workshop, September, Stuttgart

Andrä, Heiko; Kabel, Matthias; Schneider, Matti; Steiner, Konrad
Microstructure Simulation for the Determination of Nonlinear Material Parameters of Composites for Crash Simulation
Automotive CAE Grand Challenge, Hanau, April

Arne, Walter; Hietel, Dietmar
Modellierung, Simulation und Optimierung von Spinnprozessen
Vliesstofftage, Hof, November

Arne, Walter; Marheineke, Nicole; Wegener, Raimund
Viscoelastic law for Cosserat rod models with application in rotational spinning processes
ECMI, Santiago de Compostela (E), June

Balzer, M.; Burger, M.; Däuwel, T.; Ekevid, T.; Steidel, S.; Weber, D.
Coupling DEM Particles to MBS Wheel Loader via Co-Simulation
Kaiserslautern, March

Bartsch, Valeria
Programming Models for Exascale Supercomputers – A Slow Transition or Complete Disruption?
ISC'16, Bof 11.; Frankfurt, June

Biedinger, C.; Feth, S.
Usage Modeling of Commuters on Basis of Geographical Data for Vehicle Engineering
Kaiserslautern, April

Biedinger, C.; Weyh, T.; Opalinski, A.; Wagner, M.
Simulation of customer-specific vehicle usage
Kaiserslautern, March

Biedinger, C.; Weyh, T.; Speckert, M.
Simulation der kundenspezifischen Fahrzeugnutzung
München, November

Bortz, Michael
Calculating and navigating pareto sets: A versatile approach to support decisions in chemical engineering and beyond
Mathematical Methods in Process Engineering, International Workshop, Kaiserslautern, September

Bortz, Michael
Kosten und Nutzen balancieren: Entscheidungsunterstützung angefangen vom Handykauf bis hin zur Strahlentherapie
Physikalisches-Kolloquium WS/2017, Dortmund, November

Bortz, Michael; Schwientek, Jan; Burger, Jakob; Blagov, Sergej; Böttcher, Roger; Asprion, Norbert, Hasse, Hans
What ist he cost of a robust process design?
Jahrestagung der ProcessNet-Fachgemeinschaft "Prozess-, Apparate- und Anlagetechnik", Karlsruhe, November

Brand, A.; Bäcker, M.
Simulation des Reifenabriebs zur Bewertung von Nachlauflenkachskonzepten
Kaiserslautern, March

Calabrese, F.; Bäcker, M.; A., G.
Thermo-mechanical Tire Model to Predict Temperature Creation-Propagation and Rolling Resistance
Sterrebeek/Brussels (B), April

Calabrese, F.; Bäcker, M.; Gallrein, A.
Advanced structural MBD tire modelling for complex vehicle simulation scenarios
Hannover, February

Dalheimer, Mathias
Wie man ein Blackout verursacht
Security Tagung, Centrum für Informatik und Informationstechnik, TU Braunschweig, June

Dobrovolskij, Dascha
Simulation of Ultrasonic Materials Evaluation Experiments in Complex Media
19th World Conference on Non-Destructive Testing, München, June

Dobrovolskij, Dascha
Simulation of Ultrasonic Wave Propagation in Polycrystalline Material
French German Workshop, Kaiserslautern, November

Dörlich, V.; Linn, J.; Diebels, S.
Investigation of Finite Deformations of Multi-Component Cables
Châtenay-Malabry (F), April

Dreßler, K.
Fraunhofer ITWM - related products and technologies
Göteborg (S), June

Dreßler, K.
Simulationsqualität, Sensitivität und optimale Modellkomplexität
Hamburg, May

Dreßler, K.; Calabrese, F.; Bäcker, M.; Gallrein, A.
Transient structural tire simulation for complex vehicle simulation scenarios
Hanau, April

Dreßler, K.; Speckert, M.
Lastendatenanalyse und Beanspruchungsstatistik für variable Betriebslasten
München, November

Easwaran, Prakash
Representative domain size study on simulated 3D fiber systems
FILTECH Conference, Köln, October

Easwaran, Prakash
Stochastic modeling of 3D fiber systems incorporating interaction
The 19th European Conference on Mathematics for Industry, Santiago de Compostela (E), June

Eisenträger, Almut
Finite Pointset Method
British Applied Mathematics Colloquium (BAMC), Oxford (GB), April

Erlwein-Sayer, Christina
Investment and trading strategies for equities within a regime switching model
APMOD, Brno (CZ), June

Erlwein-Sayer, Christina
Methods for calculating the extent of financial losses due to healthcare fraud
EHFCN Open House, Lissabon (P), June

Ettrich, Norman
ACE – RTM at extreme scale
2016 Seam Workshop, Houston TX (USA), September

Fassbender, Achim; Orlik, Julia; Pietsch, Kathrin; Rief, Stefan; Shamanskiy, Alexander
Simulation of Elastic Properties of Spacer Fabrics and the Effective Permeability at different Compression Rates
The 7th World Conference in 3D Fabrics and Their Applications, Roubaix (F), September

Finhold, Elisabeth; Borgwardt, Steffen; De Loera, Jesús A.
The diameters of transportation polytopes satisfy the Hirsch Conjecture
SIAM Workshop on Network Science, Boston (USA), July

Fütterling, Valentin
Cluster-based Photo-realistic Real Time Rendering
IRTG General Meeting, Kaiserslautern, June und IRTG General Meeting, Berkeley (USA), October

Fütterling, Valentin
Parallel Spatial Splits in Bounding Volume Hierarchies
Eurographics Symposium on Parallel Graphics and Visualization in Groningen (NL), June

Fütterling, Valentin
Photo-realistic image synthesis with Path Tracing – An optimization problem?
Supercomputing Seminar, TU Kaiserslautern, July

Fütterling, Valentin
Towards Cluster-based Real Time Photo-realistic Rendering
Invited Talk, Computer Research Division Berkeley Lab (USA), Sept.

Gallrein, A.; Bäcker, M.; Calabrese, F.
Advanced tire modeling from multi body dynamics to linearization of the rotating tire
Coventry (GB), June

Gilberg, Dominik
On segregation in dry granular material flows in mixing processes
Talk at Young Researchers Symposium, Kaiserslautern, April

Gramsch, Simone
Virtual Nonwoven Production Processes
Mathematical Methods in Process Engineering, Kaiserslautern, September

Grün, Sarah
Estimating Discrete Dividends by No-Arbitrage
Second Quantitative Finance Symposium "Quattro Pole++", Trier, April und 9th European Summer School in Financial Mathematics Pushkin, St. Petersburg (RUS), September

Grünewald, Daniel
ACE – Reverse Time Migration at Extreme Scale
78th EAGE Conference & Exhibition, Dedicated - Towards Exascale Geophysical Applications, Wien (A), May

Grünewald, Daniel
GASPI: Bringing FDTD Simulations to Extreme Scale
Platform for advanced scientific computing conference, Minisymposium – Asynchronous Dataflow Driven Programming With GASPI, Lausanne (CH), May

Grünewald, Daniel; Machado, Rui
Tutorial: Efficient Parallel Programming with GASPI
HLRS, Stuttgart, June

Halfmann, T.
Prediction of tire performance for vehicle usage in the field
Sterrebeek/Brussels (B), April

Halfmann, T.; Steidel, S.; Gallrein, A.; Dreßler, K.; Pasalkar, V.
Extrapolation of rolling resistance for truck tires from specific load cases to vehicle usage in the field
Kaiserslautern, March

Haziza, Frédéric; Holik, Lukas; Meyer, Roland; Wolff, Sebastian
Pointer Race Freedom
POPL, St. Petersburg, Florida, (USA), January

