Fraunhofer
ITWM

FRAUNHOFER INSTITUTE FOR INDUSTRIAL MATHEMATICS ITWM

ANNUAL REPORT 2018/19

Front page

The Fraunhofer-Gesellschaft was founded in 1949 and, in the 70 years of its existence, has developed from being a bearer of hope to an engine of innovation with 72 institutes throughout Germany. We can look forward to the coming years as well: #WHATSNEXT

ANNUAL REPORT
2018/19

CONTENT

PREFACE

This is the eighteenth and the last foreword for the ITWM Annual Report that I have written. I am now entering retirement and my successor, Anita Schöbel, has assumed the duties of an Executive Directoron April 1, 2019. Anita Schöbel joins the Institute and TU Kaiserslautern as an internationally recognized scientist and an outstanding spokesperson for Kaiserslautern. Personally, I am pleased to hand over management responsibilities to her and can say with confidence that she will continue to promote applied mathematics in the department and to maintain the successful course of ITWM and, in both areas, she will set her own mark.

The year 2018 was a year of growth and future prospects are excellent. We enjoy fantastic working conditions and the accomplished and successful ITWM staff represents an outstanding team; highly motivated and highly dedicated to the institute. We are very well-connected – in the Fraunhofer-Gesellschaft, in Kaiserslautern, and in the scientific community. These networks report excellent and successful feedback. Again in 2018, all departments reported positive figures and the share of business revenue is roughly 50 percent of the operating budget. Our sister institute, Fraunhofer Chalmers Centre for Industrial Mathematics FCC in Gothenburg has grown steadily and is very well-positioned with a broad range of mathematics and engineering competence.

One of the special highlights of 2018 for ITWM was the stabilization of the High Performance Center for Simulation and Software-Based Innovation Kaiserslautern for three more years. The center focuses on research, marketing, and knowledge transfer within the general area of the digital transformation. The digital transformation is both a challenge and a great opportunity for the center. The huge potential for innovative solutions is increasingly being leveraged in areas that have not yet been penetrated by simulation and software. The performance center is ideally positioned in the area of information systems for the "Human-Machine" and "Machine-Machine" interfaces, for the implementation of AI in industrial manufacturing processes, in the design of digital infrastructure for cities, villages, factories, schools, agriculture, etc. and also in the area of logistics and industrial data.

Again in 2018, ITWM attracted many new employees and Ph.D. candidates. The especially significant news is that almost 40 percent are women. I attribute this successful recruitment effort to intensive public relations work. In this connection, we received very positive feedback regarding a special publication. The magazine »bild der wissenschaft« was published with the supplement »Erfolgsformeln – Wie die Mathematik Technik und Wirtschaft nach vorne bringt« in July 2018. The science editors dedicated 44 pages depicting a versatile and colorful picture of our institute and our research.

ITWM underwent a restructuring in 2018 that established the division as a new organizational unit. The Optimization Division was created to house the departments of "Optimization – Technical Processes" and "Optimization – Operations Research," both of which experienced strong growth. This growth is a reflection of the fact that industrial volume was more than 90 percent from key customers and, secondly, a funding balance in preliminary research. For example, in the Optimization – Operations Research department, a commission from Goldbeck Solar AG resulted in the development of a new tool for planning open space photo-voltaic systems. In the Optimization – Technical Processes department, industrial customers gained access to a new application-oriented methods and simulation tools in the context of the flagship project "Machine Learning for Production" and the "Fraunhofer Machine Learning Cluster."

The Department of Mathematical Methods in Dynamics and Durability was re-organized as the Mathematics for Vehicle Engineering (MF) Division. This new division has been assigned the two departments, "Dynamics, Loads, and Environment Data (DLU)" and "Mathematics for the Digital Factory (MDF)" as well as the project group "Tire Simulation" and the Cross Section Unit "MF-Technikum," which focuses on testing and measuring systems. The Dynamics, Loads and Environment

Data (DLU) department develops methods and tools for system simulation including environment data and variations in use. The Mathematics for the Digital Factory (MDF) department concentrates on the development of software tools for the virtual genesis and development of products.

The development of the Competence Center High Performance Computing is also accented by growth and the expansion of its portfolio of expertise and business areas, which will also undergo a re-structuring to be implemented in 2019. Last year, the EU commissioned a Europe-wide consortium to develop a European processor for a future exascale computer. The CC HPC is part of this consortium and, together with Fraunhofer IIS, is developing a special processor that will greatly accelerate a class of algorithms.

The Flow and Material Simulation department with expertise in simulation-aided characterization and virtual design of multi-functional materials enhanced its success through the further development and licensing of various simulation tools. The department works closely with the Center for Materials Characterization and Testing, which created the first ever mobile terahertz measurement system for testing plastic welds on pipelines in 2018. All focus areas of the Transport Processes department reflect positive development – in particular, the strategy of targeted software development and licensing is returning the initial successful results. Future sales of MESHFREE, our flow solver product, will be stronger as a result of increased promotion by distribution partner ScaposAG. In the Image Processing department, the research area "Industrial Image Learning" was expanded with priority on Machine Learning in image processing for manufacturing and other industries. The Financial Mathematics department succeeded in attracting well-known names in the field of data science for long term, innovative collaborative formats. In this area, anomaly detection is streamlining operative processes and optimizing accounting audits. Since April 2018, the Systems Analysis, Prognosis and Control department has been part of a consortium of eleven partners in eight countries developing an integrated simulation framework for wind farms in the Horizon2020 Project UP-WARDS.

This completes my brief summary of departmental highlights. In closing, I want to express my sincere appreciation to our employees. Today, ITWM is the largest research institute in Rhineland-Palatinate and its economic and scientific excellence is fully attributable to their know-how and experience, which together with the innovative power of mathematics is the basis of our success. Additionally, we also have our shared values and structures, i.e., sustainable employee loyalty, flat hierarchies with well-positioned autonomous departments, promising the customer only what we can deliver, and avoiding "much ado about nothing." Ours is a corporate culture characterized by tolerance and acceptance of each other, and – last, but not least – not only working together, but also celebrating together.

I thank you all for your commitment and your enthusiasm for the institute, for the excellent cooperation, and for your untiring efforts in supporting the management of ITWM. We can be very proud of our accomplishments and I am grateful for having had the opportunity to work with you all over so many years. My thoughts and appreciation go out to all of ITWM's project partners for the constructive and enjoyable cooperation and, finally, I hope you all enjoy reading the Annual Report 2018.

Prof. Dr. Dieter Prätzel-Wolters

Frau Schöbel, what motivated you to apply for the top position at our institute?

I have been intrigued by applied mathematics ever since my degree studies and wanted to support the transfer of research results into practice. I read the job announcement and found the position as director of a Fraunhofer Institute very appealing. My professional orientation is also an outstanding match with my colleagues at TU Kaiserslautern. By the way, I studied and earned by doctorate here. I was even a member of the ITWM staff for two years before accepting a professorship in Göttingen and moving there with my family in 2004. Meanwhile, my children are out of the house, so I have more time for new challenges. Finally, I really like Kaiserslautern and the surroundings, so I could well imagine coming back to the Palatinate.

What do value most about your new place of business?

That would be the employees, who maintain an open and good working atmosphere and who facilitated my start at the institute. Of course, I also appreciate the work of many exciting projects, which explore a diverse range of subjects. And, let me also mention this classy office building.

What are your special goals for the future of ITWM?

It is important to me that we are perceived as a leading research institute in the scientific community. Furthermore, I want our work at the institute to be recognized under the motto "Mathematics for a bright future." Many of our projects already represent this description, for example, the development and characterization of new useful materials, vehicle safety, and health and energy projects are just a few of them. I also want to encourage better inter-departmental cooperation to better exploit the potential synergy effects.

What do you see as the greatest challenges facing ITWM in the coming years?

The departments have established a strong reputation in industry and business in recent years. This must definitely continue in the years ahead and we must maintain our availability as a competent project partner. The digital transformation offers many areas of opportunity for applied mathematics; it would be nice to contribute to the development of innovative ideas. Internal to the institute, there is always the challenge of maintaining a good and trusting working environment for all employees, even as ITWM continues to grow in terms of space and personnel.

How are you managing so many new tasks?

I have already seen many interesting projects, gotten to know many of the employees, and am starting to understand the Fraunhofer procedures. Additionally, I am establishing initial contact to other Fraunhofer Institutes, to the government, and naturally, to the Technical University and other local scientific institutes. Fortunately, if I have questions or do not know something, everyone has been very understanding, especially, the administrative units. Mr. Prätzel-Wolters has given me great support in the first few months, and I am very grateful for his time, explanations, and answers to my many questions. I also appreciate that he is continuing his support to our institute as a consultant and I personally look forward to working with him.

A professorship is associated with your position as director of the institute. At the Georg-August University in Göttingen you were a professor for optimization at the Institute for Numerical and Applied Mathematics: As a member of the faculty of mathematics at TU Kaiserslautern, what working group will you chair?

My professorship here is quite commonly called "Professor for Applied Mathematics," which is a reflection of the diverse functional range at ITWM. My focus continues to be in the field of optimization. I am pleased that I can already contribute to an existing working group at the department and also that

PROF. DR. ANITA SCHÖBEL
DIRECTOR

the doctoral student and two post-docs, who switched from Göttingen with me to Kaiserslautern, have found such an outstanding professional environment. I also relocated my German Research Foundation (DFG) group on "Integrated Transport Planning" to TUK.

Do you see any synergies with your work at the institute?

My expertise and research interest is a natural match with the Optimization division of ITWM. Still, discrete optimization problems also exist in other departments, for example, in MF, BV, HPC, and FM (and perhaps, I will find some more!). My application area "Mobility in the Future" also overlaps several departments and I think a joint collaboration would be valuable and maybe even result in a couple of new projects. My experience includes work with multi-criteria optimization and planning under uncertainty; which are also relevant to the practical applications pursued at ITWM.

Our neighbor, the German Research Center for Artificial Intelligence has recently appointed Prof. Jana Köhler as CEO. You are one of the first women to lead a Fraunhofer Institute – does the future belong to women?

Well, the future is certainly more female than the past – we are hopefully out of the era in which people were hired or not hired because of their gender! The goal often mentioned is to have an equal number of male and female staff in each special subject area. It makes more sense to me that people work in the area of their interests. But it is important that everyone has the same opportunities for further development. For example, it should not be the case that the ratio of women to men decreases as the hierarchical level increases – there is still room for improvement in this respect!

Scientific career

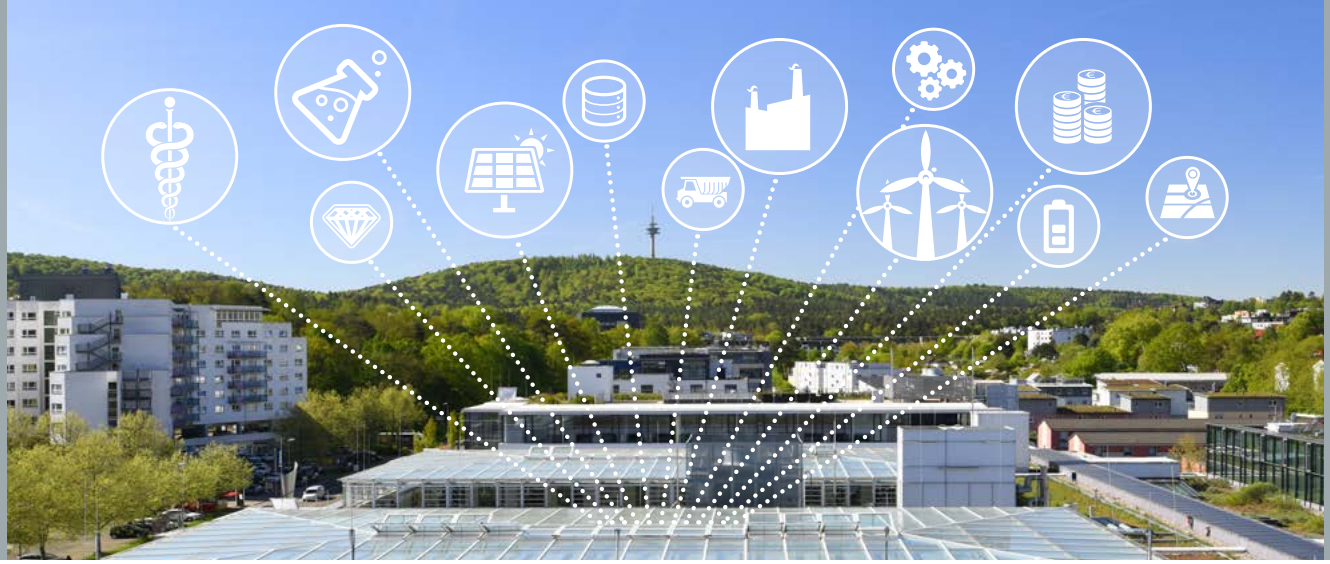
1979 – 1988	High school "Karolinengymnasium" in Frankenthal
1988 – 1994	Study of mathematics with a minor in economics at the University of Kaiserslautern
1994	Diploma thesis: Kombinatorische Optimierung in der Tarifplanung im ÖPNV
1999	Dissertation thesis: Locating Lines and Hyperplanes – Theory and Algorithms
2003	Habilitation thesis: Customer-oriented Optimization in Public Transportation

Professional activities

1994 – 1998	Research assistant at the department of mathematics, University of Kaiserslautern
1998 – 1999	Head of the traffic group at Fraunhofer ITWM
1999 – 2004	Scientific assistant (C1) at the department of mathematics of the University of Kaiserslautern
since 04.2004	Professor (W2) at the Institute for Numerical and Applied Mathematics at the Georg-August University Göttingen (since 10.2007: W3 position)
Summer 2007	Calls to W3 positions in Wuppertal and Trier
since 01.2019	Professor for Applied Mathematics, University of Kaiserslautern and director of Fraunhofer ITWM

Research interests

Integer optimization, robust optimization, optimization of public transport, geometric optimization methods, location theory



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. Because mathematics is the technology which generates these images and converts them efficiently into software, the raw material of the models and the core of every computer simulation.

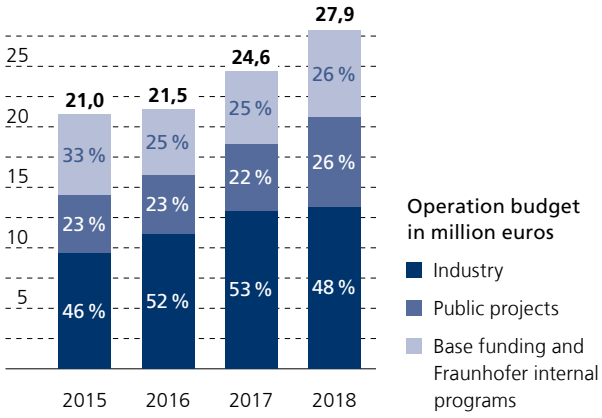
Applied mathematics as a key technology

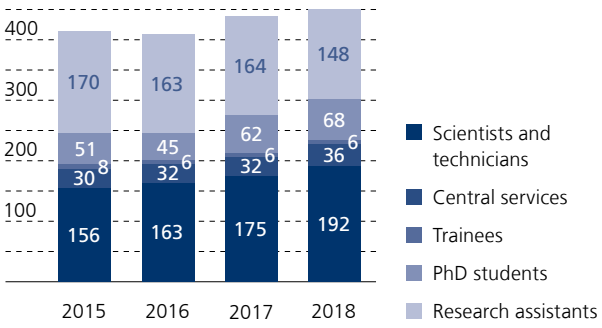
Increasingly more small and medium-sized companies utilize simulation for cost reduction. It is specifically these companies that we support with consultation and computing power. They profit in the market through the use of simulation as identification for innovation and quality assurance of their products. Of course, we also cooperate with large companies, especially in the automotive sector, mechanical engineering, the textile industry, microelectronics, the computer industry and the financial sector. Integral components of our R&D projects are consulting and implementation, support in the application of high-performance computer technology and the provision of tailor-made software solutions. We not only use simulation software, but also develop it ourselves, often in cooperation with leading software companies.

Our specific competencies 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

We not only want to build the bridge between the real and virtual world, but we also want to be the link between university mathematics and its practical implementation. Therefore, the close connection to the Department of Mathematics of the Technical University of Kaiserslautern plays a special role.





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.

Advisory board Fraunhofer ITWM

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MACHINE LEARNING – A PROMISING APPROACH

The digital transformation of the economy and society is increasingly being driven by the use of Artificial Intelligence. It is now found in everyday applications like route planners and voice assistants, but also in professional applications like industrial quality control, medical diagnostics, and autonomous vehicles. This innovation is mainly driven by Machine Learning techniques; in particular, Deep Learning or neural networks are responsible for significant progress along with the enormous increases in computing power and major investments in know-how.

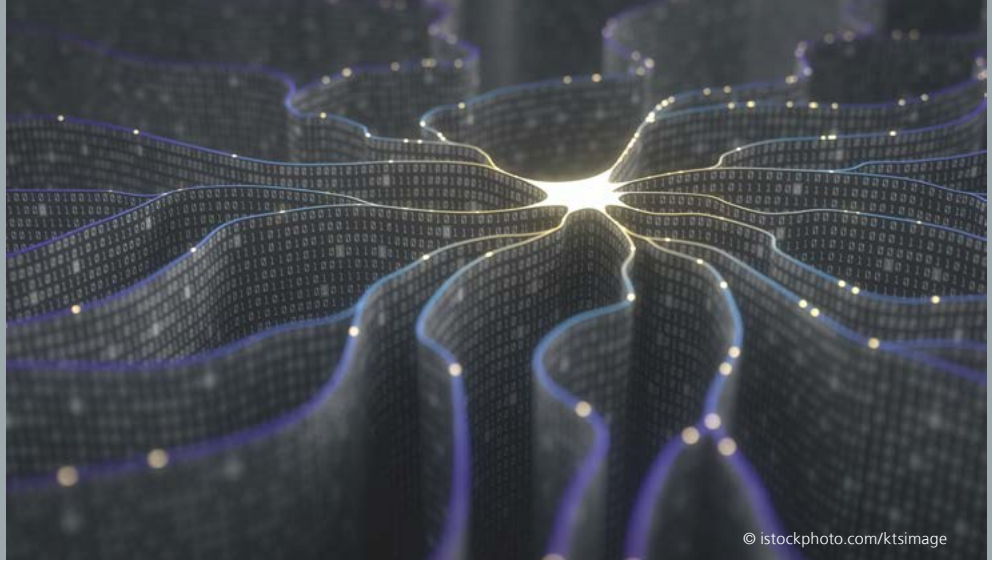
Machine Learning is now a routine technology, but every algorithm is only as good as the data used to train it. Often, large amounts of data are available in companies that want to leverage ML methods to optimize their processes and products, but rarely is this in a form easily used for Machine Learning. However, problems such as data reliability and robustness are now well understood and are being researched worldwide, including at our institute.