Hietel, Dietmar
Mathematik ist Technologie
Kassel, November

Hietel, Dietmar
Simulationsbasierte Analyse der Inhomogenitäten in Vliesstoff-Filtermedien: Stochastisches Potenzial und seine Nutzung
13. Symposium Textile Filter, Chemnitz, March

Hietel, Dietmar; Antonov, Sergey; Gramsch, Simone; Gebhardt, Rainer; Reichel, Sven
Virtual generation of global nonwoven structures: Analysis, potential and chance for tailor-made products
Man-made Fibers Congress, Dornbirn (A), September

Hietel, Dietmar; Woltz, Sebastian
AKZESS – Aerodynamic Contactless Fiberizing from Melted Glass Strings
3rd International Glass Fiber Symposium, Aachen, October

Hoffmann, Anna
Novel approach for simulation and optimization of distillation-based flowsheets using fixed-point iterations for stage-to-stage calculations
Mathematical Methods in Process Engineering, International Workshop, Kaiserslautern, September

Hoffmann, Tobias; Andrä, Heiko; Fink, Andreas; Kabel, Matthias; Schneider, Matti; Staub, Sarah; Steiner, Konrad
Material CAE: Mikrostruktursimulation der nichtlinearen mechanischen Parameter von Verbundwerkstoffen
NAFEMS-Seminar "Simulation von Composites – Bereit für die Industrie 4.0", ZAL, Hamburg, October

Hofmann, Tobias
Numerical simulation of phase separation in lithium ion batteries
Talk at Young Researchers Symposium, Kaiserslautern, April

Hofmann, Tobias; Andrä, Heiko; Fink, Andreas; Kabel, Matthias; Schneider, Matti; Staub, Sarah; Steiner, Konrad
Microstructure simulation of nonlinear mechanical parameters of composites
NAFEMS, Hamburg, November

Hofmann, Tobias; Andrä, Heiko; Müller, Ralf
Linear elasticity in phase-separating lithium ion batteries
EMMC, Brüssel (B), September

Iliev, Oleg
Microstructure Simulation and Big Data
Felix Klein Conference "Mathematical Methods in Big Data", Kaiserslautern, September

Iliev, Oleg; Despande, Ruturaj; Antonyuk, Sergiy
Analysis Of Filter Cake Formation Using Computational Fluid Dynamics - Discrete Element Method (CFD-DEM) Simulation
Plenary talk at International Conference on Advances in Scientific Computing, Chennai (IND), November

Iliev, O.; Efendiev, Y., Latz, A.; Maday, Y.; Taralova, V.; Taralov, M.; Zausch, J.; Zhang, S.
On some mathematical challenges in studying multiscale electrochemical processes in Li-ion battery
Invited presentation, Research seminar of Mitsubishi Electric Research Laboratories, Boston (USA), May

Iliev, O.; Feinauer, J.; Hein, S.; Latz, A.; Maday, Y.; Ohlberger, M.; Rave, S.; Schmidt, S.; Schmidt, V.; Zausch, J.; Westhoff, D.; Zhang, S.
MOR approaches for simulation of electrochemical processes in porous electrodes of Li-ion batteries
KOMSO Workshop on Model Reduction, Renningen, November

Iliev, Oleg; Iliev, Dimitar; Kabel, Matthias; Kirsch, Ralf; Staub, Sarah
Kopplung von CDF und Elastizitätslösern zur Simulation strömungsinduzierten Verformung von Filtermedien
NAFEMS DACH Regionalkonferenz, Bamberg, April

Iliev, Oleg; Iliev, Dimitar; Kirsch, R.
Numerical simulation of fluid flow and poroelastic deformation in round pleat cartridges
Filtech, Köln, October

Iliev, Oleg; Iliev, Dimitar; Kirsch, R.
On solving of poroelasticity problems related to simulation of filtration processes
Invited talk at Large Scale Scientific Computing, Sozopol (PL), June

Iliev, Oleg; Kabel, Matthias; Kirsch, Ralf; Staub, Sarah
CAE for filter elements: From CFD to coupled simulations
Internat. Workshop "Mathematical Methods in Process Engineering", Kaiserslautern, September

Iliev, Oleg; Kirsch, Ralf; Osterroth, Sebastian
Combined depth and cake filtration coupled to flow simulation
Filtech, Köln, October

Iliev, Oleg; Mohring, Jan; Milk, Rene; Ohlberger, Mario; Klein, Oliver; Bastian, Peter
Toward Exascale Computations of Uncertainty Quantification for Porous Media Flow Using Multilevel Monte Carlo
Plenary talk, III. International Conference «Supercomputer Technologies in Mathematical Modelling», Moscow (RUS), June und Invited talk at Annual Meeting of Bulgarian section of SIAM, December

Iliev, O.; Prill, T.; Nessler, K.; Lakdawala, Z.; Printsypar, G.; Andrä, H.; Kabel, M.; Enzmann, Frieder; Wiegmann, A.; Schwarz, J.-O.
On Digital Rock Physics extended with Chemistry
Invited presentation, Research seminar of Schlumberger-Doll Research Center, Boston (USA), May und Plenary talk, Digital Core Workshop, Qingdao (CHN), August

Iliev, O.; Prill, T.; Nessler, K.; Dick, V.; Klein, P.; Lakdawala, Z.; Printsypar, G.; Vutov, Y.
Pore scale simulation of reactive flows on 3D CT images
Kick-off meeting of the German Chapter of InterPore, Erlangen, March

Iliev, O.; Prill, T.; Nessler, K.; Lakdawala, Z.; Printsypar, G.; Vutov, Y.
On pore scale simulation of reactive flows on 3D CT images of membranes and rocks
Annual meeting of InterPore, Cincinnati (USA), May

Iliev, O.; Prill, T.; Nessler, K.; Lakdawala, Z.; Printsypar, G.
Pore scale simulation of reactive flow
Workshop on Math. Methods in Process Engineering, Kaiserslautern, September und GeoDict User Meeting, Kaiserslautern, October

Iliev, Oleg; Prill, Torben; Nessler, Katherine; Lakdawala, Zahra; Printsypar, Galina; Enzmann, Frieder
Pore scale modeling of reactive flows for applications in purification and adsorption of pollutants
Filtech, Köln, October

Iliev, O.; Zemitis, A.; Nagapetyan, T.; Shklyar, I.; Steiner, K.; Johann, C.; Schuch, H.; Rösch, U.
Numerical simulation as a powerful tool to understand and improve FFF
Invited talk at 18th International Symposium on Field- and Flow-Based Separations, Dresden, May

Jami, Neil
A model and polynominal algorithm for purchasing and repositoring returnable containers
7th IFAC Conference on Management and Control of Production and Logistics, Bremen, February

Kabel, Matthias
Composite voxels for nonlinear mechanical problems
MPIE, Düsseldorf, July

Kabel, Matthias
Recent developments of FFT-based homogenization
Seminar für Numerische Mathematik und Mechanik, Universität Duisburg-Essen, January

Kabel, Matthias; Kirsch, Ralf; Staub, Sarah
Towards the simulation of manufacturing effects on multi-layered filter media
FILTECH, Köln, October

Keuper, Janis
Distributed training of deep neural networks: theoretical and practical limits of parallel scalability.
MLHPC Workshop at Supercomputing Conference 16, Salt Lake City, Utah, (USA), November

Keuper, Janis
Seminar: Introduction to Deep Learning
Birlinghoven, December

Keuper, Janis
Skalierbare Datenanalyse mit IPython
Data2Day Conference, Karlsruhe, October