Hybrid approach: Expert knowledge combined with Machine Learning

We want our joint venture partners in industry and business to have the software tools they need to improve their processes. This refers to customized software that enables fast comparisons of different alternatives to assist in identifying potential improvements. The modeling of real processes has to be highly realistic and reliable: reality must be so well represented that the proposed improvements are both feasible and quantifiably reliable. Machine Learning processes combine with the existing expert and physical models to provide answers to this challenge. Various methods, like neural networks or support-vector machines are trained and integrated using existing data. This technique ensures the model is accurate enough to identify substantial process improvements.

ML methods in action institute-wide

At ITWM, nearly every department uses Machine Learning, mainly some hybrid simulation-based Machine Learning methods. For example, the System Analysis, Prognosis and Control department uses ML algorithms to create tools that analyze, interpret, and visualize biological medical data. ML methods are also used in a predictive maintenance context to predict the occurrence of unwanted operating states and events. The Transport Processes department develops a hybrid approach to design and optimize production processes in the textile industry using ML methods: the DensiSpul project focuses on the optimization of bobbin winding machines. Specifically, the research aim is to improve the dyeing of the yarn wound on the bobbins.



ML methods have long been important in the field of image processing: just consider the major focus on the development of safe and stable algorithms for optical quality controls in production. Quality is not the main challenge here because in a well-functioning plant many images of fault-free products are available, rather the problem is insufficient data since only a few images of products with defects are available. One possible solution is data augmentation, that is, the creation of artificial error databases that are based on real error data. You can also prepare mathematical descriptions of the defects and train the image processing algorithms with the model. The department offers classic machine-learning solutions that can be used to automate the processing of vast amounts of image data that previously had to be classified manually.

Neural networks enable significant energy savings

The Optimization Division successfully uses Machine Learning in process engineering and has created a new analytical tool to save significant amount of energy in the production of chemicals. Here, again a hybrid approach is used. Measured data such as pressure or temperature is collected with sensors in technical systems and serves as the basis of this approach. In the past, sensor data was used only for process monitoring; now is can be used for training neural networks. The development of the new tool was selected for the Fraunhofer Prize 2019.

Priority for High Performance Computing

Machine Learning and data analysis have been declared a main research focus of the Competence Center for High Performance Computing. One of the tasks is the development of new algorithms for the distributed computation for the training of neural networks and realization on specialized hardware. The main focus is on the implementation of scalable optimization algorithms for the distributed parallelization of large Machine Learning problems. In fact, the basis for this was developed at CC HPC. It is HPC components like the parallel file system BeeGFS or the programming framework GPI2.0 that make the efficient implementation of new algorithms possible.

Fraunhofer ITWM has seen increased demand in recent years not only for its outstanding research activities, but also as a service provider of seminars on Machine Learning.

“BILD DER WISSENSCHAFT” PUBLISHES FORMULA FOR SUCCESS

Two of the featured highlight projects:

1 *Radiation therapy planing*

2 *Layer thickness measurement using terahertz waves*

Our supplement was published in “bild der wissenschaft” in June – 44 pages explaining why mathematics is universally indispensable as a key technology. The successful journalistic preparation of our priorities with illustrative example projects allowed us to reach a significantly larger audience and the resulting publication can be used in the longer term for a wide variety of PR channels, target groups, and occasions. In effect, networking our multimedia content allows us to use and re-use it for a longer period of time.

The June edition of “bild der wissenschaft” marked the start of our campaign with a distribution of 90,000 copies, after which we further increased the range through targeted mailings, presentations at various events, and multiple online media publications. Another benefit from our cooperation with Konradin publishers is the access to first-class photo material: the images of the different project topics were created entirely for us and can be used in all media.

What was the outreach of our „Erfolgsformeln“?

- bild der wissenschaft: coverage approx. 505.000
- ITWM: 5.000 print copies
- Industrieanzeiger: coverage approx. 200.000
- bild der wissenschaft newsletter: approx. 19.000 subscribers
- Website wissenschaft.de: 475.000 page impressions
- Facebook: 7.100 persons reached
- Twitter: 12.000 impressions

A NIGHT OUT WITH SCIENCE: SCIENCE SLAM, MATHEMATICS WORKPLACE, AND "TRANSPARENTES GLÜCK"

ITWM participated in the local "Night out with science" again in 2018 to present our "Mathematics Workplace" to a broad public. The Science Slam kick-off event attracted many visitors to the Fraunhofer Center where they subsequently streamed into the atrium to see the ITWM exhibits that were clustered there: The Mathematics Workplace was divided into the areas "Measurement – Testing – Evaluation", "Modeling and Optimization", and "Technologies for e-mobility and energy management".

The exhibition "Transparentes Glück" by photographer Thomas Brenner was on display in the foyer of the Fraunhofer Center – nine large-format collages, composed of staged and journalistic photographs, X-rays, and even text passages. The multi-faceted work forged a creative bridge between complex high-tech subjects like High Performance Computing, Big Data, and algorithms and their sensitivity in contemporary social reality.

1 *Photo art at the entrance foyer*

2 *Within reach: real and virtual worlds in the ITWM*

3 *Another eye-catcher on Trippstadter Straße: Sandstone sculpture "Virus"*

VIRUS INSTALLATION

Since autumn, a sandstone sculpture with cast iron spines stands on a platform in front of our building: The work is titled "Virus" and it was created for the Sculptor Symposium 2017 at the Picard quarry sponsored by the Skulpturen-Verein Rheinland-Pfalz. The search for a permanent home for "Virus" proved to be difficult. Because of the heavy weight of the installation, displaying it in the interior of the Fraunhofer building was ruled out of the question and the placement in a public space requires a safety audit – a lengthy procedure. Finally, at the end of October, the Kaiserslautern Fire Department managed to transport the three-ton sculpture and, with the help of a giant crane, the piece was safely lowered into its current location.

About this piece, visual artist Monika Biet says: "Natural forms of great beauty exist in the microcosmos, but they may also hide a powerful potential for destruction. Virus represents this state of ambivalence between aesthetics and aggression, creating a visual and tactile experience."

A case can also be made for a scientific relevance: In collaboration with other Fraunhofer Institutes, mathematicians in the Optimization Division are studying the effectiveness of artificially modified Herpes viruses for use in tumor therapies in Project TheraVision.

© fleXstructures

1 *Young reseachers at our daycare*

2 *Thursday is Researchers' Day*

3 *f.l.t.r.: Dr. Ulrich Link, ISB Board Member, Maria Beck, Business + Innovation Center Kaiserslautern, Oliver Hermanns, CEO fleXstructures, and Dr. Klaus Dreßler, Head of Mathematics for Vehicle Engineering at the ITWM, after the award ceremony*

KITA KLAMMERÄFFCHEN DESIGNATED AS A »HAUS DER KLEINEN FORSCHER«

The "Klammeräffchen" daycare center at the Fraunhofer Center celebrated its certification as "Haus der kleinen Forscher" with a science festival. Klammeräffchen became the fourth institution in Kaiserslautern to be awarded this title. The certification is awarded by the non-profit "Haus der kleinen Forscher" Foundation to daycare centers committed to a good early education. The aim is to prepare girls and boys for a strong future with the main focus on the domains of natural sciences, engineering, computer science, and mathematics (MINT) – while also teaching them to act in the interests of sustainability.

"Thursday is research day!" at our daycare center. Our educators continuously train for this. Their dedication was also rewarded by the Fraunhofer Headquarters with a second place finish in the "Creative kids" competition: The winner's certificate is accompanied by new toys, a 300 euro voucher, and DOCH gym bags.

"SUCCESS AWARD 2018" FOR ITWM SPIN-OFF FLEXSTRUCTURES

The Ministry of Economics Affairs, Transport, Agriculture and Viticulture Rhineland Palatinate and the state's Investment and Economic Development Bank (ISB) selected our spin-off "fleXstructures" for the Success Award 2018. Every year, this award is presented to a small and medium-sized company that has developed and brought future-oriented new products, production processes, and technology-oriented services successfully to the market. fleXstructures was awarded the highest endowed technology prize of 15,000 euro for its innovative measuring machine MeSOMICS, which is integrated in the proven IPS software.

In combination with the simulation software IPS Cable Simulation, it is now possible to optimally accommodate several kilometers of cables and hoses in the small installation spaces available in modern vehicles. The product was developed and patented by the department of Mathematical Methods in Dynamics and Durability and is now distributed worldwide by fleXstructures GmbH.

DOUBLE AWARD: YEAR'S BEST TRAINEE AND COMPANY

The IHK Pfalz not only honored the trainee, but the training company too in November 2018. Tobias Grau (former trainee assigned to the IT department of ITWM), as well as his training institution (= Fraunhofer ITWM) were selected as the "Year's Best" in a ceremony at the Bad Dürkheim Salier Hall. Tobias Grau completed the program with a grade of 1.7 (excellent), graduating as an IT specialist with a concentration in in system integration. During his three years at ITWM, he was exposed to many different areas: Windows and Linux administration, desktop management, conference systems, and selected parts of network administration.

1 *Year´s Best IT specialist : Tobias Grau*

2 *ITWM-Alumni at the first part of the networking meeting*

ALUMNI DAY: STRENGTHENING THE BONDS – FORGING NEW OPPORTUNITIES

The second ITWM Alumni Day looked to the future with a look back: in the afternoon, the fifty or so alumni were introduced to current and future-oriented projects at the institute in 16 "elevator pitches" given by the current staff. The pitches focused, for example, on industrial image learning, thickness transparency, MESHFREE, or district heat. Next, visits to the relevant working groups led to detailed discussions. Later that evening, current employees met with the former employees at a strategic networking event at the Fruchthalle in Kaiserslautern. A stage play conceived by employees and alumni focused on the institute's past. In a three-act play, they reviewed the last twenty years of the institute – a pleasant history lesson for many of the alumni. The catalyst was the upcoming farewell of our longtime director Dieter Prätzel-Wolters, who retired in April. During his tenure, he intensified the networking of the ITWM within Fraunhofer and with universities and non-university organizations; but also increasingly important is networking with alumni.

This commitment to our alumni is supported by the Fraunhofer Alumni Association. Among other activities, the association awards prizes for successful new member recruitment concepts. The submitted concepts are evaluated at the end of the year. The evaluation criteria includes the effectiveness of the concept in terms of increasing the membership in the Fraunhofer Alumni Association, planning alumni events, or other successful networking formats at the institute. The idea of an ITWM Alumni Day was nominated for a prize!

1 © halbscharf.com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CAREER NIGHT AT FRAUNHOFER CENTER

1 *Tinkering together in the Escape Game: in our lecture hall, a 5×6 m cube was built and converted into the office of a Fraunhofer scientist.*

2 *Our scientists were sought-after contacts at Fraunhofer Career Night.*

Can you master team challenges while at the same time realizing your own ideas? YES you can; for example, when you play the Fraunhofer Escape Game, one of the many activities at Career Night at the Fraunhofer Center. ITWM and IESE jointly organized the event to attract interest in Fraunhofer as an employer: more than 150 MINT students and even recent graduates spent the entire evening at the Fraunhofer Center gathering first-hand information about initial entry jobs and the career outlook at Fraunhofer.

The highlight of the evening was the "Escape Game". In a specially built room, players solved riddles together and tried to fend off a hacker attack, all to protect and save some critical data – a challenge which demanded knowledge, technical savvy, and team spirit to win. In addition to the Escape Game, participants enjoyed guided tours through the two institutes and individual sessions on selected "Research Live" projects. The event came to an end with in-depth networking in a relaxed atmosphere with the current employees of both Fraunhofer IESE and Fraunhofer ITWM.

MINT-EC MATH TALENT SCHOOL

What does the professional world of a mathematician look like and what is applied mathematics? In August, 26 school children from schools in national excellence network "MINT-EC" learned the answers at the Math-Talent-School at our institute. The school is supported by MINT-EC in cooperation with the Felix-Klein Center for Mathematics (a joint institute of Fraunhofer ITWM and the Mathematics Department at TU Kaiserslautern).

The students who come to work on various issues using mathematical modeling and computer simulations are passionate about math. The issues are broad enough to reflect the diversity of mathematics in everyday life: "Choreographies for music wells", "Navigation in times of e-mobility", "Produce together, consume together" and "Smart farming - the digital farm". At the end of the Math Talent School, each group presented and discussed their solutions in a plenary session. Of course, a visit to the Department of Mathematics of the Technical University of Kaiserslautern was also on the program, which included detailed information about the mathematics program.

Front, left to right: Brigitte Williard, Sylvia Gerwalin, Dr. Markus Pfeffer, Esther Packullat, Ilka Blauth, Martin Vogt, Michaela Grimberg-Mang, Prof. Dr. Anita Schöbel, Katharina Parusel, Stephanie Beck, Manuela Hoffmann, Jana Mai, Eva Schimmele, Dieter Eubell, Prof. Dr. Dieter Prätzel-Wolters, Hülya Zimmer, Waltraud Dully, Gaby Gramsch, Steffen Grützner, Tino Labudda, Christian Fuchs, Mirko Spell, Yvonne Kusch-Engers, Brigitte Biguet, Elmar Gerwalin, Christian Peter, Dominic Schunk, Martin Braun

OUR NETWORK

CUSTOMERS AND COOPERATION PARTNERS SELECTON 2018

- AAC Technologies, Turku (FIN), Nanjing(RC) Shenzhen (RC)
- AbbVie Deutschland GmbH & Co. KG, Ludwighafen
- AL-KO GmbH, Kötz
- Altair Engineering, Troy (USA)
- AUDI AG, Ingolstadt
- BASF SE, Ludwigshafen
- BioNTech AG, Mainz
- BMW, München
- BPW Bergische Achsen Kommanditgesellschaft, Wiehl
- Brückner Group GmbH, Siegsdorf
- BSN Medical, Emmerich
- ContiTech Transportbandsysteme GmbH, Northeim
- Corning GmbH, Kaiserslautern
- Daimler AG, Stuttgart
- das-Nano S.L., Tajonar, Navarra (E)
- delta h Ingenieurgesellschaft mbH, Witten
- Deutsche Institute für Textil- und Faserforschung Denkendorf
- Dilo Machines GmbH, Eberbach
- Dres. Englmaier Beratungs GmbH, Waldkraiburg
- ebm papst, Mulfingen
- Equinor ASA, Stavanger (N), Trondheim (N), Oslo (N)
- ESI Group, Paris (F)
- Evonik Technology & Infrastructure GmbH, Hanau
- EWR AG, Worms
- FLSmidth A/S, Kopenhagen (DK)
- Freudenberg Filtration Technologies, Kaiserslautern
- GEF Ingenieur AG, Leimen
- GKV Spitzenverband, Berlin
- Goldbeck Solar GmbH, Hirschberg
- Goodyear S.A., Colmar-Berg, Luxembourg
- Grimme Landmaschinenfabrik GmbH & Co. KG, Damme
- Groz-Beckert KG, Albstadt
- GRS mbH, Köln
- Haas Schleifmaschinen GmbH, Trossingen
- Helmholtz-Institut für elektrochem. Energiespeicherung, Ulm
- Universities of Applied Sciences: Berlin, Birkenfeld (Trier), Darmstadt, Kaiserslautern, Lübeck, Mainz
- Hubert Stüken GmbH & Co. KG, Rinteln
- Hübner Gmbh&Co. KG, Kassel
- IAV Group, Berlin
- IBS FILTRAN GMBH, Morsbach-Lichtenberg
- Imilia Interactive Mobile Applications GmbH, Berlin
- Institut für Textiltechnik (ITA), Aachen
- IPConcept (Luxemburg) S.A., Luxemburg (L)
- John Deere GmbH & Co.KG, Mannheim, Kaiserslautern
- Johns Manville Europe GmbH, Bobingen
- Karl Mayer, Chemnitz
- Kelheim Fibres GmbH, Kelheim
- Kreisverwaltung Mainz-Bingen
- KSB Aktiengesellschaft, Frankenthal
- Liebherr, Kirchdorf / Colmar
- Lonza AG, Basel
- MAGMA Gießereitechnologie GmbH, Aachen
- Mahle GmbH, Stuttgart

- Maja Möbelwerk GmbH, Wittichenau
- MAN Truck & Bus Deutschland GmbH, München
- Maserati S.p.A./Alfa Romeo, Modena (I)
- Meggitt Polymers & Composites, Stevenage (GB)
- Merck KGaA, Darmstadt
- mfd Diagnostics, Wendelsheim
- Netze BW GmbH, Stuttgart
- Nissan, Kanagawa (J)
- Odenwald Faserplattenwerk GmbH, Amorbach
- Panasonic R&D Center Germany GmbH, Langen
- Paul Wild GmbH, Kirschweiler
- Plastic Omnium, Brüssel (B)
- Porsche AG, Stuttgart, Weissach
- proALPHA Business Solutions GmbH, Weilerbach
- Procter & Gamble, Cincinnati (USA), Schwalbach, Kronberg
- Progress Rail Inspection & Information Systems, Bad Dürkheim
- PSA Peugeot Citroen, Velizy-Villacoublay Cedex (F)
- PSI Software AG, Aschaffenburg, Dortmund
- R+V Versicherung, Wiesbaden
- Repsol, Houston (USA)
- Rittal, Herborn
- RJL Micro & Analytic GmbH, Karlsdorf-Neuthard
- Robert Bosch GmbH, Stuttgart
- Rolls-Royce, Berlin
- RWE Generation SE, Essen
- Santander Consumer Bank AG, Mönchengladbach
- SAP AG, Walldorf
- Scania CV AB, Södertälje (S)
- Schaeffler Automotive Aftermarket GmbH & Co. KG, Langen
- Schleifring und Apparatebau GmbH, Fürstenfeldbruck
- Schmitz Cargobull AG, Altenberge
- Seismic Imaging Processing SIP, Aberdeen (GB)
- SIEDA GmbH, Kaiserslautern
- Spin-offs of ITWM: fleXstructures, Math2Market, Produktinformationsstelle Altersvorsorge, Sharp Reflections, ThinkParQ (alle Kaiserslautern)
- Stadtentwässerung Kaiserslautern AöR, Kaiserslautern
- Stryker GmbH & Co. KG, Freiburg
- Technische Werke Ludwigshafen
- TGS Nopec, Houston (USA)
- Toyota Motor Europe NV/SA, Brüssel (B)
- Umicore, Hanau
- Union Investment Privatfonds GmbH, Frankfurt/Main
- uniper Anlagenservice, Gelsenkirchen
- Universities: Aachen, Berlin, Bordeaux (F), Bremen, Dortmund, Dresden, Erlangen, Frankfurt/Main, Freiberg, Freiburg, Heidelberg, Kaiserslautern, Karlsruhe, Kassel, Mainz, München, Münster, Nancy(F), Saarbrücken, Trier, Ulm
- VAN DE WIELE, Kortrijk (B)
- Varian Medical Systems International AG, Cham
- Voith GmbH & Co. KGaA, Heidenheim
- Volkswagen AG, Wolfsburg
- Volvo, Eskilstuna (S)
- ZF, Friedrichshafen

OUTSTANDING NETWORKS IN KAISERSLAUTERN

The High Performance Center for Simulation and Software-based Innovation was established three years ago. In April 2018, it entered the second funding period after a successful evaluation. This ensures the continuation of the success story in the area of application-oriented simulation and software technologies resulting from the cooperation of two Fraunhofer institutes IESE and ITWM with the Technical University, the University of Applied Sciences, other research institutions such as the German Research Center for Artificial Intelligence and the Institute for Composite Materials and several companies.