Kleer, M.; Bitsch, G.; Dreßler, K.; Pena Vina, E.; Rothmann, T.
Ein neues Konzept zur Erprobung und Absicherung von Gesamtfahrzeugfunktionen
Baden-Baden, November

Kleer, M.; Dreßler, K.
Robot Based Driving and Operation Simulator (RODOS) – Excavator development
Eskilstuna (S), September

Kleer, M.; Gizatullin, A.; Pena Vina, E.; Dreßler, K.
New Environment Generation Techniques for Interactive Driving Simulation
Wiesbaden, April

Kleer, M.and Dreßler, K.
New Environment Generation Techniques for Vehicle and Machine Development
Stuttgart, April

Kleer, M.and Dreßler, K.
Upgrading machine development and proving processes with interactive simulations
Sindelfingen, September

Klein, Matthias
Das Fraunhofer ITWM als attraktiver Arbeitgeber
E-world energy & water, Essen, February

Köbler, Jonathan; Schneider, Matti; Andrä, Heiko
An efficient multiscale method for computing the effective viscoelastic response of short fiber reinforced thermoplastics
2016 EMI International Conference, Metz (F), October

Korn, Ralf
Aspekte der Chancen-Risiko-Klassifizerung
Qx-Club, Wiesbaden, January

Korn, Ralf
Das Effektivkostenkonzept
Assekuranzforum, Neu-Isenburg, April

Korn, Ralf
Das Risikobeurteilungsverfahren des EI-QFM
Tag des EI-QFM, Kaiserslautern, October

Korn, Ralf
Risiko
Nacht, die Wissen schaft, Kaiserslautern, April

Korn, Ralf
Stochastik und Statistik für Sekundarstufe II
Lehrerfortbildung (Philologenverband), Neustadt, February

Krüger, Jens
High Performance Tools for Big Data
Big Data Networking Day, Brüssel (B), January

Krüger, Jens
Smart Data for Smart Energy
Fraunhofer IAO, Stuttgart

Krüger, Jens
Technologies for High Performance Data Analytics
Fraunhofer IAO, Stuttgart und ComplexWorld, EASA Köln, September

Kuhnert, Jörg
Finite Pointset Method (FPM) in selected industrial applications
USACM Conference on Isogeometric Analysis and Meshfree Methods, La Jolla (USA), October

Kuhnert, Jörg
Meshfree numerical simulation in the industrial context: true problems that might arise if a scientific tool goes to the market
International Conference on Advances in Scientific Computing, Chennai (IND), November

Kuhnert, Jörg
True meshfree simulation in the industrial context
Volkswagen AG, CFD-Seminar, Wolfsburg, January

Küsters, Ferdinand
Beobachtbarkeit des Schaltsignals bei geschalteten ODEs und DAEs
10. Elgersburg Workshop, Elgersburg, February

Küsters, Ferdinand; Trenn, Stephan; Wirsen, Andreas
Constant-input observability of DAEs
GAMM/DMV Jahrestagung, Braunschweig, March

Küsters, Ferdinand; Trenn, Stephan; Wirsen, Andreas
Gemeinsame Beobachtbarkeit von Zustand und Schaltsignal bei homogenen geschalteten DAEs
GAMM-Fachausschuss "Dynamics and Control", Anif (A), September

Küsters, Ferdinand; Wirsen, Andreas
Constant-input observability of DAEs with application to power networks
Young Researchers Symposium, Kaiserslautern, April

Lamann, J.; Weyh, T.
Einsatz der Mehrkörpersimulation in der Entwicklung von Sattelaufliegern / Trailerfahrzeugen
Kaiserslautern, March

Leichner, A.; Andrä, H.; Simeon, B.
Numerical Solution of Contact Problems in Fibrous Microstructures using the Level Set Method on Voxel Discretizations
GAMM-DMV Joint Meeting, Braunschweig, March

Leithäuser, Christian; Feßler, Robert; Pinnau, René
Optimal Shape Design for Polymer Spin Packs
ECMI, Santiago de Compostela (E), June

Leoff, Elisabeth
Regime-Switching Models and Filterbased Volatility
12th German Probability and Statistics Days, Bochum, March

Lietzow, Bernd
An Introduction to BeeGFS
Des données au BigData: exploitez le stockage distribué, Gif-sur-Yvetter (F), December

Linden, Sven; Becker, Jürgen; Liping, Cheng; Wiegmann, Andreas
Estimation of Effective Cake Filtration Simulation Parameters from Resolved Filtration Simulations
Annual meeting of InterPore, Cincinnati (USA), May

Linn, J.
Discrete kinematics of Cosserat rods based on the difference geometry of framed curves
Montréal, Québec (CDN), May

Linn, J.
The Fraunhofer research project EMMA-CC: »Ergo-dynamic Moving MAnikin with Cognitive Control«
Heidelberg, October

Linn, J.; Roller, M.; Sadiku, V.; Schneider, F.; Loris, C.; Hoeft, F.
Cable dynamics simulation & comparative fatigue analysis
Göteborg (S), June

Maag, Volker
Designing hybrid energy systems for buildings
5th International Conference on Engineering Optimization, Igassu Falls (BR), June

Merten, Dirk
A Parallelization Strategy for the 5D Data Mapping Problem in Angle Migration
78th EAGE Conference & Exhibition, Dedicated - Towards Exascale Geophysical Applications, Wien (A), May

Mohrbacher, Christian
BeeGFS
Rice University Oil&Gas HPC Workshop

Mohring, Jan
RoMI – Root Cause Analysis of Measurement Issues
Symposium Integriertes 3D-Messdatenmanagement, Landau, June

Musolino, Paolo; Orlik, Julia
Homogenization of Coulomb-contact in domains with cracks via the periodic unfolding method
Minisymposium "Asymptotic analysis: homogenization and thin structures", 14th IMSE, Padova (I), July

Neunzert, Helmut
SURPRISES: Problems and theories I had not expected to be so beneficial for industrial mathematics
21th International Conference Mathematical Modelling and Analysis (MMA2016), Tartu (EST), June

Neunzert, Helmut; Iliev, Oleg
What is industrial mathematics and why should we do it?
Plenary talk, International Conference on Advances in Mathematics, Chennai (IND), November

Orlik, Julia; Musolino, Paolo
General rescaling of basic inequalities and co-normal derivatives in second order elliptic PDEs in periodic domains
4th Workshop of the GAMM Activity Group on Analysis of Partial Differential Equations, TU Dortmund, September

Orlik, Julia; Neusius, David
Simulation and Optimization of Textile Membrane via Homogenization and Beam Approximation
Multiscale Modeling of Fibrous and Textile Materials,Colloquium 569 , 5 April – 7 April, Chatenay-Malabry (F)

Orlik, Julia; Shiryaev, Vladimir
Simulation and optimization of textile membrane via homogenization and beam Approximations
Workshop Multi-Scale and Multi-Physics Testing of High-Performance Materials, TU Berlin, February

Osterroth, S.; Iliev, O.; Pinnau, R.
A combined sensitivity analysis and model reduction workflow for the simulation of cake filtration
Young Researchers Symposium, Kaiserslautern, April

Pfreundt, Franz-Josef
BeeGFS
15th HLRS/hww Workshop on Scalable Global Parallel File Systems, HRLS, Stuttgart, April

Pfreundt, Franz-Josef
Deep Learning - a Performance and Data Challenge
Advanced Analytics Infrastructure Dialog München, December

Pfreundt, Franz-Josef
Next Step: Big Data im Kontext der künstlichen Intelligenz
Big Data Strategiedialog, Bonn, April