The center provides a cross-sector, application-oriented, interdisciplinary framework for pre-competitive research and cooperation. Sectors include chemical and process engineering, the vehicle industry (especially, commercial vehicle engineering) as well as the information and energy sectors. The research institutions involved cover the entire spectrum of expertise in the modeling of technical processes and products, simulation and software methods, optimization, and decision support.

Research labs and transfer centers

The center's organization remains centered on R&D labs and transfer centers. The research and development labs are oriented mainly on methods; they develop the concepts and algorithms that are then made available to the transfer centers as basic technologies.

The topics in "MSO-Based Process Engineering" are centered on modeling, simulation, and optimization (MSO) in process engineering. The "Digital Commercial Vehicle Technology" transfer center focuses on commercial vehicle systems, while "Smart Ecosystems" investigates Smart Energy, Smart Health, and Green by IT in addition to adaptive and open systems.

Research subjects

- System modeling and software solutions, e.g., for e-mobility
- Lightweight construction, digitalization, and software-ecosystems
- Decision support for industrial process optimization
- Human-Machine-Environment Interaction
- Digital twins for production and autonomous systems
- Safety concepts for open and adaptive systems
- Machine Learning, in particular, Deep Learning algorithms

The High Performance Center is known nationally and internationally through its individual research partners. Overall, it has a strong regional orientation, partly due to strong regional industrial partners such as BASF, Daimler Trucks and John Deere. To increase national and international visibility, the center is increasingly cooperating with other centers of excellence.

Transfer path

To achieve our major goal – the sustainable transfer of the results to business and science – various transfer paths are considered from the center to the economy and to society along with their concomitant impact on research. Currently the following paths are taken:

Contract research

- Industrial contracts: Key customers and new acquisitions
- Industry seminars and conferences
- Demonstrators and real labs

HIGH PERFORMANCE CENTER
SIMULATION AND SOFTWARE-BASED INNOVATION

Licensing (proprietary rights)

- IP exploitation of software and simulation products
- Licensing business with spin-offs and software companies

Spin-offs

- Incubator for simulation and software technologies
- Closing the technology gaps at external start-ups and SMEs

Continuing education (for business)

- Software engineering, digital commercial vehicle technology, deep learning
- Planned: Industry 4.0, Process simulation

Clever minds and cool careers

- Youth development at TU Kaiserslautern(workshops, lectures, graduate studies)
- Scholarship programs for bachelor, master, and Ph.D. degrees at the Felix Klein Academy for Mathematics

Community involvement

- Events sponsored by the Science and Innovation Alliance, such as "A Night out with Science"
- Participation in long term regional projects: OD Pfalz, "Digitale Dörfer", EnStadt: Pfaff

The High Performance Center relies on cooperation with established local partners specializing in spin-offs (Gründungsbüro KL, IHK Pfalz), continuing education (DISC for post-grad distance learning programs), and civic organizations (Science and Innovation Alliance, ZukunftsRegion Westpfalz) for the implementation of this last transfer path.

NETWORKING AND COOPERATION WITHIN THE FRAUNHOFER-GESELLSCHAFT

A large network and innovative partners are crucial for the success of projects. That is why we are part of a network of national and international cooperations and a member of several associations within the Fraunhofer-Gesellschaft:

- Fraunhofer Groups
  - Fraunhofer ICT Group
  - Fraunhofer Group for Materials and Components – MATERIALS (as associated institute)

- Fraunhofer Alliances
  - Automobile Production
  - Battery
  - Big Data
  - Cloud Computing
  - Lightweight Design
  - Simulation
  - Textile
  - Traffic and Transportation
  - Vision

Within Fraunhofer, we are a sought-after research partner because we are involved in various internal research projects, such as MAVO/WISA projects, five SME/MEF projects and a Discover project. Fraunhofer research clusters promote the cooperative development and handling of system-relevant topics through a cross-institutional research structure. In organizational terms, these research clusters correspond to a "virtual institute" that is spread over several locations. We are involved in these clusters:

- Programmable Materials
- Advanced Photon Sources
- CIT – Cognitive Internet Technologies

Lighthouse Projects: Preliminary research alliance

The lighthouse projects represent a special feature of Fraunhofer research. Their topics are determined on the basis of current industry demands and rely on the expertise of various institutes to provide efficient preliminary research. The aim is to secure the technological leadership of Fraunhofer – in addition to high standards of scientific excellence. The program aims to exploit the synergistic potential of the Fraunhofer Gesellschaft by bringing together the competencies of several Fraunhofer institutes to provide solutions to the challenges facing German industry. The central hub is always a specific project. Fraunhofer funded research in 14 lighthouse projects in 2018; we participate in four of these.

ML4P – Machine Learning for Production

This lighthouse project bundles the extensive expertise of seven Fraunhofer institutes in the field of Machine Learning in production processes. The need is great as both the process and the piece goods sector have processes that are interconnected and machines, interfaces, and components that communicate with each other.

The goal is to model an entire plant and, based on this overall model, use mathematical optimization methods to propose improvements in system design or operating modes. To achieve this goal we use our knowledge of physical modelling and Machine Learning methods. These learning methods are based on complex simulation data as well as on measured operating data from the production units. The operating data is obtained from sensor monitoring or from the documentation of operating conditions. The priorities are to use ML methods in statistical analysis of time series and to achieve the automated analysis of image data.

QUILT – Quantum Methods for Advanced Imaging Solutions

The QUILT network is currently very well-positioned in the field of quantum imaging thanks to technology platforms, groundbreaking experiments, and a worldwide collaborative research alliance. This position is to be further strengthened in the future as a lighthouse project, in which we perform a key role in the modeling, simulation, and optimization of quantum-based, non-contact methods. Our goal is to design more reliable, faster, and cost effective imaging processes for material surfaces. The focus is on the development of a digital twin to enable quantitative predictions of quantum-optical experiments as well as a terahertz structural analysis system to improve detection efficiency.

COGNAC – COGNitive AgriCulture

The Fraunhofer lighthouse project "Cognitive Agriculture" aims to automatically record and process the complex relationships found in crop production and optimize crop-specific operations that result in increased productivity at no consequential ecological risk. Our contribution is in the innovative area of new sensor technologies and is dedicated to the modeling, simulation, and optimization of agronomic processes (for example, the growth and yield of wheat crops). An important objective is to identify correlations and influencing factors for the purpose of deriving recommendations for action, for example, for robust crop campaign planning. We continuously monitor weather updates and harvesting data to enable us to plan personnel and equipment requirements in advance. Robust models and algorithms help us to reduce the costs of drying and fuel, while simultaneously increasing food quality and customer satisfaction.

eOPT – Electricity as a resource

The project develops electro-chemical processes for fluctuating power and resource systems; the result provides the opportunity to use low-cost electricity as the energy source – even for power intensive sectors like chemical production. Specifically, the project focuses on the electrochemical conversion processes used for the production of hydrogen peroxide as a green bleaching agent and for the conversion of CO2 into valuable basic chemicals.

We prepare estimates of kinetic constants by adjusting the variables in RRDE experiments and modeling the electrochemical cells, including transport phenomena. We implement the cell models for a commercial flowchart simulator and integrate them in an overall flowchart. Our expertise in multi-criteria optimization facilitates identifying the best possible operating strategy for the process, while accounting for fluctuation in the price of electricity.

SPIN-OFFS

Math2Market

Math2Market, our first and largest spin-off, was responsible in the early years for the marketing of the GeoDict software developed by the Flow and Material Simulation department. This software has meanwhile grown into the Digital Material Lab GeoDict®, which Math2Market continues to develop by integrating tools generated at ITWM. Math2Market supports companies with an integrated package for the efficient development of better materials and processes. Customers are located worldwide and represent a range of sectors including filtration, composites, and electrochemistry. However, manufacturers of batteries and fuel cells make up the majority.

fleXstructures

fleXstructures is a spin-off company of the department Mathematical Methods in Dynamics and Durability. It distributes the IPS software jointly developed with Fraunhofer-Chalmers Research Centre for Industrial Mathematics in Göteborg, Sweden. The IPS Cable Simulation is a major tool in this product group; it is used in the automotive and commercial vehicle industries, but also in aerospace and mechanical engineering to ensure the efficient laying of cables and hoses, for example in the vehicle engine compartments.

Sharp Reflections

The Competence Center for High Performance Computing jointly develops the Pre-Stack Pro software with the Norwegian oil and gas company Statoil, for the analysis of seismic reflection data. Sharp Reflections is responsible for the distribution and continuing development. Pre-Stack Pro applies parallel computer technology to derive reliable information about the properties of oil and gas deposits from large data sets. In Norway, Sharp Reflections supports the local customers and manages the worldwide distribution of the products.

ThinkParQ

ThinkParQ, another spin-off from the Competence Center for High Performance Computing, is the company behind the parallel cluster-file system BeeGFS. Large volumes of data are managed in a user-friendly way, both locally and in the cloud using this highly scalable storage product.

Product information office for retirement planning PIA

Since January 2017, on behalf of the Federal Ministry of Finance, this independent office performs the classification of the opportunity and risk profiles of funded pension plan products. It is a wholly owned Fraunhofer subsidiary and works closely with our Financial Mathematics department.

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 and Innovation Alliance Kaiserslautern SIAK
  SIAK is a network for digital transformation, innovation and interdisciplinary research. It is regionally anchored through its members from science – universities and research institutes – and industry – especially from small and medium-sized enterprises.

- Software-Cluster
  The software cluster is a network of companies, educational and research institutions in the field of software development around the cities of Darmstadt, Kaiserslautern, Karlsruhe, Saarbrücken and Walldorf.

- MINT-EC
  The national Excellence School Network MINT-EC has set itself the goal of inspiring students for MINT subjects (mathematics, computer science, natural sciences and technology). In cooperation with MINT-EC, regular events such as the Math Talent School take place.

- ZukunftsRegion Westpfalz e.V.
  The association ZukunftsRegion Westpfalz wants to bring together people, companies and organisations from the region in order to work together for strengthening the Westpfalz and the future viability of this region.

- KOMMS
  The Competence Center for Mathematical Modelling in STEM projects was established to connect school projects, teacher trainings, education of teacher students and research.

- EMVA
  EMVA (European Machine Vision Association) is a non-profit organization with the purpose to represent the machine vision industry in Europe. Since January 2018, the Image Processing and Materials Characterization and Testing departments have been involved as members.

- Kompetenznetz Verfahrenstechnik Pro3
  Kompetenznetz Verfahrenstechnik Pro3 stands for the networking of industrial partners with research and teaching in process engineering, bioengineering and chemical engineering. The aim is to strengthen process engineering in Germany.

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 department. 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 55 employees and a budget of six million euros in 2018.

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.

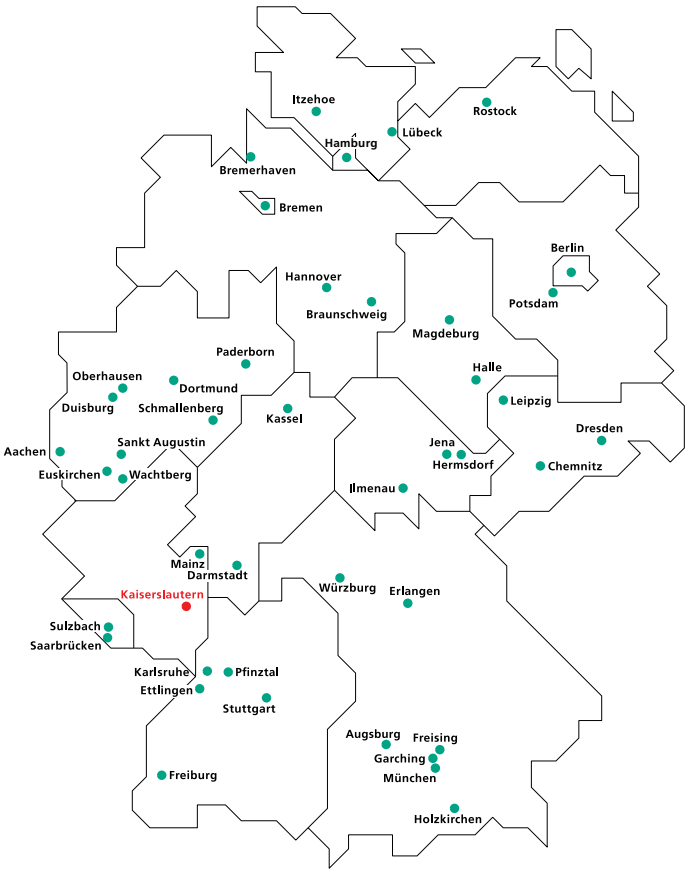
At present, the Fraunhofer-Gesellschaft maintains 72 institutes and research units. The majority of the more than 26,600 staff are qualified scientists and engineers, who work with an annual research budget of 2.6 billion euros. Of this sum, 2.2 billion euros is generated through contract research. Around 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Around 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.

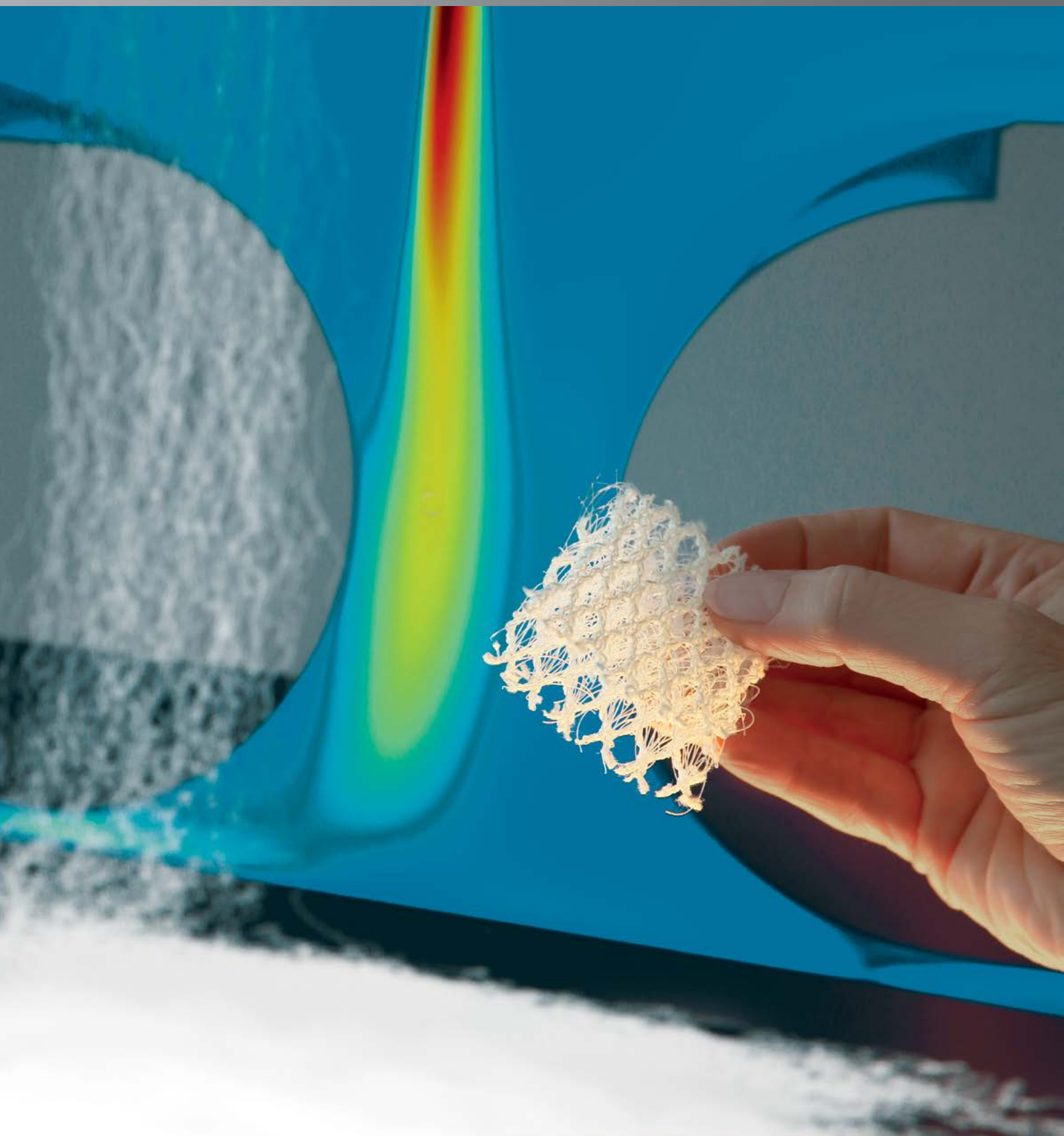
With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits 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.



TRANSPORT PROCESSES



DR. DIETMAR HIETEL
DR. RAIMUND WEGENER
HEADS OF DEPARTMENT

MATHEMATICAL MODELING AND SIMULATION-BASED OPTIMIZATION OF TRANSPORT PROCESSES

The Transport Processes department models complex industrial challenges and develops efficient algorithms for their computer-based simulation and optimization. Our primary tasks occur in the context of the technical-natural sciences (fluid dynamics, radiative transport, optics, structural mechanics, etc.) which, when modeled, lead to differential equations that are mainly characterized as transport algorithms.

From the perspective of our industry customers, such tasks typically concern product optimization or the design of the production processes. The department's expertise includes collaborative research projects with engineering-oriented research and development departments at our partner companies, studies that include design and optimization recommendations, as well as software programming support of components or complete tools.

As in previous years, we balanced the budget and were economically successful again in the year 2018. As part of a scientific institution, our department further improved its position as documented by the increase in publication activity. Consequently, we were able to acquire new, longer-term, public funding for research projects.