Pfreundt, Franz-Josef
Programming large memory machines
Hewlett Packard Enterprise, Kalifornien, (USA), October

Prill, Torben; Iliev, Oleg; Nessler, Katherine; Lakdawala, Zahra
Scale Simulation of Reactive Transport in Technical and Natural Porous Media
InterPore, First German National Chapter Meeting, Leipzig, November

Prill, T.; Zausch, J.; Latz, A.; Becker-Steinberger, K.
Simulation of Ion-Transport in Deforming Porous Battery Electrodes
ModVal 13, Lausanne (CH), March

Prill, T.; Iliev, O.; Nessler, K.; Lakdawala, Z., Printsypar, G.; Enzmann, F.
Pore-Scale Modeling of Reactive Flows for Applications in Water Purification and Absorption of Pollutants in Soil
XXI International Conference Computational Methods in Water Resources, Toronto (CDN), June

Prill, T.; Iliev, O.; Nessler, K.; Lakdawala, Z.; Printsypar, G.; Enzmann, F.; Kersten, M.
Pore-Scale Simulation of Reactive Flows
French-German Workshop "Mathematische Bildverarbeitung / Traitement d'image mathématique"

Rahn, Mirko
GPI-Space – how it works as auto-parallelization framework
Hewlett Packard Enterprise, California, (USA), October

Rau, S.; Niedziela, D.; Neusius, D., Zausch, J.; Schmidt, S.
Granular flow in Food Industries: Simulation of Silo Discharge and pneumatic transport
KoMSO Challenge Workshop: Mathematical Modelling, Simulation and Optimization in Food Industries, Trier, March

Rau, S.; Niedziela, D.; Steiner, K.; de Vita, S.; Richter, M.; Lutsche, M.; Schmidt, M.; Stoltz, C.
Virtual characterization of dense granular flow through a vertically rotating feeding experiment
Partec, Nürnberg, April

Rau, S.; Niedziela, D.; Zausch, J.; Neusius, D.; Gilberg, D.; Schmidt, S.
Granular flow simulations with continuum models
Mathem. Methods in Process Engineering, Kaiserslautern, September

Rauhut, Markus
POD as a Tool Evaluating the Quality of Optical NDT Approaches
19th World Conference on Non-Destructive Testing, München, June

Rief Stefan, Aibibu Dilibaier, Kocaman Türkay, Cherif Chokri
Experimental and numerical study of high density filter textiles to determine permeability and retention properties under tensile stress.
FILTECH, Köln, October

Roller, M.; Linn, J.
Discrete geometric modeling of slender flexible structures for interactive assembly simulation in automotive industry
Santiago de Compostela (E), June

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

Rösch, Ronald
Fehlerdetektion in texturierten Oberflächen im praktischen Einsatz
9. Fraunhofer Vision Technologietag, Fürth, October

Sayer, Tilman
Beating Markowitz with Sentiment and Downside Risk Control
AI, Machine Learning & Sentiment Analysis Applied to Finance, London (GB), July

Sayer, Tilman
Data Analytics and Sentiment Analysis as Sources of Business Intelligence
Data Analytics and Sentiment Analysis as Sources of Business Intelligence, London (GB), April

Schladitz, Katja
3D Bildanalyse der Mikrostruktur komplexer Materialien
9. Fraunhofer Vision Technologietag, Fürth, October

Schladitz, Katja
3D image analysis and stochastic geometry models for materials structures
International Workshop on Characterization of Material Properties based on X-ray Tomography, Panagyurishte (BG), April

Schladitz, Katja
Characterization of biological structures by the intrinsic volumes
Analysis of image data for diagnostics, Prag (CZ), October

Schladitz, Katja
Micro-structural analysis of leather based on 3D image data
6. Freiberger Kollagensymposium, Freiberg, September

Schladitz, Katja
Natural and man-made multiscale materials structures
From Nano to Macrostructures and Characterisation of Soft Materials, Strömstad (S), August

Schneider, F.; Burger, M.; Linn, J.
Efficient and robust co-simulation of geometrically exact Cosserat rod model and multibody system
Santiago de Compostela (E), June

Schneider, Matti
Generating fiber-filled volume elements with high fiber volume fraction and prescribed fourth order fiber orientation tensor
GAMM AG DATA Kick-Off Workshop, Stuttgart, September

Schneider, Matti
Numerical homogenization of the viscosity of a fiber suspension
Seminar-Serie des GRK 2078 CoDiCoFRP, KIT, Karlsruhe, January

Schneider, Matti; Kabel, Matthias; Andrä, Heiko
Thermal fiber orientation tensors - a novel approach for characterizing the local fiber orientation in paper and paperboard
Progress in Paper Physics Seminar, Darmstadt, August

Schneider, Matti; Merkert, Dennis; Kabel, Matthias
FFT-based homogenization for microstructures discretized by linear hexahedral elements
2016 EMI International Conference, Metz (F), October

Schröder, Simon
Visualization of Meshfree Simulations with STRING 3
11. SPRING User Conference, Pretoria (ZA), September

Schwientek, Jan
Using data in process engineering: Mode building, sensitivity analysis and optimization
Mathematical Methods in Process Engineering, International Workshop, Kaiserslautern, September

Siedow, N.; Mohring, J.; Linn, D.; Brüggemann, T.; Heidenbluth, M.
Dynamische Netzsimulation zur Effizienzsteigerung und Emissionsreduzierung in der Fernwärmeversorgung
UMSICHT: Zur Sache! Strom-Wärme-Kopplung neu denken; Oberhausen, December

Slater, A.; Rief, S.; Steiner, K.
Automotive filtration – fibrillation makes the difference
55th Dornbirn man-made fibres Congress, Dornbirn (A), September

Speckert, M.; Dreßler, K.
Statistische Lastendatenanalyse unter Verwendung von Faktormodellen
München, November

Speckert, M.; Dreßler, K.; Lübke, M.; Halfmann, T.
Automatisierte und um GEO-Daten angereicherte Auswertung von Messdaten zur Herleitung von Beanspruchungsverteilungen
Steyr (A), October

Staub, S.; Andrä, H.; Fink, A.; Kabel, M.; Sliseris, J.; Steiner, K.
Stochastic Fiber Network Models for Paper: Generation, Deformation, Permeability
Interpore 8th International Conference on Porous Media, Cincinnati (USA), May

Staub, S.; Andrä, H.; Kabel, M.
Rate-Dependent Deformation Simulation of Nonwovens
Euromech 569, Multiscale modeling of fibrous and textile materials, Paris (F), April

Staub, Sarah; Andrä, Heiko; Kabel Matthias; Steiner, Konrad
Structure Generation and Nonlinear Deformation Simulation of Thin Nonwoven Structures at the Micro-Scale
Interpore 8th International Conference on Porous Media, Cincinnati (USA), May

Staub, Sarah; Andrä, Heiko; Kabel, Matthias
Modeling and Nonlinear Deformation Simulation of Thin Nonwoven Textiles
GeoDict User Meeting, Kaiserslautern, October

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

Wächtler, Timo
A Finite Pointset Model For Reactive Mixing
USACM Conference on Isogeometric Analysis and Meshfree Methods, La Jolla (USA), October

Wagner, Andreas
Integrated Electricity Price Model
Energy Finance Italia II, Padua (I), December

Weis, M.; Kleer, M.; von Holst, C.; Gizatullin, A.
Interactive Tractor Driving Simulation
Kaiserslautern, March

Wirsen, Andreas
Matlab Toolbox: Controller Design for Active Vibration Damping
Seminar on Modeling, Simulation and Optimization in Automotive and Vehicle Industry, Fraunhofer Chalmers Centre, Göteburg (S), December

Zausch, Jochen
Coupled thermal-electrochemical simulation of Li-ion batteries on micro and cell scale
Warwick University, Coventry (UK), June

Zausch, Jochen
Das Verbundprojekt "TopBat": Temperaturoptimierte Batteriemodule mit instrumentierten Zellen
Fraunhofer Symposium Netzwert, München, February

Zausch, Jochen; Prill, Torben; Latz, Arnulf
Modeling of lithium ion batteries on micro and cell scale with emphasis on thermal coupling and spatial fluctuations
ISE 67th Annual Meeting, Den Haag (NL), August

Zémerli, C.
A simulation framework for optimising wiring harness while accommodating the needs of manufacturing constraints and assembly
Bad Nauheim, February

TEACHING ACTIVITIES

Andrä, Heiko
Festigkeitslehre
DHBW CAS Heilbronn, Winter term 2015/16

Andrä, Heiko
Höhere Mathematik
DHBW CAS Heilbronn, Winter term 2015/16

Andrä, Heiko
Kontaktmechanik
University of Kaiserslautern, Winter term 2016/2017

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

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

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

Burger, Michael
Optimal Control of ODEs and DAEs
University of Kaiserslautern, Summer term 2016

Dreßler, Klaus
Durability Load Data Analysis
TU Kaiserslautern, Summer term 2016

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

Kabel, Matthias
Digital Material Characterization of Composites
University Stuttgart, October 2016

Kleer, Michael
Robotik 1
University of Applied Sciences Kaiserslautern Kaiserslautern, 2015 – 2017

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

Küfer, Karl-Heinz
Probability and Algorithms
University of Kaiserslautern, Winter term 2016/17

Küfer, Karl-Heinz
Theory of Scheduling Problems
University of Kaiserslautern, Summer term 2016

Prätzel-Wolters, Dieter
Professur für Technomathematik
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Steidel, Stefan
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University of Applied Sciences Kaiserslautern, Winter term 2015/2016

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A differential-algebraic coupling approach for force-displacement co-simulation of flexible multibody systems with kinematic coupling
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Schneider, M.; Ospald, F.; Kabel, M.:
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Schneider, Matti:
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Schwerdfeger, S.; Walter, Rico:
A fast and effective subset sum based improvement procedure for workload balancing on identical parallel machines
In: Computers & operations research 73 (2016), S.84-91

Shahzad, F.; Kreutzer, M.; Zeiser, T.; Machado, R.; Pieper, A.; Hager, G.; Wellein, G.:
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Steidel, S.; Halfmann, T.; Bäcker, M.; Gallrein, A.:
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Vabishchevich, P.N.; Zakharov, P.E.:
Alternating triangular schemes for convection-diffusion problems
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Vecchio, I.; Redenbach, C.; Schladitz, K.; Kraynik, A.M.:
Improved models of solid foams based on soap froth
In: Computational materials science 120 (2016), S.60-69

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In: Molecular physics (2016), 14 S.

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In: Image, analysis & stereology 35 (2016), Nr.3, S.167-179

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SCIENTIFIC GRADUATION THESES

Akinlabi, Emmanuel Olutayo
Simulation of Cerebrospinal Fluid (CSF) Flow with the Finite Pointset Method (FPM)
Master thesis, African Institute for Mathematical Sciences (AIMS), Senegal

Barthlen, Andreas Michael
Stability Preservation for parametric model order reduction by matrix interpolation
Doctoral thesis, University of Kaiserslautern, Dept. of Mathematics

Becker, Yannick
Evaluation der Umsetzung agiler Softwareentwicklung in heterogenen Projektteams und unter besonderer Berücksichtigung der testgetriebenen Entwicklung
Bachelor thesis, University of Applied Sciences Trier, Dept. of Environmental Planning and Engineering

Bergner, Tim
Verteilte Algorithmen für gewichtete Matchings
Bachelor thesis, University of Kaiserslautern, Dept. of Mathematics

Brugger, Patrick
Testen funktionaler Zusammenhänge von Beanstandungsquoten in der Betrugsdetektion
Bachelor thesis, University of Kaiserslautern, Dept. of Mathematics

Cruz Lopez, Rogelio
Electronic Interface for on board Instruments in a Driving Simulator
Master thesis, University of Applied Sciences Kaiserslautern, Dept. of Applied Engineering Sciences

D'Angelo, Phillipp
Statistische Lernmethoden zur Bestimmung der Ausfallwahrscheinlichkeiten
Master thesis, University of Kaiserslautern, Dept. of Mathematics

Dondelinger, Fabienne
Estimation of the local pore size distribution from granulometric data
Master thesis, University of Kaiserslautern, Dept. of Mathematics

Dürig, Dominik
Greybox-Ansatz für chemische Anlagen – Integration von Prozessdaten und Simulation
Master thesis, RWTH Aachen, Aachener Verfahrenstechnik (AVT)

Gnanasambandham, Chandramouli
Model Reduction of Nonlinear Systems using Proper Orthogonal Decomposition
Master thesis, University of Kaiserslautern, Dept. of Mechanical and Process Engineering

Gottschalk, Simon
One-Shot Methods for ODE/DAE Optimal Control Problems
Master thesis, University of Kaiserslautern, Dept. of Mathematics

Grimm, Stefanie
An Interest Rate Model with Regime-Switching Mean-Reversion Level
Doctoral thesis, University of Kaiserslautern, Dept. of Mathematics

Gross, Andreas
Aufbau eines Messfahrzeugs (Demonstration zur laserbasierten Umwelterfassung)
Bachelor thesis, University of Applied Sciences Kaiserslautern, Dept. of Applied Engineering Sciences

Hambardzumyan, Hayk
Aspects of Surplus Distribution in Life Insurance
Master thesis, University of Kaiserslautern, Dept. of Mathematics

Hauck, Michael
Stucture optimization for cylindric multi-scale shell
Master thesis, University of Kaiserslautern, Dept. of Mathematics

Heimfarth, Tobias
Integration of shallow water modellings in computational fluid dynamics based on the Finite-Pointset-Method (FPM)
Diploma thesis, University of Kaiserslautern, Dept. of Mechanical and Process Engineering

Hermann, Florian
Untersuchung der 3D-Faserarchitektur von trockenen und imprägnierten C-Faser-Textilien mittels Computertomografie
Bachelor thesis, University Stuttgart, Institute for Aircraft Construction

Hinderks, Wieger
Factor Models & Electricity Markets – Modeling Mean Reversion and Spikes
Master thesis, University of Kaiserslautern, Dept. of Mathematics

Hoffmann, Anna
Integrated simulation and optimization of distillation-based flowsheets
Doctoral thesis, University of Kaiserslautern, Dept. of Mathematics

Hohmann, Raphael
Ein volumengemitteltes Modell für Partikeltransportprobleme in Fluiden
Master thesis, University of Kassel, Dept. of Mathematics

Iliev, Dimitar
Numerical Algorithms for Fluid Interaction with a Thin Porous Structure
Doctoral thesis, University of Kaiserslautern, Dept. of Mathematics

Jung, Thomas
Numerik und Analyse mikroskopischer Verkehrsmodelle
Master thesis, University of Kaiserslautern, Dept. of Mathematics

Kass, Benjamin
Modellierung von Hydraulikschläuchen unter Innendruck
Master thesis, University of Kaiserslautern, Dept. of Mechanical and Process Engineering

Keller, Niclas
Uniforme Konfidenzintervalle für nicht-homogene Beanstandungsquoten in der Betrugsdetektion
Bachelor thesis, University of Kaiserslautern, Dept. of Mathematics