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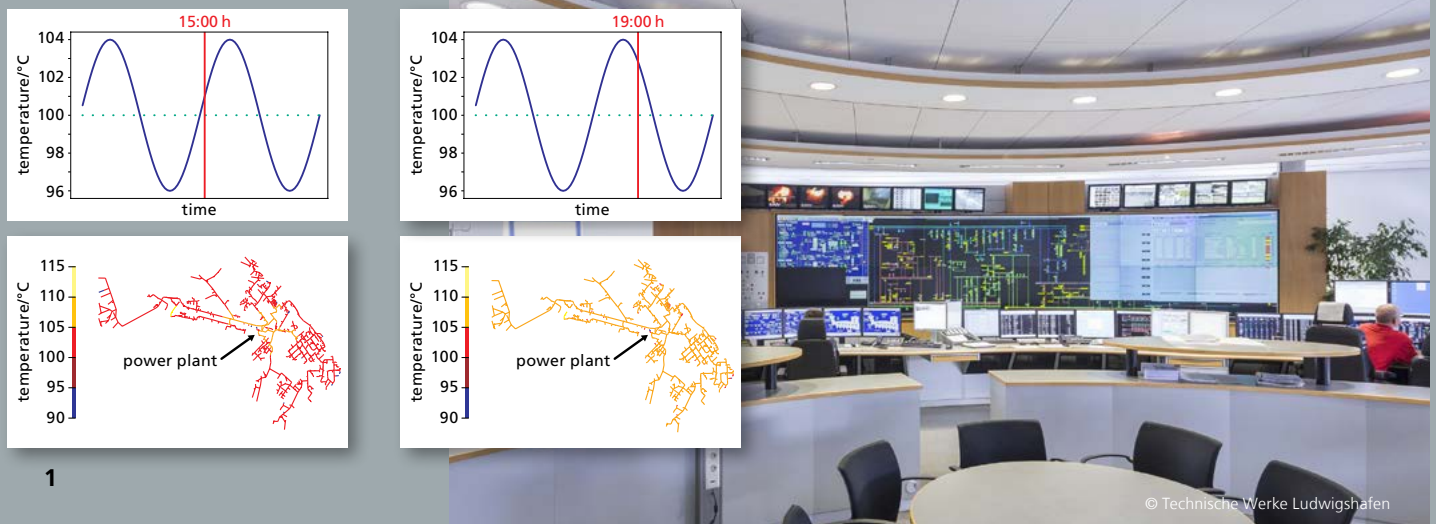
MAIN TOPICS

- Flexible structures
- Fluid dynamical process design
- Grid-free methods
- Energy transport networks and model reduction



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DYNAMIC SIMULATION TO IMPROVE EFFICIENCY OF DISTRICT HEATING GRIDS

1 *Dynamic simulation of the sub-network in Ludwigshafen: feed-in temperature at the power plant (top), temperature in the district heating network (bottom)*

The project is sponsored by the Federal Ministry for Economic Affairs and Energy (BMWi) and implemented in cooperation with GEF (engineering company) and TWL (Technische Werke Ludwigshafen) with the aim of developing dynamic network simulations to improve the efficiency of district heating operations. The project has already developed and tested a software tool for network simulation, which TWL uses to optimize its operations.

District heating grids supply heat and warm water. The operators of district heating plants generate part of their revenues from the sale of electricity, generated in parallel at the combined heat and power (CHP) plants. The integration and dynamic control of the district heating grids as energy storage systems ensures efficient operation of the turbines and optimal use of the existing storage tanks.

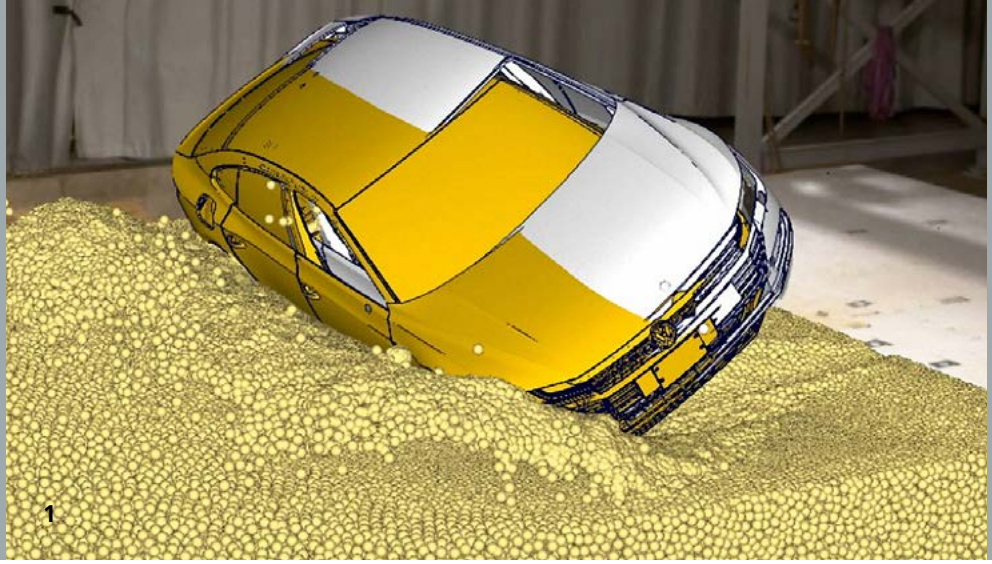
Software models optimize grid operations at district heating power stations

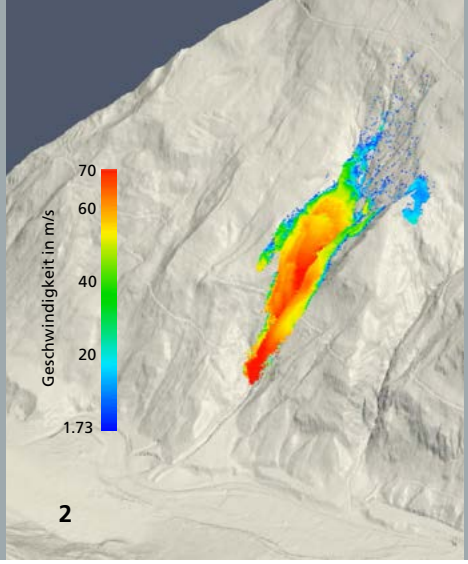
The current software to support the operation of CHP plants focuses on either the optimal use of local resources, where the district heating network is managed as an unstructured sink, or on detailed models of the power grid and locally triggered hydrothermal conditions to ensure supply to all customers. However, this usually happens without having an integrated simulation of the overall picture with fluctuating operating conditions.

The dynamic simulation of district heating grids has huge advantages: using the software, the grid operator can read both the temperature and the flow conditions at any point in the district heating grid at all times. In doing so, the inlet temperatures provided at the power plant and mass flow fed into the grid can be controlled, which implies that the costs of switching on gas turbines for heat generation can be avoided.

Mathematics creates a digital twin behind the software

The traditional methods of solving the fluctuating thermohydraulic equations are too inaccurate or too expensive for use in proposing operational controls for district heating grids. This is the reason the project developed a new numerical method that does not need to further subdivide the lines. The software creates a digital image of the real district heating grid and an automated control center, which is more necessary than ever before considering the ongoing decentralization of input points. The optimization horizons over a few days can be mastered using model-predictive control and automatic differentiation.





MODELING NON-NEWTONIAN FLUIDS WITH MESHFREE

In cooperation with Fraunhofer SCAI since 2018, we supply a software product for the mesh-free simulation of physical processes. The innovative software combines the expertise of both institutes in the area of meshfree scientific computing and satisfies a wide range of applications.

1 *Lateral rollover of a vehicle in sand: comparison of experiment and simulation*

2 *Simulation of the Wolfsgruben avalanche (March 13. 1988), geo data: with kind support of BFW Austria.*

Our development of the Finite-Point-Method

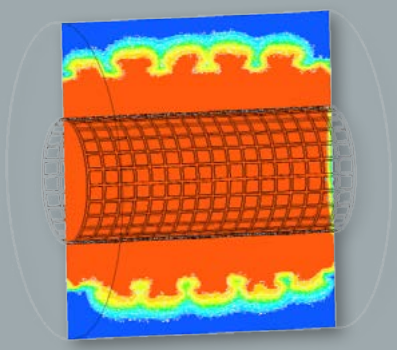
Meshfree simulation expands the horizon of computational models, in particular, in the context of industrial applications. The Finite-Point-Method (FPM) was originally developed at ITWM and has been in use since the year 2000 in many projects with European partners. The method was first developed and used to model airbag deployment. Later, FPM evolved into an implicit, meshfree flow tool.

The absence of calculation grids saves preparation time for the simulations. How do you model the flow of rain water, the passage of water, the filling or sloshing from a passing auto? How do you emplace floating pontoon bridges? How do you optimize Pelton turbines in hydropower plants? The applications are plentiful and FPM has a clear advantage over mesh-based methods in the area of free surface flows and fluid structure interaction (FSI). This implies the need to solve large linear equation systems. Combining FPM with the algebraic multi-grid process (SAMG, Fraunhofer SCAI) enables efficient solving of linear systems. The resulting software is called MESHFREE.

Meshfree simulation of granular media

We are significantly expanding the focus of meshfree simulation. Not only do we rely on completely new applications, for example, for process engineering or processes in the food industry. We are also exploring a much wider range of materials. In addition to traditional computational fluid dynamics (CFD), we also focus on non-Newtonian fluids – for example, foams, batters, or polymer melts. MESHFREE is also used to model the dynamics of granular media like sand, gravel, snow, grain, flour, etc. For example, this is part of a German Research Foundation (DFG) project at University of Innsbruck (Working Group for Geotechnical and Tunnel Engineering). In addition to the simple Drucker-Prager material model, we anchor hypoplastic and barodesy descriptions (complex, non-linear, constitutive frameworks to express very exact surface behavior) in MESHFREE. Together with automobile manufacturer VW we rely on VPS (Virtual Performance Solution), a software package from the ESI Group, for example, to simulate an overturning vehicle (rollover processes) on sandy surfaces.

MESHFREE



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MACHINE LEARNING IN TEXTILE MANUFACTURING

1 *CFD simulation of a virtual bobbin in a dye bath*

2 *Colored bobbins in textile production*

Today, we see dramatic changes in the demands being made of the textile industry. The trend in many areas is towards customization, similar, for example, to buying a new car. Consumers increasingly demand tailor made products. This shift in consumer behavior is lucrative for European textile companies as production of customer-specific products in small lot sizes results in the return of manufacturing to Europe. However, this requires the digital transformation of production, which we support with our hybrid simulation-based machine learning (ML) methods.

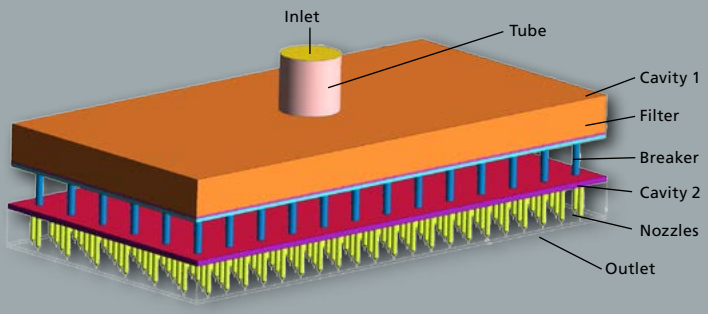
Data-based machine learning by itself is not sufficient

In data-based machine learning, we develop statistical learning algorithms that recognize patterns and laws in given data. The benefits of ML algorithms depend to a great extent on the quality and quantity of the available data. As a rule, enough measured data is collected for the purpose of quality assurance in the textile industry. However, only in the rarest of cases is sufficient data available to make a connection between the process parameters and the product quality. Consequently, we are not able to use pure, data-driven machine learning – especially for plant and process optimization for today's customized production processes.

Hybrid simulation-based machine learning

To design and optimize production processes in the textile branch with ML methods, we develop and apply a hybrid approach. Extensive experience is available for process and product design in textile industry. We formalize this expert know-how by building a physical model to describe the process and, subsequently, implement a computer based simulation. Models provide the missing data for the development of suitable ML algorithms and linking with available measurements. In this concept, ML closes the gap between physical based simulation of production processes and the level of quality of the end products – which, in many cases, is not accessible to physical models.

The optimization of winding machines with regard to a better dyeing of the wound bobbins illustrates this innovative hybrid ML process in AiF's DensiSpul project.



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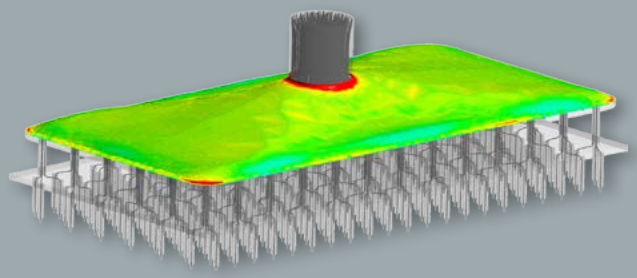


2

DYNAMIC FLOW DESIGN OF POLYMER SPIN PACKS

The melt spinning process is the most common way to produce synthetic fibers. We use simulation and optimization methods to help our clients with the development, design, and improvement of spin packs.

1 *Geometry of a characteristic spin pack*

2 *Spin pack with improved distributing cavity*

Spin packs are used in the manufacture of synthetic fibers and nonwoven fabric. The spin pack is a metal block, consisting of cavities and tiny channels through which the thick viscous liquid – the polymer melt – is forced to flow. The molten mass is fed through a tube into the spin pack. On entering the first cavity, the molten mass spreads across the entire width of the spin pack. The melt passes through several layers of filters that are held in place by a support plate before being extruded through the fine capillaries of the spinneret. The extruded filaments are either wound into yarn or formed into a nonwoven fabric.

Analysis and simulation provides a look inside the spin packs

Our work always begins with a fluid dynamics analysis of the actual state. We simulate the flow within the spin pack while taking the characteristic flow properties of the polymers into account. Using special tools, we then evaluate the residence times and pressure profiles.

The analysis provides specific information about which component of the spin pack needs to be improved. Frequently, we find significantly long residence times in the cavities. This is damaging to the polymers which decompose after some time under thermal stress. To prevent this, we use shape optimization to design components with very low and even residence times. The analysis also reveals strong pressure generators, which indicates the need to make appropriate adaptations to the corresponding components.

The simulation-based analysis enables us to look inside the spin pack, which otherwise remains hidden. This is a decisive design advantage, as now all fluid dynamic parameters become directly quantifiable. Problematic components are identified and modifications are directly validated. Another benefit is that the development times are faster and companies can avoid costly design errors.

NEWS

SEMINAR ON MACHINE LEARNING IN PROCESS ENGINEERING

In November 2018, the department organized a workshop titled "Introduction to machine learning (ML) in process engineering." The seminar gave participants a detailed introduction to the world of machine learning. The workshop focused on understanding the most important terms like supervised versus unsupervised learning, as well as an overview of ML algorithms typically used in regression or classification problems. An overview of Deep Learning completed the theoretical background portion. Dr. Simone Gramsch and Dr. Andre Schmeißer shared their expertise in lectures and a stimulating final discussion round of questions and answers. The event was jointly organized together with our long term partner, the non-profit association COMPETENCE NETWORK PROCESS ENGINEERING PRO3.

NEW WEBSITE "MESHFREE.EU"

The department has worked with the Fraunhofer Institute for Algorithms and Scientific Computing, SCAI since 2018 to develop MESHFREE, an innovative software product for meshfree simulations of physical processes. We combine the expertise of both mathematical institutes in the field of mesh-free systems computing on the English language website meshfree.eu. All developments surrounding the product are quickly and clearly visible on that media for industry and research purposes. The website is one leg in our support and promotion of the software as a major player in the market. More information is provided on page 25.

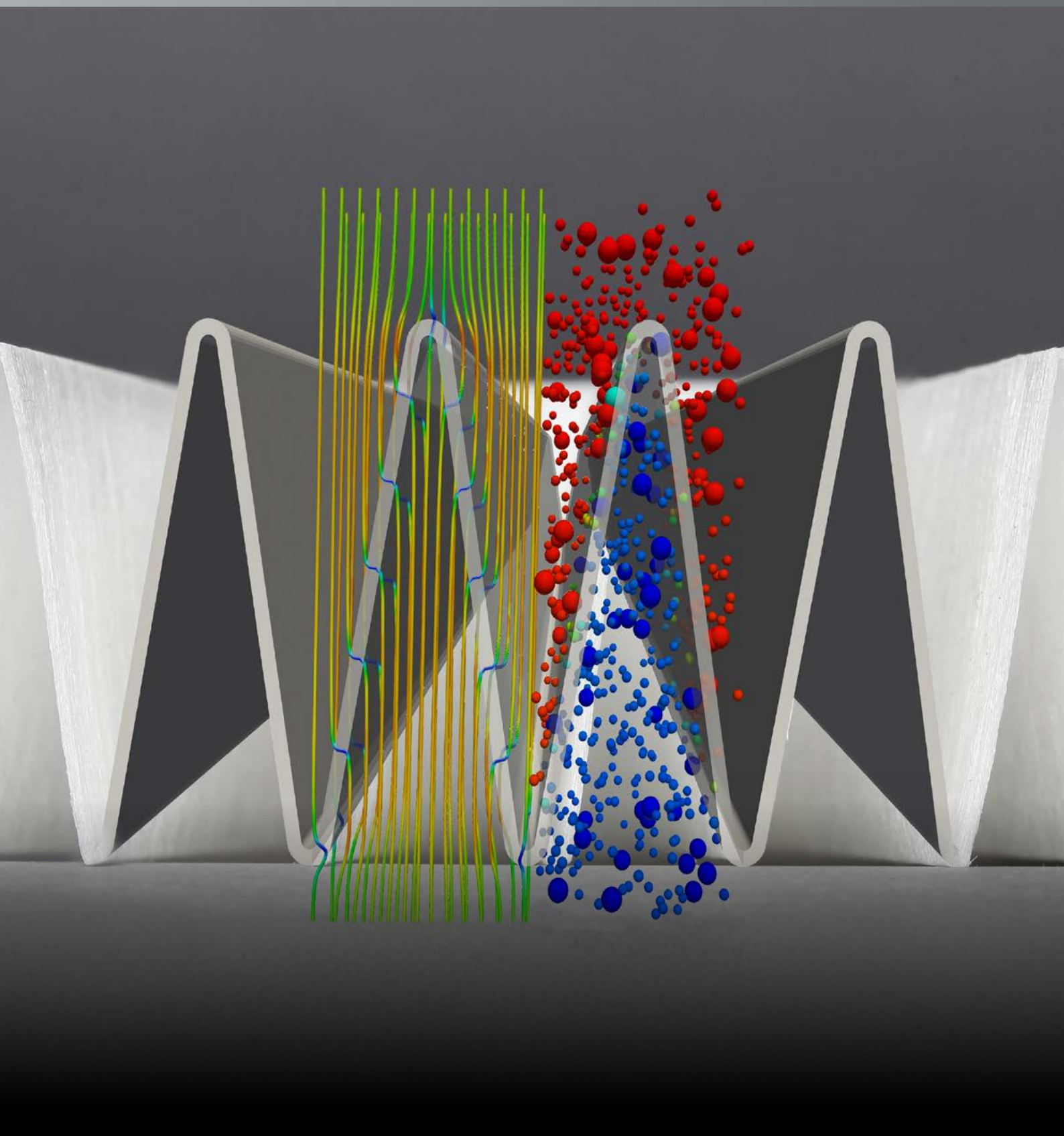
MESHFREE

TOOLS FOR FLEXIBLE AND EFFICIENT DISTRICT HEATING SUPPLY SYMPOSIUM

The March 2018 symposium highlighted the ongoing transformation in the district heating industry and showed participants how to optimize the operation of district heating networks and make them more flexible. AGFW, the energy efficiency association for heating, cooling, and co-generation organized the event and Fraunhofer Center Kaiserslautern provided the venue. The research project DYNEEF (see page 24) served as the incentive for the event. The project develops new methods for requirements-based operational control of district heating power plants.

Front, left to right: Dr. Andre Schmeißer, Dr. Tobias Seifarth, Dr. Almut Eisenträger, Dr. Isabel Michel, Sergey Antonov, Dominik Linn, Dr. Norbert Siedow, Dr. Pratik Suchde, Dr. Jaroslaw Wlazlo, Sebastian Blauth, Niklas Lehne, Dr. Raimund Wegener, Dr. Dietmar Hietel, Dr. Jörg Kuhnert, Johannes Schnebele, Markus Rein, Manuel Wieland, Jens Bender, Dr. Robert Feßler, Matthias Eimer, Dr. Jan Mohring, Dr. Christian Leithäuser

FLOW AND MATERIAL SIMULATION



DR. KONRAD STEINER
HEAD OF DEPARTMENT

MULTI-SCALE SIMULATION AND CUSTOMIZED SOFTWARE FOR INDUSTRIAL APPLICATIONS

Our department, Flow and Material Simulation develops multi-scale methods and software tools for product development and process engineering. One of the typical challenges is to model the interrelated influences of production processes and multi-functional local material properties. Our unique knowhow lies in the development of company-specific software and the supply of specific, industrial use application solutions featuring multi-scale and multi-physics approaches. As indicated by our name, the department is divided into two major areas of expertise. The subject area "Computer-aided material design and microstructure simulation" focuses on simulation-based optimization of the functional properties of porous materials and composites. We experience a high demand for our highly efficient, micro-mechanical simulation methods for material engineering of fiber reinforced composites and technical textiles. Currently, our major research focus is on the design and structural optimization of programmable materials and on modeling the production process by means of additive processes.

The subject area "Simulation-aided design of complex flow processes" studies the associated production processes like mixing, dispersing, injecting, filtering, coating, and separating. With the new tool FOAM we simulate the reaction injection molding process of rigid and flexible foam for various applications as well as the foaming of vehicle seats, the insertion of insulation foam or the infiltration of textile reinforcements for composite components.

Another use case is in the field of electro-chemistry where we investigate various aspects of the production and material design of batteries and fuel cells, for example, the filling of the battery cells with electrolyte.

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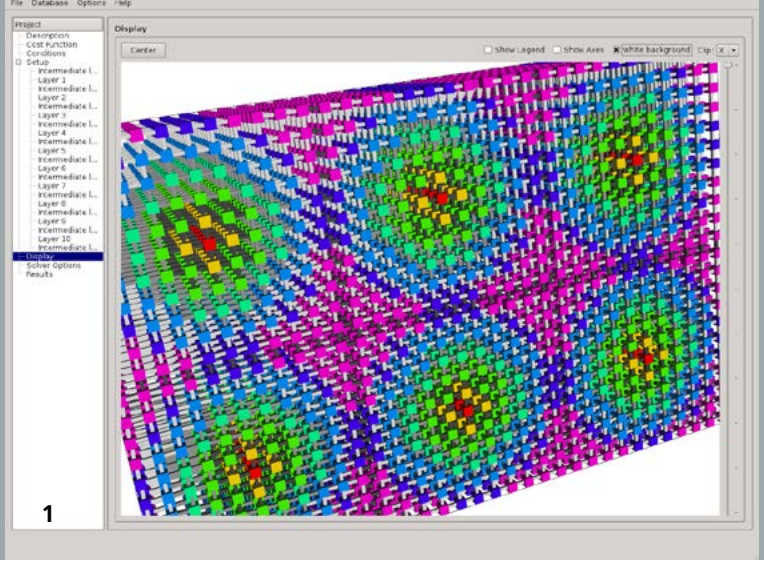
MAIN TOPICS

- Technical textiles and nonwovens
- Virtual material design and microstructure simulation
- Lightweight and insulation materials
- Filtration and separation
- Complex fluid dynamics and multiphase flows
- Electrochemistry and batteries



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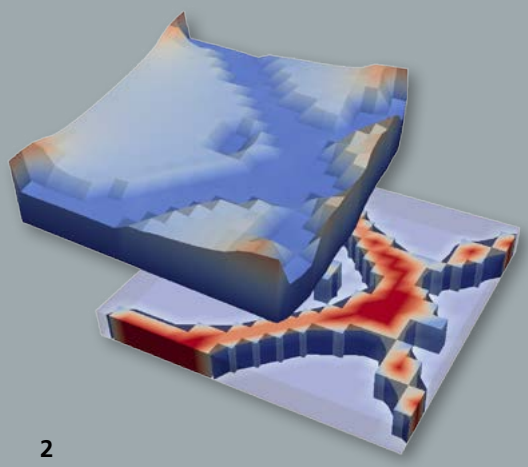


2

PROGRAMMABLE MATERIALS – MECHANICS AND TRANSPORT ON REQUEST

1 *Design study for a metamaterial, constructed from different elementary cells*

2 *Non-linear deformation of a topologically optimized metamaterial*

Giving materials new functionalities? We are finding ways to do that in various projects in the field of "Programmable Materials." What we find is that not only the basic material itself is changed, but also its internal structures.

New manufacturing methods make it possible to specifically produce structures in the micrometer range. These methods include for example, additive processes like 3D-printing. An engineer uses these methods not only to design the outer shape, but also to target the internal microstructures to give certain properties to a component. In cooperation with other Fraunhofer Institutes, we go one step further and define multiple states for such microstructures and apply external stimuli to switch between them.

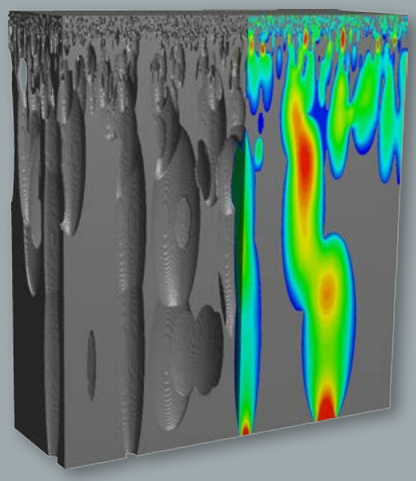
Programmable mechanics and a tool kit full of structural possibilities

At Fraunhofer Cluster of Excellence "Programmable Materials", we develop mathematical procedures for optimizing structures and provide support to engineers in designing production processes and choosing the appropriate microstructures. Working with the Fraunhofer Institute for Mechanics of Materials, IWM, we develop the microstructures for 3D-printing, which can change the internal stiffness or the surface shape as desired when subjected to external mechanical stress. Specifically, we have achieved extraordinary mechanical effects that do not exist in the naturally occurring material.

For example, the so-called pentamode mechanical meta-materials are solid structures that behave like liquids. These materials consist of three-dimensional arrays of cubic cells. Each cell exhibits a non-linear mechanical behavior and multiple stable states. Such cells are developed, printed, and tested at Fraunhofer IWM.

Algorithms for very special cells

There are many different ways to shape these cells. One type is known as auxetic cellular material that expands orthogonally when under tension, that is, it becomes thinner when compressed and thicker when stretched. Many more options are created when thousands of these unit cells are arranged into an array. We develop an algorithm that computes a possible selection and arrangement of the cells on request. We developed a graphical user interface for the design of programmable materials made from these unit cells – similar to the CAD software used in architecture. In the long term, these computed structures will be output for immediate use as input to 3D-printers.



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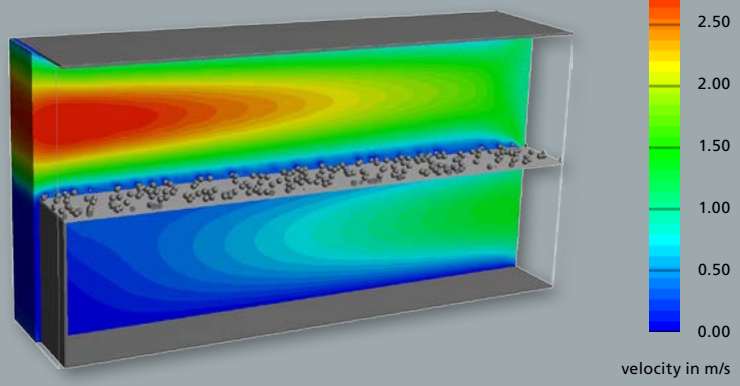


2

Programmable transport: Clean filters with smart materials

Together with the Fraunhofer Institute for Applied Polymer Research IAP, we are developing filter membranes. In this case, the focus is on the use of programmable materials that can change their properties as a result of external stimuli, in particular, in the area of effective filter cleaning.

These membranes are made from thermally activated shape memory polymers, with or without a porous structure, that can change form at the time of cleaning and make the process more effective. Shape memory polymers are polymers that seem able to "remember" their previous form. The project also studies membranes with additional surface structuring for applications with cross-flow filtration. Such structuring can delay the fouling process during the filtration phase, for example, by keeping away bacteria from the membrane. Another kind is the chemo-selective membranes, where permeability can change depending on the presence of certain chemicals. This effect is used to block pollutants. In all cases, we assist project partners with simulations to support their development efforts.

Adaptive filtration using membrane structure

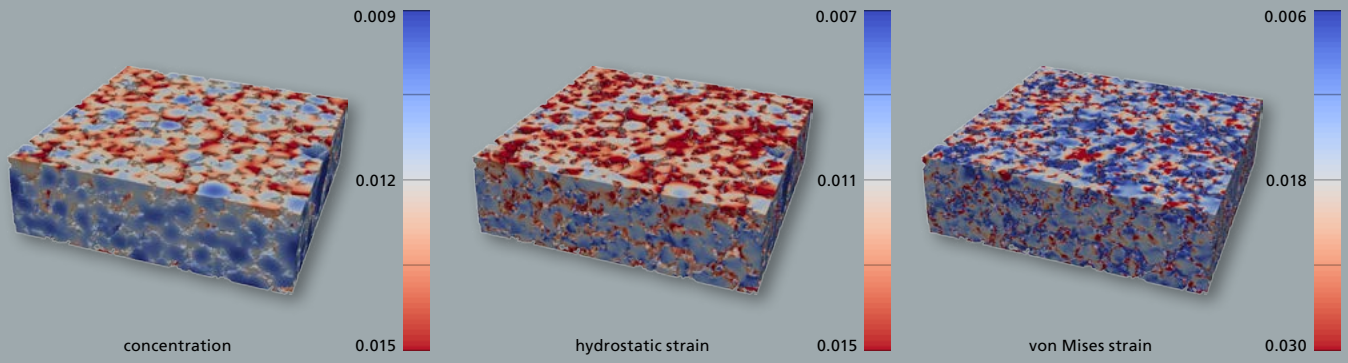
The "Programmable Materials in Science and Engineering (ProMiSE)" project is a collaborative project with other Fraunhofer Institutes, with a research focus on new programmable materials, specifically, "programmable porosity."

As possible trigger mechanisms, we are exploring piezoelectrical and thermo-mechanical effects. The aim is to achieve a deformation of the pore geometry on the micro-scale and, in this way, change the material porosity. This ability can be used in adaptive filtration, for example, in water treatment or chemical processes.

The modeling and simulation of the piezoelectrical effects poses a challenge. These methods describe the changes in electrical polarization and show the presence of electrical current in solids under conditions of elastic deformation. The expansion and orientation of the polymer must be mechanically modeled on a continuum scale. We then compare the effects of differently structured pore geometries. Project partner Fraunhofer Institute for Applied Optics and Precision Engineering IOF, produced the necessary membrane geometries using laser irradiation. The required adaptive filtration is achieved through deliberate deformation.

1 *Flux through a virtual microstructure*

2 *Transversal filtration through a membran with surface structure*



1

BATTERY SIMULATION TOOL BEST – NEW EFFICIENT SOLVERS AND INTEGRATION IN GeoDict

1 *Lithium Ion concentration (mol/cm³), hydrostatic strain, and von Mises strain simulated with BESTmicroFFT for a realistic, stochastic electrode structure (structure generation: Inst. of Stochastics, Univ. Ulm)*

Electric mobility places a high demand on the energy storage systems – mainly lithium-ion batteries. Computer simulations can help in evaluating the performance of new battery cells, in understanding the microscopic reasons for the observed behaviour, and in optimizing the design. Several years ago, ITWM started the development of BEST (Battery and Electrochemistry Simulation Tool), which is continuously updated in public and private industrial projects.

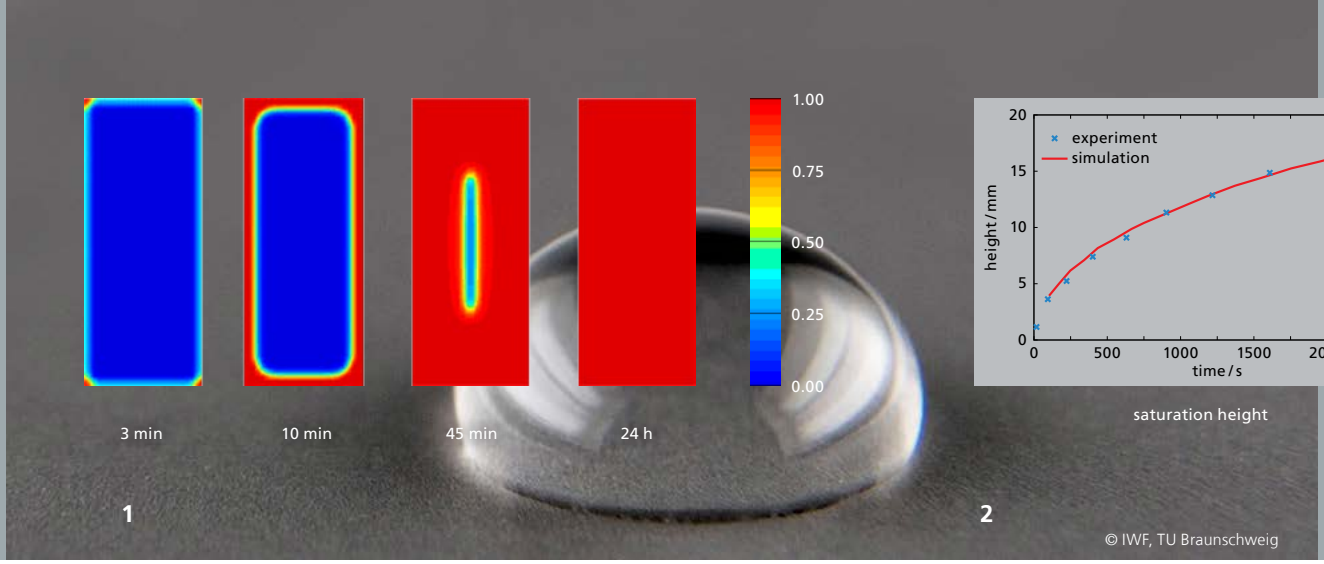
Interesting problems range from design issues at the macroscopic battery cell scale (BESTmeso) to the effects of the microscopic design of electrodes (BESTmicro) on the electric, thermal, and mechanical characteristics of the cell. Two different software components are used to account for these multiscale aspects: BESTmeso and BESTmicro.

BESTmicroFFT reduces computing and storage costs

Simulations that account for the three dimensional microstructure of electrodes are very expensive because of the fine spatial discretization required. BESTmicro can sometimes take several days of computing time on common work stations. In many standard cases, the recently developed BESTmicroFFT software-module provides the remedy. Similar to ITWM's mechanical solver FeelMath, the new solver is also based on a Fourier method (FFT) and requires significantly less computing and storage effort for simulations. The user can now decide between the two micro-solvers depending on the current requirements.

BatteryDict as new GeoDict component

The BESTmicro and BESTmicroFFT solvers are fully compatible with the structure generators in the GeoDict software from Math2Market (M2M). In the area of battery simulation, we began collaborating with M2M last year on the joint development of the new GeoDict module BatteryDict. The new module is now commercially available in the GeoDict2018 release and offers BESTmicroFFT-based battery simulation in a fully integrated GeoDict workflow. The GeoDict2019 version has been expanded to provide for electrodes made from different active materials (electrode blends) and additional material classes (conductive additives).



MODELING THE PRODUCTION PROCESS OF LITHIUM-ION BATTERIES

Scientists at twelve German universities and research institutes are working in the competence cluster for battery cell production (the ProZell Cluster) for the purpose of studying and improving the production process of battery cells and assessing various influences on cell properties and product development costs. Their work will provide the scientific basis for the sustainable development of a globally competitive battery cell production industry in Germany. We are involved in the project Cell-Fi which aims at improving the electrolyte filling process.

1 *Electrolyte saturation within electrode plane at different times during the wetting process*

2 *Comparison of liquid rise in porous electrode in simulation and experiment Exp. data: IWF, TU Braunschweig)*

Cell-Fi: Modeling electrolyte filling of battery cells

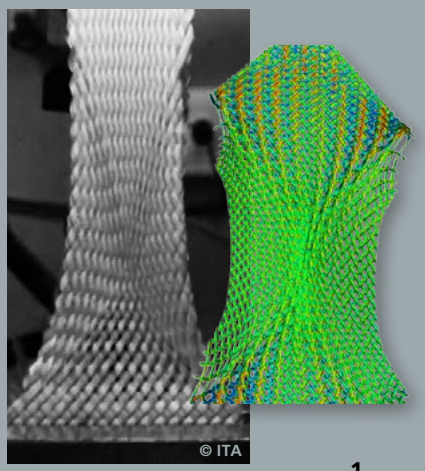
The topic of the project Cell-Fi is the acceleration of electrolyte uptake through optimized filling and wetting processes: After the assembly of the cells, billions of pores of the battery components – at most only a few micrometers in diameter – are filled with an electrolyte solution. The process takes several hours because the solution penetrates via the cell's small side faces into the pore volume only driven by capillary forces. Furthermore, it is difficult to assess the time required to ensure a uniform wetting.