Leoff, Elisabeth
Stochastic Filtering in Regime-Switching Models: Econometric Properties, Discretization and Convergence
Doctoral thesis, University of Kaiserslautern, Dept. of Mathematics

Leoff, Jens
Hierarchical scheduling and cutting stock with bounded open orders
Doctoral thesis, University of Kaiserslautern, Dept. of Mathematics

Lichti, Tobias
Nichtlineares viskoelastisches Materialmodell für das Kompressionsverhalten von Vliesstoffen
Bachelor thesis, DHBW Mannheim, Mechanical Engineering

Linn, Dominik
Reconstruction of three dimensional fiber structures from orthogonal projections
Master thesis, University of Kaiserslautern, Dept. of Mathematics

Migunova, Anastasia
Outer-plane properties of thin heterogeneous periodic layers
Doctoral thesis, University of Kaiserslautern, Dept. of Mathematics

Neusius, David
Advanced interpolation cut-cell method for numerically solving continuum granular flow equations
Doctoral thesis, University of Kaiserslautern, Dept. of Mathematics

Peters, Christian Dietrich
Aerodynamic damping of an oscillating fan blade: Numerical Fluid Structure Interaction Analysis
Master thesis, Univ. Stellenbosch, South Africa, Department of Mechanical Engineering

Roller, Michael
Dynamische Reifensimulation mit geometrisch exakten Schalen
Doctoral thesis, Karlsruhe Institute of Technology (KIT), Department of Civil Engineering, Geo and Environmental Sciences

Schäb, Lisa
Bewertung der EEX Wind-Futures
Bachelor thesis, THM University of Applied Sciences, Friedberg, Dept. MND

PARTICIPATION IN FAIRS AND CONFERENCES

Schledjewski, Malte
MapViewer – eine Softwarekomponente zur Visualisierung statistischer und georeferenzierter Daten
Bachelor thesis, University of Applied Sciences Kaiserslautern, Dept. of Applied Computer Sciences

Schmeißer, Andre
Contact Modeling Algorithms for Fiber Dynamics Simulations
Doctoral thesis, University of Kaiserslautern, Dept. of Applied Computer Sciences

Schneider, Fabio
A differential-algebraic coupling approach for force-displacement co-simulation of flexible multibody systems with kinematic coupling
Doctoral thesis, University of Kaiserslautern, Dept. of Mathematics

Schneider, Johanna
Einsatzoptimierung für mobile Röntgeneinheiten im Mammografiescreeningprogramm
Master thesis, University of Kaiserslautern, Dept. of Mathematics

Schwartz, Patrick
Konzeption und prototypische Umsetzung eines Ausdrucksrechners und Faktoreditors für VMC
Master thesis, University of Applied Sciences Kaiserslautern, Dept. of Applied Computer Sciences

Seidel, Tobias
Construction of Pareto-Frontiers for Risk-Averse Selective Newsvendor Problems
Master thesis, University of Kaiserslautern, Dept. of Mathematics

Syeda, Sonia
Using Business Intelligence Techniques to Analyze Truck Chassis Design Data
Master thesis, University of Kaiserslautern, Dept. of Mathematics

Volmerg, Kim
Scheduling mit Batching – Produktionsplanung in einem Leimholzwerk
Master thesis, University of Kaiserslautern, Dept. of Mathematics

Wackerle, Stephan
Mean-field limit of particle disease spreading models
Master thesis, University of Kaiserslautern, Dept. of Mathematics

Wagner, Christian
GPS-gestützte Positionsschätzung zur autonomen Navigation eines Quadrokopters
Bachelor thesis, University of Applied Sciences Kaiserslautern, Dept. of Applied Engineering Sciences

Wieland, Manuel
Modellierung und Simulation der charakteristischen Instabilität beim Elektrospinnprozess
Master thesis, FAU Erlangen, Dept. of Mathematics

Zintsova, Anastasia
POD-based model reduction for unsteady diffusion in spherical particle subject to linear and nonlinear Robin boundary conditions
Master thesis, University of Kaiserslautern, Dept. of Mathematics

67th Annual Meeting of the International Society of Electrochemistry
Den Haag (NL), August, Lecture

60. Bildverarbeitungsforum: Multisensorielle 3D-Datenfusion
Wiesbaden, March

61. Bildverarbeitungsforum: Erfolge, Defizite und Zukunftsthemen der Bildverarbeitung
Heidelberg, April

62. Bildverarbeitungsforum: Hochleistungsbildaufnahmesysteme quer durch das elektromagnetische Spektrum
Bensheim, July

63. Bildverarbeitungsforum: Bildverarbeitung und Robotik
Renningen, October

British Applied Mathematics Colloquium (BAMC)
Oxford (GB), April, Lecture

CMWR 2016
Toronto (CDN), June, Lecture

Felix-Klein-Konferenz: Mathematical Methods in Big Data
Kaiserslautern, September

Control 2016
Stuttgart, April, Exhibitor

CVC-Jahrestagung
Mannheim, November, Exhibitor, Lecture

CVC-Mitgliederversammlung
Maynz, March

DVM Arbeitskreis Betriebsfestigkeit: Potenziale im Zusammenspiel von Versuch und Berechnung in der Betriebsfestigkeit
Steyr (A), October, Exhibitor, Lecture

EAGE 2016
Wien (A), May, Exhibitor, Lecture

ECCOMAS 2016
Kreta (GR), June, Lecture, Poster

ECMI 2016
Santiago de Compostela (E), July, Lecture

EMI 2016
Metz (F), October, Lecture

EMMC
Brüssel (B), September, Lecture

Energy Finance Italia
Padua (I), December, Lecture, Poster

EngOPT 2016
Igassu Falls (BR), June, Lecture

ERWAS Workshop
Frankfurt, March

7th European Congress of Mathematics
Berlin, July, Exhibitor

European Symposium on Computer-Aided Process Engineering
Portoroz (SLO), June, Lecture

E-World energy & water
Essen, February, Exhibitor, Lecture

FILTECH 2016
Köln, October, Exhibitor, Lecture, Poster

Fraunhofer-Symposium Netzwert
München, February, Lecture

9. Fraunhofer Vision Technologietag
Fürth, October, Exhibitor, Lecture

French-German Workshop: Mathematische Bildverarbeitung/Traitement d'image mathématique
Kaiserslautern, November, Lecture

GAMM/DMV-Jahrestagung 2016
Braunschweig, March, Lecture

GeoDict User-Meeting 2016
Kaiserlautern, October, Lecture

Hannover-Messe
Hannover, April, Exhibitor

31. Hofer Vliesstofftage
Hof, November, Exhibitor, Lecture

7th IFAC Conference on Management and Control of Production and Logistics
Bremen, February, Lecture

International Workshop: Mathematical Methods in Process Engineering
Kaiserslautern, September, Lecture

AWARDS AND PRIZES

Bortz, Michael; Küfer, Karl-Heinz; Scherrer, Alexander; Süss, Philipp; Teichert, Katrin
Stifterverband Science Prize
Stifterverband für die Deutsche Wissenschaft e. V.
May

Gilberg, Dominik
Young Researcher Symposium 1st Prize Category »Best Talk«
TU-Nachwuchsring, Kaiserslautern
April

Hofmann, Tobias
Young Researcher Symposium 3rd Prize Category »Best Talk«
TU-Nachwuchsring, Kaiserslautern
April

Kleinert, Jan
ICT Dissertation Award
Gesellschaft für Informatik e.V. (GI), Klagenfurt (A)
October