Until now, the process of electrolyte filling has hardly been scientifically investigated. A great potential exists for companies to achieve higher throughput in production and to save costs if the relationships between process parameters and wetting speed and quality are better understood.

Calculating on micrometer scale and macroscopic scale

Our task in this project is the development of simulation methods that describe the capillary-driven flow within the different porous layers of the cell. This involves several different length scales: The pore morphology at the micro-scale, together with the physical surface characteristics of the materials involved, influences the capillary forces responsible for the wetting speed. We calculate the required input parameters from the micro-scale using the GeoDict simulation software from Math2Market.

On a macroscopic scale, the main influences affecting how the liquid distributes within the cell are the cell dimensions and the positioning of the surfaces through which the electrolyte enters the cell. Here, we use our ITWM software platform CoRheoS. Together, the GeoDict and CoRheoS tools let us predict the wetting times for various cell geometries, pore distributions, and material properties.



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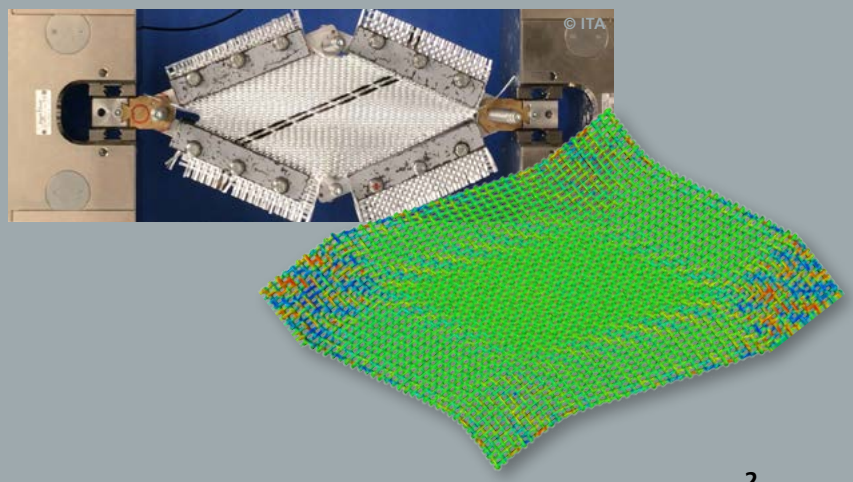


2

OPTIMIZING THE DRAPING PROCESS FOR FRP COMPONENTS MADE FROM HIGH PERFORMANCE TEXTILES

1 *Critical shear angle experiment performed by ITA and simulation of wrinkling*

2 *45°-tension test of a woven fabric with fixed frame performed by ITA and corresponding simulation*

As part of the AIF Project OptiDrape we are developing a draping catalog for small and medium-sized enterprises (SMEs) in cooperation with the Institute for Textile Technology (ITA) and the Institute for Management Cybernetics (IfU), Aachen.

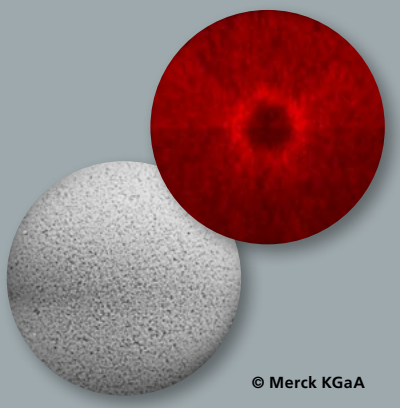
The potential of components made from fiber reinforced polymers (FRP) is highly dependent on the type of reinforcing textiles used and their drapability (ductility). The draping quality is evaluated on the basis of defects and wrinkles in the textile after preforming. Preforming refers to the process for producing a dry reinforcement structure. The potential of the anisotropic material is enormous for lightweight construction and can be specifically exploited only if the textile fibers are present locally in the required orientation. The draping process takes place during the production of complex geometries by experienced specialists. From a technical and economic point of view, the process lacks standards and objective criteria and requires optimization.

Improve quality and shorten times

The aim of the OptiDrape project is to improve the quality of the preforms for FRP components and to shorten the development time. We classify the different mats and weaves in terms of draping properties according to the type of bond as well as by the roving material and cross-sections. A roving is a bundle, strand, or multi-filament yarn made from parallel filaments. Also, a textile-specific shear angle is given. This indicates the point at which the textile starts to wrinkle. We selected a total of 16 carbon and glass fiber textiles with different cross sections and bond types as well as various offsets. ITA conducted a number of experiments and determined the effective tensile, shearing, and bending properties and shear angles. In parallel, we also used our FEM software to simulate and validate these properties. In contrast to experimentation, simulation at the roving level enables a virtual material design with precision detail. Among other things, the roving cross sections as well as the materials and distances of the bonds can be more efficiently varied; and, the experiment catalog was significantly expanded.

Model for a wide range of uses

The project used comprehensive mathematical analysis to develop a predictive model that calculates the critical shear angle. It relies on previously defined roving materials and dimensions, the type of bond, as well as experimentally determined contact point data. Additional model parameters include the offset of the bond as well as the distances. The resulting model not only allows companies to set up a very broad catalog, but also to continuously vary all of the design parameters for any application and requirement in the interests of optimizing the design.



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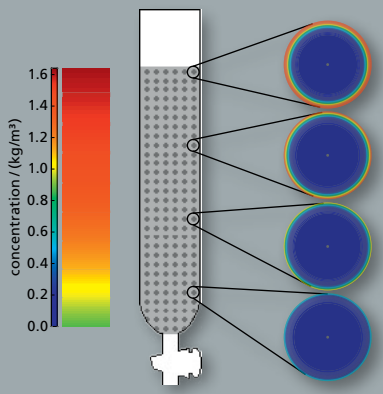

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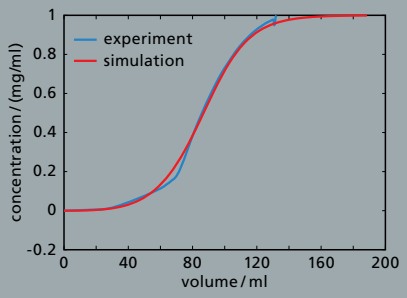


3

MODELLING AND SIMULATION OF CHROMATOGRAPHY WITH SPHERICAL BEADS

In the BMBF joint research project AMSCHA, we develop models for the simulation of separation processes of protein and cell suspensions. The abbreviation stands for "Analysis, modelling and simulation of chromatographic purification processes". In collaboration with researchers from the Technical University Kaiserslautern and the University of Applied Sciences Darmstadt, the processes are investigated on different length scales. The chemical and pharmaceutical company Merck KGaA and the manufacturer of optical microscopes Leica Microsystems support the research project as industrial partners.

The separation of target substances from a suspension is an important and often undervalued step in the manufacturing of agents in the pharmaceutical industry, although one cannot imagine laboratory and industrial work without chromatography as a separation process. One well-established form is column chromatography. The efficiency and the throughput of these columns strongly depend on the process conditions and the used chromatographic media.

Model, simulate and optimize protein purification

In one part of the project, we consider the separation of protein suspensions using chromatographic purification. The goal is to extract one target protein from a mixture. This is done with the help of spherical, microporous beads (pearls). In column chromatography, a cylindrical tube – the separating column – is packed with the stationary phase – the beads – and is flowed through by a protein suspension. In this connection, part of the proteins is deposited within the beads.

The industry partner Merck conducts for this application several experiments in the laboratory. To reproduce the processes in the simulation, we determine suitable model parameters based on static and dynamic measurements of the binding capacities (protein concentration). Additionally, Merck visualizes the concentration profiles in the static experiments using confocal laser scanning microscopy.

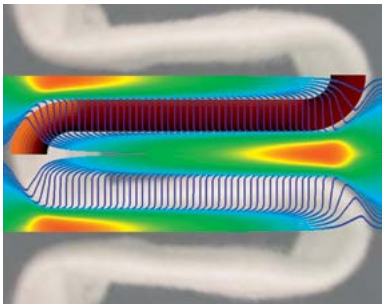
1 *Microscopy image of a chromatography bead. Confocal laser scanning microscopy image of a labeled bead. The dye intensity is indicating the loading (lightest red strongest loading).*

2 *Overview on the simulation of a chromatography column (dynamic process conditions; left: concentration profile in the column, right: the loading of single beads at different positions in the column*

3 *Comparison of the simulated protein breakthrough curve with experimental data*

NEWS

AWARD FOR DISSERTATION ON THE SIMULATION OF CAKE AND DEPTH FILTRATIONS



In November 2018, Dr. Sebastian Osterroth took third place in the ICT Dissertation Award presented by Fraunhofer Information and Communication Technology Group. The jury presents the award to outstanding dissertations originating at the Fraunhofer Institutes that deal with innovative developments and technologies in the computer sciences, mathematics, or related fields.

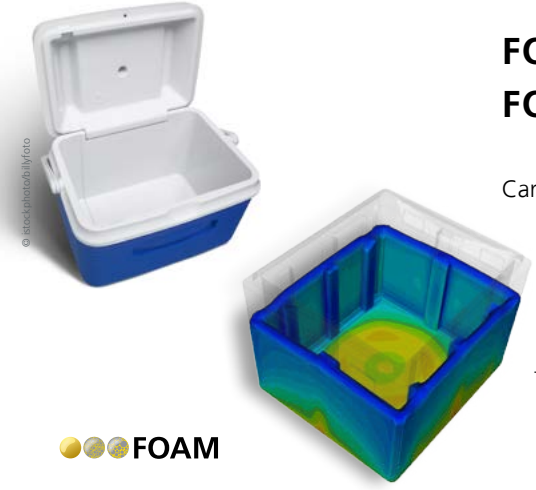
Osterroth's dissertation deals with mathematical modeling and simulation of cake filters and depth filtration. The filter cake functions as a supplemental filter medium, with increasing thickness. This study provides a major contribution towards the optimal design of filter elements.

NEW TEST DEVICE FOR POROUS MEDIA

Departmental lab is home to a new air permeability test apparatus. We are now able to determine the permeability of a wide spectrum of porous materials (for example, nonwoven fabrics, weaves, knits, crochets, foams) because of the device's large measuring range.

In future combination with the existing DMTA (dynamic-mechanic-thermal analysis) test unit, material characterizations with flow and structural mechanics will be possible from a single source. In particular, it enables us to investigate the relationships between mechanical deformation and the associated changes in flow resistance.

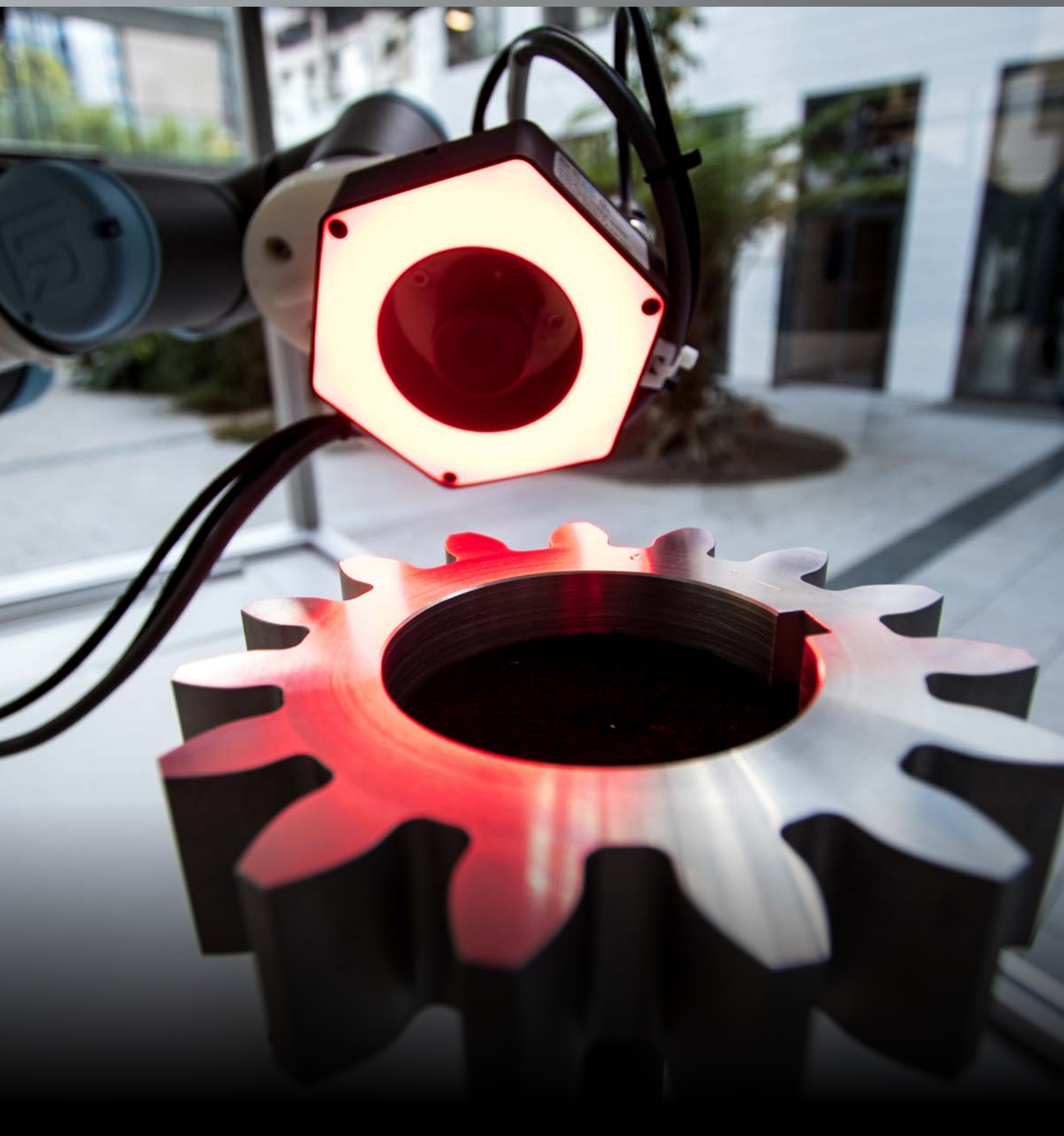
FOAM: RELIABLE SIMULATION OF POLYURETHANE FOAM



Car seats, mattresses, and insulation materials mainly consist of polyurethane (PU) foams. The foaming process of the liquid polymer emulsion is complex. In cooperation with colleagues at the Department of Lightweight Structures and Polymer Engineering at Chemnitz University of Technology, our department has developed software to simulate the foaming behavior and reliably characterize the material. FOAM also works for composites where plastic foams are injected into textile structures.

Front, left to right: Dr. Olga Lykhachova, Jan Lammel, Inga Shklyar, Ruturaj Deshpande, Dr.-Ing. Sarah Staub, Pavel Gavrilenko, Alexander Leichner, Dr. Olena Sivak, Dr. Xingxing Zhang, Dr.-Ing. Tobias Hofmann, Christine Roth, Dr. Larysa Khilkova, Pavel Toktaliev, Dr. Sebastian Osterroth, Dr. Dariusz Niedziela, Dr. Konrad Steiner, Jonathan Köbler, Dr. David Neusius, Dr. Ralf Kirsch, Dr. Stefan Rief, Dr. Heiko Andrä, Dr. Aivars Zemitis, Dr. Matthias Kabel, Prof. Dr. Oleg Iliev, Dr. Stephan Kramer, Stephan Wackerle, Riccardo Falconi, Dominik Gilberg, Dr. Torben Prill, Dr. Jochen Zausch, Thomas Palmer, Dr. Hannes Grimm-Strele, Michael Hauck

IMAGE PROCESSING



MARKUS RAUHUT
HEAD OF DEPARTMENT

CUSTOM-MADE IMAGE ANALYSIS SOLUTIONS FOR THE PRODUCTION AND ANALYSIS OF MICROSTRUCTURES

We develop mathematical models and image analysis algorithms and convert them into efficient industrial software. We solve inspection tasks, mainly for production facilities.

The areas of application include in particular complex surface inspections and the analysis of microstructures. Our large portfolio of algorithms enables us to solve image processing tasks for which commercially available systems cannot yet be used or only partially. For these problems, we develop custom-made, sophisticated image processing solutions.

Machine learning has been an integral part of many projects and research activities in the department for years. In the area of surface inspection, hybrids of "classical" image processing algorithms and learning approaches are used increasingly. Learning methods require a large amount of annotated data, which can usually neither be financed nor generated in an industrial project. Therefore, we use model-based machine learning: We model properties of the objects to be found and use this modelling as partial input for automated processes.

Furthermore, we offer technical consulting services, for example for optimal hardware configurations in image processing systems or for the integration of additional components into an existing system. However, we also provide independent consulting in the field of optical quality control or algorithm development.

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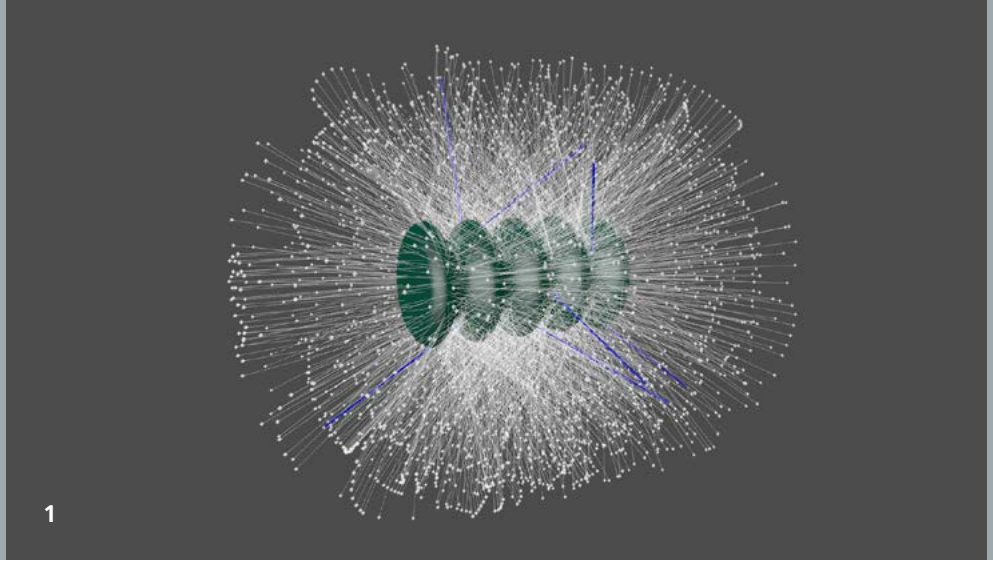
MAIN TOPICS

- Surface and material characterization
- Quality assurance and optimization
- Industrial image learning
- Virtual image processing



1

VIRTUAL IMAGE PROCESSING

1 *CAD model of a test object with camera viewpoint candidates (white) and the final viewpoints selected in the optimization step (blue).*

Factories are getting more and more automated. Production plants are becoming more flexible, so that no new facilities have to be built when switching to new products. However, the integration of automated quality control systems is often neglected. Inspection systems, on the other hand, are inflexible and designed to inspect specific products at great expense. Virtual image processing is one way to solve this problems.