Schulz-Reese, Marion
Fraunhofer Taler
Fraunhofer-Gesellschaft, München
June

Zausch, Jochen
ELEKTRONIK »Artikel des Jahres«
Redaktion ELEKTRONIK
March

OWN EVENTS

»Abschiede sind Tore in neue Welten«
Farewell ceremony for Dr. Marion Schulz-Reese
Kaiserslautern, June

»Türen auf für die Maus!« – Lach- und Sachgeschichten aus der »Bildverarbeitung«
Kaiserslautern, October

BeeGFS Usermeeting
Kaiserslautern, May

German-French Workshop: Mathematische Bildverarbeitung/Traitement d'image mathematique
Kaiserslautern, November

Opening ceremony des High Performance Center "Simulation and Software-based Innovation"
Kaiserslautern, March

Felix-Klein-Conference: Mathematical Methods in Big Data
Kaiserslautern, September

Felix-Klein-Annual Conference with Modeling Week
Kaiserslautern, September

Festive Colloquium for Prof. Helmut Neunzert
Kaiserslautern, September

International Workshop: Mathematical Methods in Process Engineering
Kaiserslautern, September

4. Internationales Commercial Vehicle Technology Symposium
Kaiserslautern, March

Nacht, die Wissen schafft
Kaiserslautern, April

Seminar: Data Scientist for Smart Energy Systems
Kaiserslautern, November

Seminar: Introduction to Deep Learning
Birlinghoven, November

Seminar: KL-Regelungstechnik
together with professors of the University of Kaiserslautern, monthly since November 2016

4. Internationales Commercial Vehicle Technology Symposium
Kaiserslautern, March, Exhibitor, Lecture

Interpore
Cincinnati (USA), May, Exhibitor, Lecture

Interpore Benelux
Venlo (NL), October, Exhibitor

InterPore: 1st German National Chapter Meeting
Leipzig, November, Lecture

IPS User Conference 2016
Göteburg (S), June, Exhibitor, Lecture

ISC High Performance 2016
Frankfurt, June, Exhibitor

K 2016
Düsseldorf, October

Man-made Fibers Congress 2016
Dornbirn (A), September, Lecture

ModVal 13
Lausanne (CH), March, Lecture

Multibody Simulation User Group Meeting
Darmstadt, November, Exhibitor

Multiscale phenomena in electrochemical and porous system
Coventry (GB), June, Lecture

Nacht, die Wissen schafft
Kaiserslautern, April, Exhibitor

NAFEMS
Hamburg, November, Lecture

NAFEMS DACH
Bamberg, April, Lecture

PARTEC International congress on Particle Technology
Nürnberg, April, Lecture, Poster

PASC 16
Lausanne (F), May, Lecture

POWTECH 2016
Nürnberg, April, Exhibitor

REC 2016 International Workshop on Reliable Engineering Computing
Bochum, June

SC 16 – Supercomputing 2016
Salt Lake City (USA), November, Exhibitor, Lecture

SCA – Society of Core Analysts
Snowmass (USA), August, Exhibitor

Seam Workshop 2016
Houston (USA), September, Lecture

SEG International Exposition 2016
Dallas (USA), October, Exhibitor

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

Seminar on Modeling, Simulation and Optimization in Automotive and Vehicle Industry
Göteborg (S), December, Lecture

SIAM Workshop
Boston (USA), July

SIMVEC – Simulation und Erprobung in der Fahrzeugentwicklung
Baden-Baden, November, Exhibitor, Lecture

Symposium Computer-Aided Process Optimization
Hürth, February

13. Symposium: Textile Filter
Chemnitz, March, Exhibitor, Lecture

Tag der Mathematik
Kaiserslautern, July, Exhibitor

UMSICHT: Zur Sache! Strom-Wärme-Kopplung neu denken
Oberhausen, December, Lecture

VI-grade Users Conference 2016
Wiesbaden, April, Exhibitor, Lecture

Vision 2016
Stuttgart, November, Exhibitor

7th World Conference in 3D Fabrics and Their Applications
Roubaix, (F), September

WORM 2016
Bad Herrenalb, August, Lecture

GUESTS

Seminar: Lastdaten – Analyse, Bemessung, Simulation
Kaiserslautern, May

Seminar: Statistische Methoden in der Betriebsfestigkeit
Kaiserslautern, June

Seminar: Wissenschaftliche Anwendungen in Python
Kaiserslautern, September

Symposium: Kick-off-Meeting FuE-Lab 2 des Leistungszentrums »Simulations- und Software-basierte Innovation«
Kaiserslautern, July

Technology-Day on geo-referenced Analysis and Usage Simulation for Vehicle Development
Kaiserslautern, March

Tutorial: Efficient Parallel Programming With GASPI
Stuttgart, June und Kaiserslautern, October

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

Workshop: Designing Materials for Mechanical Properties with GeoDict
Kaiserslautern, February

Workshop: Mathematical Methods in Process Engineering
Kaiserslautern, September

Workshop: Neuerungen im Produktinformationsblatt
Kaiserslautern, November

Young Researchers Symposium
together with Innovationszentrum Applied System Modeling for Computational Engineering (ASM4CE) and TU-Nachwuchsring, Kaiserslautern, April

Series of lectures "Blick über den Tellerrand"
Kaiserslautern

Schumacher, Hajo
Journalist, Berlin
Restlaufzeit – wie ein gutes, lustiges und bezahlbares Leben im Alter gelingen kann
January

Liessmann, Konrad Paul
University of Wien (A), Institute of Philosophy
Freiheit von Forschung und Lehre - Nostalgie oder Utopie?
February

Grützner, Andrea
Photografer, Berlin
Um die Ecke denken – Andere Räume in der Fotografie
March

Keßler, Walter
Kaiserslautern
Fraunhofer – Pauli – Denis
April

Tetens, Holm
Freie Universität Berlin, Theoretical Philosophy
Ist der Gottesglaube wissenschaftlich betrachtet unvernünftig?
May

Ziegler, Günter M.
Freie Universität Berlin, Institute of Mathematics
Das Mädchen mit den Taschenrechnern – Bilder aus der Mathematik
June

Goebel, Johannes
Curtis R. Priem Experimental Media and Performing Arts Center, Rensselaer Polytechnic Institute, Troy, USA
Über Unterschiede: Kunst, Wissenschaft und Engineering
September

Rentzsch, Oliver
University of Applied Sciences, Lübeck
Kann Medizin wirklich ein »Geschäft« sein?
November

Stichweh, Rudolf
University of Bonn, Forum of International Science
Das Wissenschaftssystem der Moderne: Entstehung, Strukturen, gesellschaftliche Einbettung
December

Argatov, Ivan
(University of Oulu (FIN))
Contact problems with thin layers
October-November

Arnold, Martin
(Martin-Luther-University of Halle-Wittenberg)
Numerics for Multibody systems
March, July, November

Betsch, Peter
(University of Siegen)
Modeling of tires
February

Biegler, Lorenz T.
(Carnegie Mellon University, Pittsburgh (USA))
Advanced nonlinear programming strategies for process optimization
September

Cesarek, Peter
(University of Ljubljana (SLO))
Structural Dynamics, Finite Element Analysis, Civil Engineering
May

Chabardes, Théodore
(Centre de Morphologie Mathématique, MINES Paristech (F))
Automatic segmentation of granular materials
October-December

Delescluse, Matthias
(École Normale Supérieure, Paris (F))
Géologie / Waveform tomography imaging of shallow earth structures using long-streamer seismic data
November

Diebels, Stefan
(Universität des Saarlandes)
Technical Mechanics
September

Engell, Sebastian
(TU Dortmund University)
Process operation and real-time optimization
September

Gauger, Nicolas R. (University of Kaiserslautern)
Semi-Automatic Transition from Simulation to Optimization
December

Gibali, Aviv
(ORT Braude College, Karmiel (IL))
The Douglas-Rachford algorithm for the unary resource constraint problem
January

Griso, Georges (Laboratoire J.-L. Lions, Université Pierre et Marie Curie, BC187, Paris (F))
A simplified model for elastic thin shells
June

Griso, Georges
(Laboratorium Lions, Paris (F))
Homogenization for thin plates composed of thin beams
June

Jenkins, David
(CSIRO, North Ryde (AUS))
Micro-CT Analysis of Metallurgical Coke for Understanding Coke Quality
September

Klawonn, Axel
(University of Köln)
Towards Computing on the Extreme Scale in Nonlinear Structural Mechanics
June

Knabner, Peter
(University of Erlangen)
Reactive transport and multiphase multicomponent flow in potentially evolving porous media
January

Margenov, Svetozar
(University of Sofia (BG))
Supercomputing: Scalable Numerical Methods and Algorithms, and Biomedical and Engineering Applications"
October

Musolino, Paolo
(University of Padova (I))
Analysis for multiscale contact problems
May-July

Nordbotten, Jan Martin
(Universitity of Bergen (N))
Finite Volume discretizations for elasticity and Biot
July

COLLABORATION IN BOARDS, EDITORSHIPS

Panasenko, Grigory
(Uni. St. Etienne (F))
Fluid-solid interaction for spacer fabrics
July

Phutane, Uday
(Universität Erlangen-Nürnberg)
Multi-Body Dynamics, Non-Linear Finite Elements
January, June

Preissler, Gabi
(University of Applied Sciences, Stuttgart)
Hybrid Energy Systems
January

Printsypar, Galina
(WIAS Institute, Berlin)
Micro and Macro Scale Simulation of Oscmotic Processes
May

Rawal, Amit
(IIT Delhi (IND))
Technical and smart textiles
January-July

Schildgen, Johannes (Technische Universität, Kaiserslautern)
NoSQL Data Bases
October

Siikanen, Milla (Tampere University of Technology (FIN))
Liquidity in FX limit order markets
June

Silberstein, Mark
(Technion Computer Engineering Center, Haifa (IL))
Providing I/O abstractions to GPUs
February

Vabishchevich, Petr
(Russian Academy of Science, Moskau (RUS))
Numerical methods for inverse problems for parabolic equations
October

Dreßler, Klaus
- Proceedings of the 4rd Commercial Vehicle Technology Symposium (CVT 2016), (Co-Editor)

Gerwalin, Elmar
- Wissenschaftlich-Technischer Rat (WTR) der Fraunhofer-Gesellschaft (Member)
- Fachgremium IT-Geschäftsprozessunterstützung der Fraunhofer-Gesellschaft
- Fachgruppe IT-Controlling der Gesellschaft für Informatik (Deputy Speaker)

Gramsch, Simone
- KOMMS – Kompetenzzentrum für Mathematische Modellierung in MINT-Projekten in der Schule (Member of the scientific board)
- Wissenschaftlich-Technischer Rat (WTR) der Fraunhofer-Gesellschaft (Member)

Iliev, Oleg
- DFG (Reviewer)
- University of Wisconsin-Milwaukee (Reviewer Full Professor Position)
- Journal of Porous Media (Editor)
- Mathematical Methods and Analysis (Editor)
- Transport in Porous Media (Reviewer)
- Computational and Applied Mathematics (Reviewer)
- International Society of Porous Media, InterPore (Chair of Event Committee)

Kabel, Matthias
- International Journal for Numerical Methods in Engineering (Reviewer)
- Computer Methods in Applied Mechanics and Engineering (Reviewer)
- Mechanics of Materials (Reviewer)
- Computational Materials Science (Reviewer)
- Journal of Material Science (Reviewer)
- International Journal of Computer and Software Engineering (Editor)

Keuper, Janis
- Program Committee MLHPC Workshop
- BMBF Roundtable "Machine Learning"

Kirsch, Ralf
- Scientific Committee of the American Filtration Society (Member)

Korn, Ralf
- European Actuarial Journal (Editor)
- "Quantitative Finance" Series of books, Imperial College Press, World Scientific (Editor)

Krüger, Jens
- Fraunhofer Data Scientist Zertifizierung (Technical committee)

Küfer, Karl-Heinz
- BMBF-Programm »Mathematik für Innovationen in Industrie und Dienstleistungen« (Reviewer)

Kuhnert, Jörg
- Scientific Visualization Contest 2016 (Member of the jury)

Maasland, Mark
- Fraunhofer-Allianz Vision (Member)
- International Journal of Telemedicine and Clinical Practices (IJ1MCP, Reviewer)

Michel, Isabel
- Scientific Visualization Contest 2016 (Member of the jury)

Pfreundt, Franz-Josef
- ETP4HPC (Member)

Prätzel-Wolters, Dieter
- Applied Mathematics Committee (AMC) of the European Mathematical Society (Member)
- BMBF Strategiekommittee für mathematische Modellierung, Simulation und Optimierung (KoMSO) (Member)
- European Research Centres on Mathematics ERCOM (Member)
- Felix-Klein-Zentrum für Mathematik (Chairman)
- Forschungszentrum »Center of Mathematical and Computational Modeling CM²« der TU Kaiserslautern (Member)
- Fraunhofer-Chalmers Research Centre for Industrial Mathematics FCC (Member of Advisory Boards)
- Fraunhofer-Gesellschaft: Member of presidential council and senate (until 2016/11/02)
- High Performance Center »Simulation- and Software-based Innovation« (Spokesman of steering committee)
- GAMM-Fachausschuss Dynamik und Regelungstheorie (Member)
- Institut für Verbundwerkstoffe GmbH (Member of the advisory board)
- Kompetenzzentrum für mathematische Modellierung in MINT-Projekten in der Schule, KOMMS (Member of the advisory board)
- Rat für Technologie Rheinland-Pfalz (Member)
- Stiftungsrat »Fraunhofer-Zukunftsstiftung« (Member)
- Wissenschaftlich-Technischer Rat und Hauptkommission der Fraunhofer-Gesellschaft (Chairman until 2016/11/02)

Prill, Torben
- Steering Committee of German National Chapter of Interpore Society (Member)

Rösch, Ronald
- Fraunhofer Vision Alliance (Coordination Board)
- Fraunhofer Lightweight Design Alliance (Member)
- Heidelberger Bildverarbeitungsforum (Advisory board)
- Deutsche Gesellschaft fiir Materialkunde e. V. (DGM, Member)
- DGM-Arbeitskreis Tomographie (Member)
- DGM-Fachausschuss Strahllinien (Member)
- Deutsche Gesellschaft für Zerstörungsfreie Prüfung e. V. (DGZfP, Member)

Schladitz, Katja
- Leichtbau-Cluster (Member)
- Spatial Statistics (Reviewer)
- Journal of Microscopy (Reviewer)
- Image Analysis & Stereology (Editorial Board, Reviewer)
- Journal ofthe Science of Food and Agriculture (Reviewer)
- Methodology and Computing in Applied Probability (Reviewer)
- Karbala International Journal of Modern Science (Reviewer)

Schröder, Simon
- Scientific Visualization Contest 2016 (Jurymember)

Stephani, Henrike
- International Conference on Pattern Recognition (ICPR, Reviewer)
- Sensors (ISSN 1424-8220; CODEN: SENSC9, Reviewer)

Zausch, Jochen
- Journal of Power Sources (Reviewer)
- Fraunhofer Battery Alliance (Expert Group Leader "Simulation")

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