An inspection system consists of many hardware components, typically selected and parameterized by experienced engineers on the basis of physical tests. New systems are developed iteratively. Experts design an initial system, which is then modified until it can inspect the product with sufficient accuracy. These tests of different hardware solutions cost a lot of time and effort – several hours per test run. Therefore, a configuration is often chosen that works but is not optimal. The resulting sub-optimal image quality must be algorithmically compensated later.

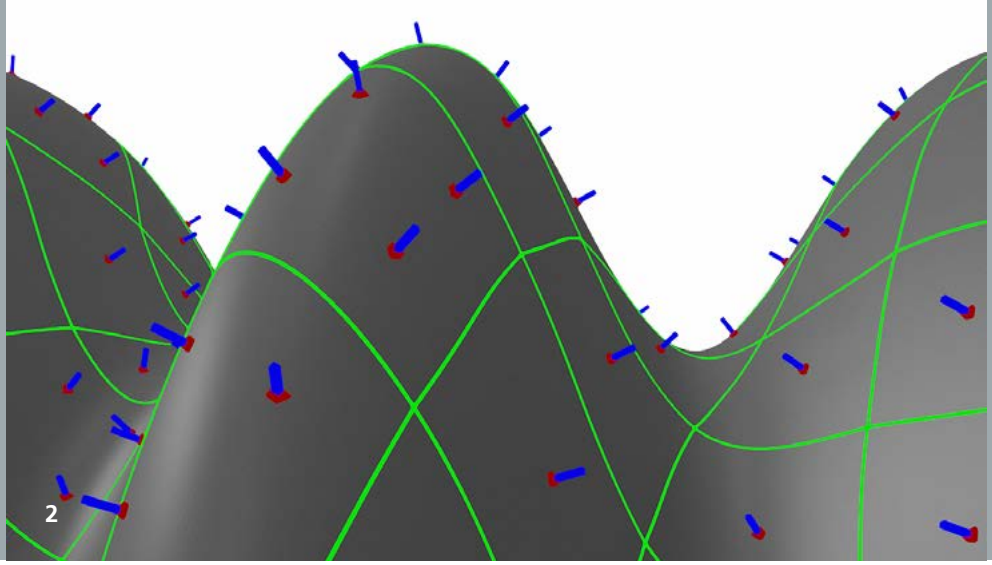
Digital twins simplify quality control

To make this process more flexible and efficient, we are developing an adaptive, simulation-based framework that will revolutionize the development process for inspection systems. In the future, industrial inspection systems will be completely virtual designed and tested for reliability using this framework.

For most of the produced components, there will be a CAD model, the so-called digital twin. Every step of the production process will be computer controlled. It will be possible to manufacture different products in small quantities with the same equipment. At the same time, the demands on quality are also growing. So what does an inspection system in such a factory have to look like? Above all, it must be possible to adapt it quickly and easily to changed production conditions. This will involve the use of several robots that can take analyzable images from free-form surfaces and even complicated geometries. The inspection system of the future will also predict how reliable it can detect certain defects at different areas of the product.

Virtualization core for planning and simulation

On the way to a complete framework for virtual inspection planning and image processing, we first optimize the positioning of product and camera; in addition, we develop simulation algorithms to generate a sufficient number of images of all defects to be found. These are often lacking in areas where defects can have devastating effects, such as turbine disks or brakes.



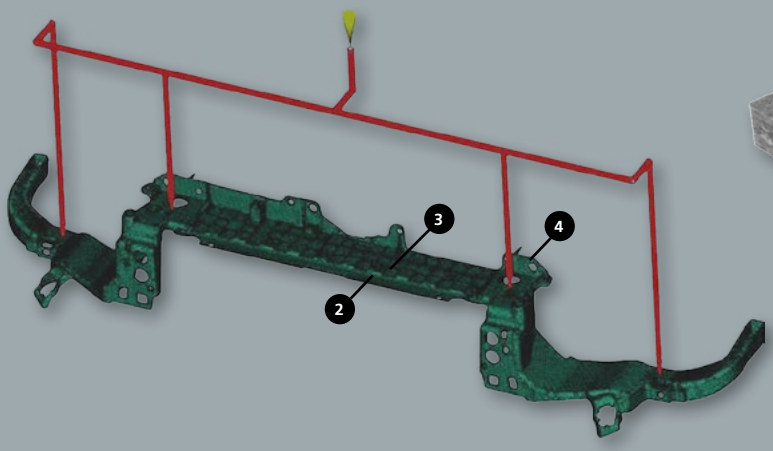
2 *Close-up of the pivot points for the camera viewpoint candidates. A few points cover flat areas, while more points are generated in strongly curved regions*

The virtualization core of the system consists of the components "Planning" and "Simulation". We simulate what the camera sees and use this information to design the inspection system. The planning component calculates multiple system configurations, consisting of cameras, optics, lighting, etc., which the robot can later use for optimal inspection. The virtualization core calculates possible hardware solutions from the CAD model - the geometry - of the product and various inspection parameters such as defect types, product material and inspection speed. In addition, the user receives a series of simulated images that can be used to test the inspection system during development.

The planning component calculates an inspection process with optimal surface coverage of the product according to the previously defined requirements. With the help of the simulation component, it is possible to carry out this planning even for geometrically complex products where the automation of today's systems has so far failed. The necessary illumination and a list of camera viewpoints are calculated from the CAD model of the product. For this process, the entire inspection environment is modelled and the behavior of the sensors is simulated using a physical based rendering. The traversal path of the camera is then planned based on a list of viewpoints.

Current research results: Position planning

Currently we research and develop our framework on many topics in parallel: parametric surface reconstruction, active model-based position planning, camera lens modeling, position-based error augmentation and surface illumination modeling. The focus is primarily on position planning - the backbone of the overall system. We will modularly extend and supplement it with new functionality in order to be adapt the framework to product-specific requirements.



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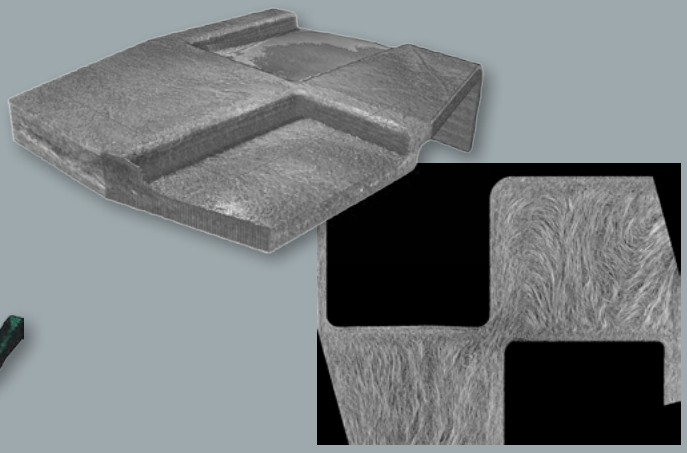

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NON-DESTRUCTIVE MICRO-STRUCTURE ANALYSIS FOR FIBER REINFORCED POLYMER PARTS

1 *Long glass fiber reinforced carrier, surface mesh from Moldflow*

2 – 4 *Volume rendering and virtual slices of regions marked in 1, imaged by Region-of-Interest micro-computed tomography. Coloured: diagonal component of orientation tensor in flow direction*

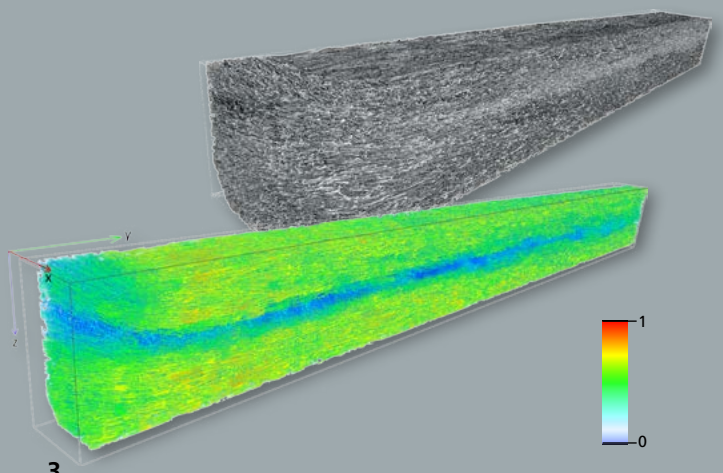
More and more often, parts made of fiber reinforced polymer replace parts formerly made of metal alloys, as they save energy due to their lighter weight while preserving the same mechanical properties. They consist of a polymer matrix and included fibers, usually made of glass or carbon. These fibers are mechanically stiffer than the polymer matrix surrounding them. This results in high mechanical strength of the composite in fiber direction. Thanks to their light weight, and their high stiffness and strength, fiber reinforced polymers are particularly well suited for light weight design for example in automobile and aircraft industry.

On the other hand, it is more difficult to design fiber reinforced polymer parts load optimized since mechanical properties like load capacity and durability depend critically on the specific micro-structure. Compared to classical materials, the relation between mechanical and micro-structural properties is less well understood – not the least since the micro-structure is more complex, just but not only due to having several components. Moreover, significant micro-structural characteristics can vary strongly within a part due to the production methods. Hence, heavily loaded and vital parts have to be reliably non-destructively tested.

Fiber orientation influences material properties

The local properties in a part vary with the spatial arrangement of the fibers due to the differing mechanical properties of matrix and fibers: Parallel fibers yield high tensile strength of the composite in fiber direction while completely randomly (isotropically) oriented fiber systems yield composites whose mechanical strength does not depend on direction. Consequently, local fiber volume fraction and local orientation of the reinforcing fibers are decisive for the behavior of fiber reinforced polymer parts.

Spatial imaging using micro-computed tomography has delivered this valuable micro-structure information already. From projections, the tomographic reconstruction generates 3D images, whose gray values essentially reflect the local X-ray absorption. Hence, glass fibers appear considerably brighter than the polymer matrix. It is impossible to identify individual fibers as image objects in 3D. However, the fiber system can be separated from the matrix easily. Based on this, the local fiber volume fraction is derived as the proportion of the numbers of fiber voxels and all voxels in the investigated region.



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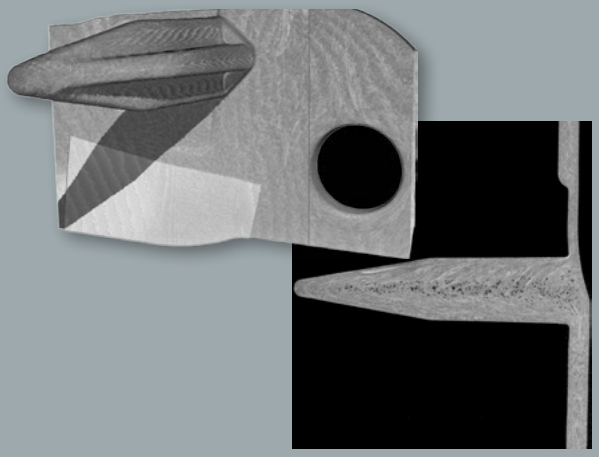

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Algorithms calculate preferred directions based on gray values

During the last 10 years, not the least at ITWM, image processing algorithms have been developed that compute the local fiber orientation in each voxel in the fiber component based on the local gray values. The 2nd order orientation tensor is derived from these local orientations. For this analysis, the fiber diameter of 10-20 µm has to be resolved by at least three voxels. That is, for fibers that are 10 µm thick, the voxel edge length has to be below 3.5 µm. Therefore, till now, small samples of an edge length of a few millimeters had to be cut to image them that highly resolved by a cone beam. This renders the method too complicated and expensive to be used in serial testing. Even more severe, the method is not non-destructive for large parts and can thus not be used for quality surveillance.

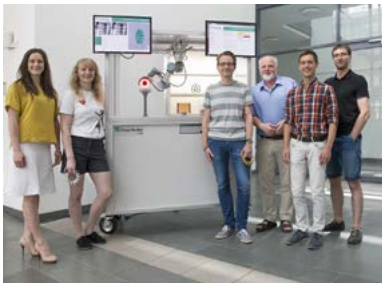
Given a dedicated setup of the tomography device, micro-computed tomography is able to image very small regions of a sample without actually cutting. This has been known for a long time. However, practically, imaging artifacts reduced the quality to an extent that prohibited the quantitative analysis of the 3D images of such »regions-of-interest«.

»3d Volant« avoids imaging artifacts and characterizes micro-structures correctly

This problem has been solved in the MEF project »3d Volant« of ITWM and the project group »NanoCT systems« of IIS. For the first time, practically relevant parts from the automotive industry have been spatially imaged by micro-computed tomography well enough for the resulting volume images of particularly interesting regions to be subsequently analyzed quantitatively. The local micro-structure of the parts can be completely described that way. Moreover, based on the 3D images, the real micro-structure can be compared to the one derived from simulating the flow in the whole part.

A the same time, new challenges arise from the opportunity to image a part of about 0.5 m length in regions-of-interest with voxel size 3 µm. The huge amounts of data generated cannot be processed interactively anymore. It is therefore planned to automatize all steps from choice of regions to be imaged to output of analysis results in an additional project.

NEWS



RESEARCH GROUP BREAKS NEW GROUND IN IMAGE PROCESSING

Online inspection systems have proven themselves in many production environments. However, what happens when products become more complicated? How can an inspection system be automated despite the increasing individualization of industrially manufactured products? Answers are provided by virtual image processing, which completely simulates and optimizes the inspection process.

The cooperation between the "Computer Graphics" working group at Technical University in Kaiserslautern and the "Image Processing" department at the "High Performance Center Simulation and Software Based Innovation" in the past two years has provided important impetus. It became clear that research in the field of virtual image processing could only progress if the knowledge of different disciplines comes together. The cooperation has existed for many years and has now led to the foundation of an international research group. One step on the way to virtual inspection has already been taken: The Revolving Product Inspection EPI developed at the Fraunhofer ITWM takes into account not only general conditions such as component geometry and surface texture, but also calculates where problems may arise in the analysis.

IMAGE PROCESSING DEPARTMENT NOW A MEMBER OF EMVA

emva
european machine vision association

During the Control trade fair, the department "Image Processing" became a member of the European Machine Vision Association. The EMVA is a non-profit and non-commercial association representing the machine vision industry in Europe. The association was founded in Barcelona in 2003 by industry representatives from all over Europe as a network to promote the development and use of machine vision technology.

ORGANIZATION OF THE WORKSHOP "3D FIB-SEM IMAGING AND ANALYSIS"

In the project "Reconstruction of POrous Structures from FIB-SEM Images" (REPOS) of the Federal Ministry of Education and Research (BMBF), the department co-organized the workshop on 3D FIB-SEM Imaging and Analysis in October 2018. The workshop took place at KIT Campus North and focused on the acquisition of 3D Slice&View stacks and the alignment and segmentation of FIB data sets with a focus on porous materials.

Front, left to right: Yuli Afrianti, Annika Schwarz, DamjanHatić, Tessa Kuschnerus, Dr. Ronald Rösch, Petra Gospodnetić, Bess, Dr. Xiaoyin Cheng, Dascha Dobrovolskij, Markus Rauhut, Kai Taeubner, Dr. Katja Schladitz, Dr. Ali Mogiseh, Michael Godehardt, Falco Hirschenberger , Dr. Markus Kronenberger, Franz Schreiber, Konstantin Hauch, Thomas Redenbach, Dennis Mosbach, Martin Braun, Nikita Nobel, Dr. Thomas Weibel

SYSTEM ANALYSIS, PROGNOSIS AND CONTROLE

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DR. ANDREAS WIRSEN
HEAD OF DEPARTMENT

ANALYSIS, PROGNOSIS AND CONTROL OF COMPLEX SYSTEM AND PROCESS BEHAVIOR

The complex dynamic systems we consider arise from the application fields of energy systems, plant and machine control as well as biology and medicine. The complexity of the systems results from the combination of different subsystems and structures. The systems are each equipped with specific sensor and actuator configurations. In doing so, we often have to consider measurement data superimposed on disturbances if we want to obtain information about current and future system behavior from data streams. In addition, system and structure descriptions are often incomplete.

Typical tasks we deal with in biology are, for example, sensor signal analysis or in medicine the identification of constant and dynamic model parameters in the active substance analysis of drugs. In addition to the control of systems and machines, we also develop innovative methods for predictive maintenance of components. In the field of energy, we develop monitoring systems for power suppliers as well as predictive control strategies for power grids. We support our customers from method development to hardware integration and validation of electronic control units with hardware-in-the-loop.

We use methods from the areas of system and control theory and machine learning to deal with problems in the various fields of application. We have special competencies in the areas of differential algebraic equations and switched systems, in the application of sequential Monte Carlo approaches for the simulation and state estimation of stochastic processes, in statistical learning theory and in the area of machine learning, even with deep architectures (deep learning).

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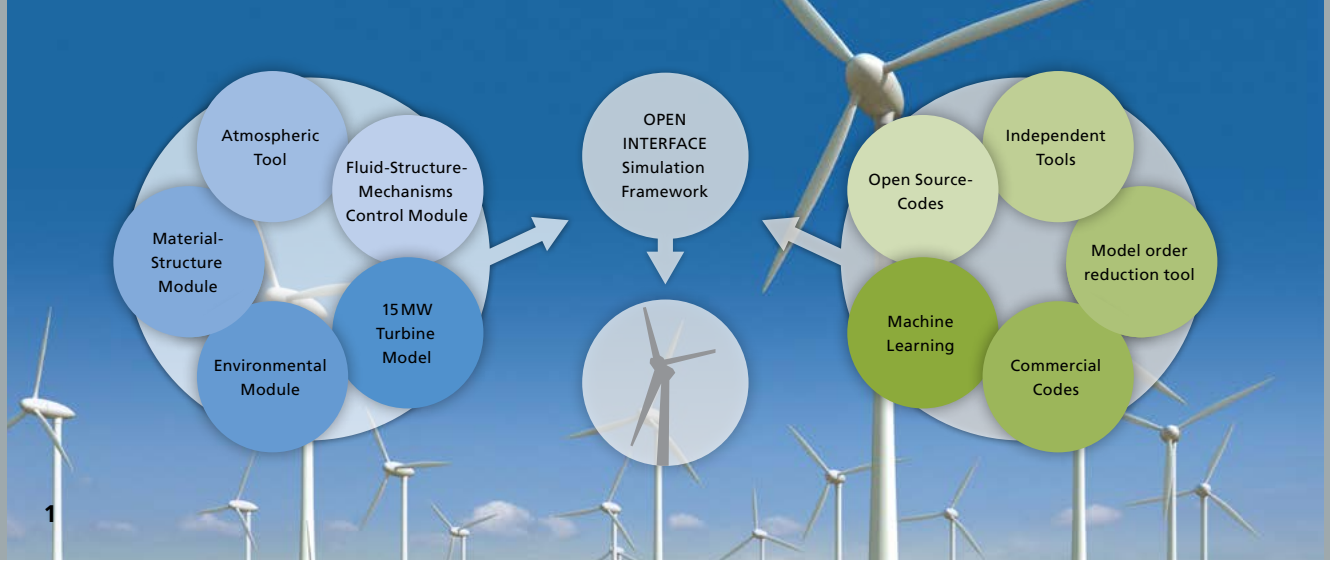
MAIN TOPICS

- Power generation and distribution
- Maschine monitoring and control
- Bio-sensors and medical devices



1 *Overall simulation of a wind farm*

UPWARDS – SIMULATION OF THE PHYSICS OF WIND TURBINES AND ROTOR DYNAMICS

The EU project »UPWARDS - Understanding of the Physics of Wind Turbine and Rotor Dynamics through an Integrated Simulation Framework« was launched in April 2018 with the aim of enabling the development of bigger and better designed wind turbines and thus increasing wind energy capacities throughout Europe and the rest of the world.

This goal will be pursued through the development of the next generation of multiphysical simulations specializing in wind flow, turbine mechanics and their interactions. These simulation tools enable a more cost-effective and faster development of prototypes for wind turbines.

UPWARDS is of strategic importance for the future of sustainable development in Europe and is implemented by a consortium of eleven partners (companies, research institutions and universities) from eight countries and two continents.

Road to more efficient wind turbines

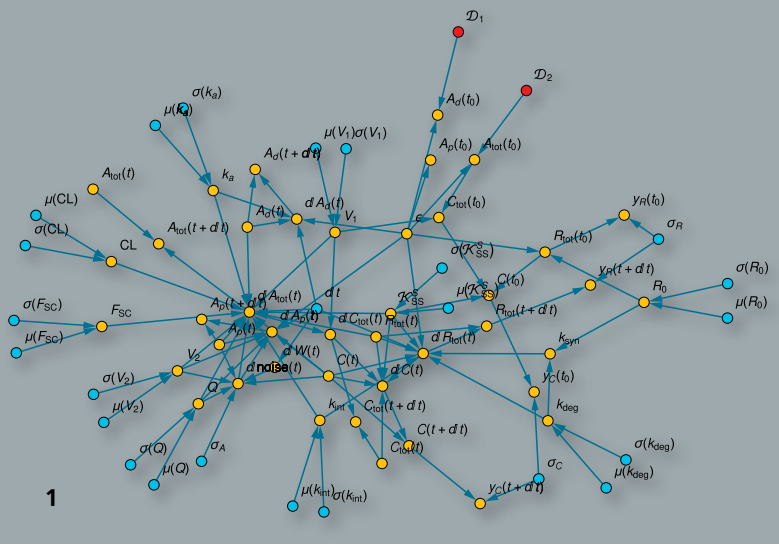
The most important challenges for the development of larger and more efficient wind turbines are:

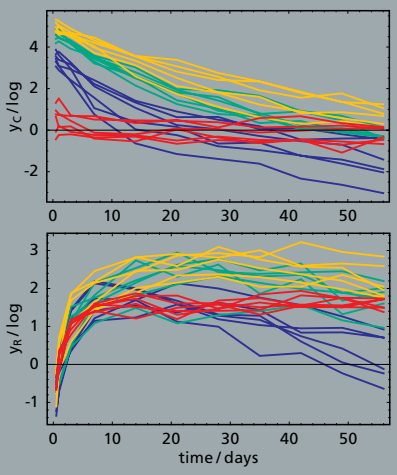
- Turbulence originating from atmospheric conditions, terrain or wind turbine wake that causes significant fatigue on the rotors
- As rotors become larger the tip speeds increase, resulting in more noise that potentially prohibit use in many onshore locations
- Longer and more slender blades will experience more bending that results in complex, dynamic stresses that need to be accounted for in structural design and material qualification.

Added value through mathematical and computer science methods

Fraunhofer ITWM is developing an integrated simulation platform for the individual software modules; these simulate wind turbines and wind farms with high precision, including wind flow, fully coupled fluid structure interaction, system fatigue and sound propagation.

Methods of model order reduction and high performance computing generate precise simulation results of the relevant system behavior in a short computing time. Machine learning methods are used to identify correlations between important phenomena such as inflow and turbine wind, rotor noise and failure of the composite materials in order to optimize the performance of the associated wind turbines.





DOSAGE, EFFECT, RISK: MATHEMATICS FOR NEW DRUG DEVELOPMENT

The development of new active ingredients for pharmaceutical purposes is now supported by mathematical learning methods. This capability relates to an important question: What is the proper dosage? The new remedy should work, but not harm the patient. In cooperation with our partner institute, FCC in Gothenburg, we develop and use mathematical simulation and learning methods to find an answer to the question being tested in clinical trials: What is the distribution of active ingredients throughout the body and what effects occur at the targeted sites of action?

1 *Complex interdependencies of the variables in a stochastic pharmaco-kinetic/ pharmaco-dynamic model*

2 *Temporal development of two substance concentrations (drug and target molecule) in blood plasma of 24 patients (4 dosis groups of 6 patients each; simulated data). Dosis groups are identifiable based on color.*

In trial testing, as many patients as possible are given different doses of the new drug and the development of the disease in each individual patient is monitored over a long period of time. Monitoring, in this case, means: evaluation of blood samples and body functions. Unfortunately, not all processes in the body can be measured directly.

Every patient is different

Patients are distinguished by individual characteristics (male/female, age), disease stages, dosages, and method of administration of the active ingredient (infusion, injection, ingestion). Within each of these groups, each person has additional random individual divergences. Here, random means: not everything can happen, just somethings are more probable. This probability can and must be modeled.

The administered drug causes a change in the disease-related condition of each patient over time. These time-dependent changes, in turn, affect the probability that other disease-related events will occur. To truly assess how a drug works, such complex relationships need to be understood.

Mathematical models master complexity

Mathematical models are able to capture the complex interrelationships of our bodies, our individual differences, temporal changes, and the changing risk of illness-related events occurring. Initially, however, these models contain many unknown time-dependent and constant variables. We can determine these unknown variables using measured data and the latest computer-aided mathematical learning methods (state filtering and parameter estimation in nonlinear dynamic models with mixed effects). The results provide information about the best dosage and best mode of action of the new drug.

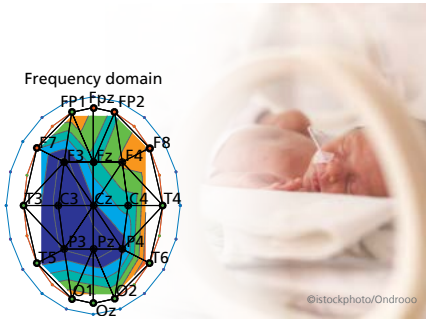
NEWS

BIOCOMP TO CONTINUE AS A MAJOR RESEARCH FOCUS

BioComp is a major research focus of the state of Rhineland-Palatinate. Since 2014, members of various faculties of the Technical University of Kaiserslautern have worked together on interdisciplinary projects using mathematical/computer-aided methods to study biological questions. Our department continues its involvement in several projects and this is expected to last through the 2019–2023 project phase. During this time, our goal is to develop a software infrastructure for integrative analysis of biological data. Challenges ranging from the processing and evaluation of raw data to the identification of interconnections and relationships within the data have to be overcome.

THEORY AND PRACTICE: KL-CONTROL SYSTEMS SEMINAR

The department has organized a monthly KL Control Systems Seminar for the past two years. What began as a loose association between our department and several working groups from the faculties at TU Kaiserslautern has developed substantially over the past year with a focus on control systems engineering. The seminar now includes inviting external speakers from industry to speak about ongoing research and development, for example, forecasting strategies for fuel-optimized operation of plug-in hybrid vehicles. In addition, the seminar concept was expanded to include the topic of machine learning (ML) in a control systems environment.



EEG ANALYSIS SOFTWARE FOR PREEMIES

A goal of the recently ended Tenecor project of BMWi was the design of a "diagnostic support system for the health status and brain development of premature babies." Our department developed the required EEG analysis software for the project, which is a multi-functional monitoring system for babies born prematurely. The innovative approach is based on machine learning methods and enables predictions of the various age-dependent, generic brain states and state change characteristics over time. After monitoring complex brain development, a 3D visualization of the data is prepared and the similarities between patients are easily detected.

Front, left ot right: Dr. Benjamin Adrian, Dr. Alex Sarishvili, Michael Sendhoff, Dr. Andreas Wirsen, Hans Trinkaus, Jens Göbel, Dr. Christian Salzig, Dimitri Morgenstern, Dr. Jan Hauth

OPTIMIZATION

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PROF. DR. KARL-HEINZ KÜFER
DIVISION DIRECTOR

PD DR. MICHAEL BORTZ
HEAD OF DEPARTMENT

INTERACTIVE DECISION SUPPORT BASED ON MODELS AND DATA

The main activity of the division is to develop custom solutions for planning and decision problems, especially, in the logistic, engineering, and life sciences while working in close cooperation with our partners in research and industry.

The work takes a methodical approach by integrating simulation, optimization, and decision support systems. Simulation in this context refers to the construction of mathematical models while taking into account the design parameters, restrictions, and the variables to be optimized such as cost.

The division's core competencies include the development and implementation of application- and customer-specific optimization methods. These methods provide the best possible solutions for process and product design. The close integration of simulation and optimization algorithms that give special consideration to multi-criteria approaches is our unique selling point along with the development and implementation of interactive decision support tools.

Overall, optimization is viewed not so much as a mathematical problem to be solved, but rather as a continuous process to be supported by the department with the development of suitable tools. Particular attention is paid to the selection of an adequate model in terms of quantity and quality of available data. We use machine learning methods to process the data and to calibrate the models, as well as to supplement and explain phenomena that cannot be explicitly modeled.

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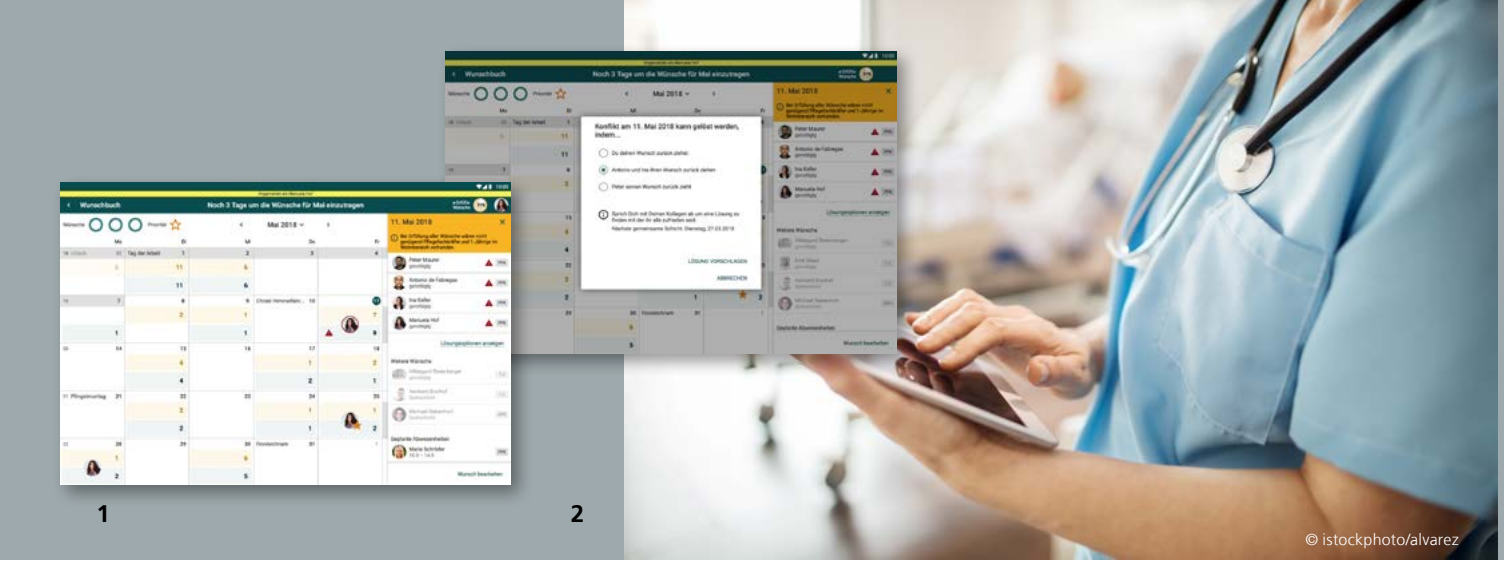
MAIN TOPICS

Operations Research

- Production planning and scheduling
- Layout and cutting problems
- Supply chain networks

Technical Processes

- Process engineering
- Medical planning
- Machine learning and hybrid models



1 2

GAMOR – COLLABORATIVE DUTY SCHEDULING IN THE CARE SECTOR

1 *Digital wish book*

2 *Conflict resolution options*

The care sector suffers from a massive shortage of skilled workers. The nursing profession is perceived as unattractive: physical strain, shift work, comparatively low salary are the decisive factors. Negative effects of shift work can be reduced by increasing the autonomy of the employees. They no longer have the feeling that their private life is at their employer's disposal in addition to their professional life. Instead, they have the chance to create and shape the balance themselves.

The GamOR project addresses this creative scope: with the help of collaborative and digitally supported duty planning, the satisfaction of nursing staff is to be increased. The design of the duty planning process based on ergonomic and experience-oriented aspects ensures integration into everyday work life as well as sustainable motivation.

Minimal conflicts: recognition and resolution

From an employee's point of view, one of the main quality measures of a duty roster is compliance with desired days off. We call a set of such wishes, which can´t be fulfilled at the same time, conflicts. Conflicts that can be resolved by cancelling any involved wish are "minimal conflicts". These must be resolved independently of any wishes added later. In GamOR we develop algorithms for the efficient determination of minimal conflicts as well as game theoretical models for their (partially) automated resolution. In addition, we use constraint-based models to calculate optimized duty roster alternatives. In addition to wishes and staffing requirements, both legal and ergonomic rules are taken into account.

Implementation through a digital services platform

The concepts for collaborative duty scheduling and the algorithms for planning support are implemented prototypically by a service platform. The employees operate the platform via tablets, in perspective also from their own smartphone. Employees see the planning month with all wishes entered (Fig. 1). New wishes can be added, existing wishes can be withdrawn. Conflicts that involve the employee are presented clearly and possible solutions are shown (Fig. 2). Those responsible for planning can directly use a web interface for data maintenance.

This research and development project is funded by the Federal Ministry of Education and Research (BMBF) and the European Social Fund (ESF) as part of the "Future of Work" programme and supervised by the Karlsruhe Project Management Organisation (PTKA).

ELIMINATING TRACE ELEMENTS WITH SUSTAINABLE ADSORBENTS

Water pollution from medications, biocides, and industrial chemicals is on the increase because sewage plants do not break down many of these substances, so they are released into the environment. BioSorb is a three-year joint project with Fraunhofer UMSICHT to develop new adsorbents that can eliminate such molecules from municipal wastewater.

1 *Protein-based bioadsorbents are being investigated to improve the adsorption of drugs from wastewater in order to reduce the burden on humans and the environment in sewage plants.*

The approach is based on renewable raw materials which are more resource-friendly and significantly more selective than conventional activated charcoal filtering. Especially promising are protein-based materials, called bioadsorbents, because these are cheap and a nearly infinitly available worldwide.

Step by step to cleaner water

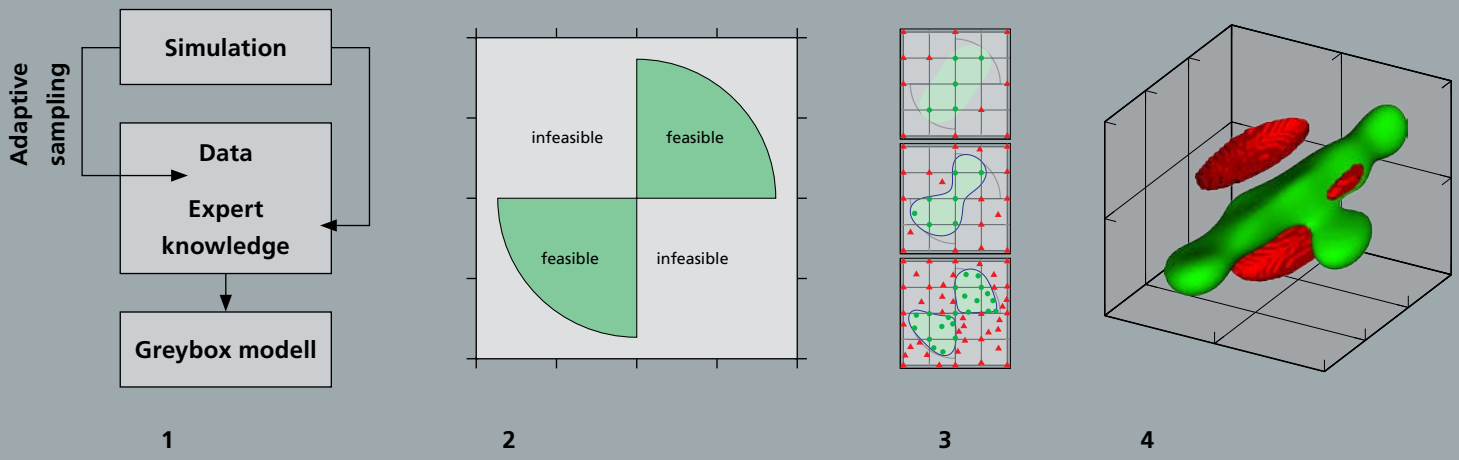
We start by screening various protein-rich materials. We focus our detailed investigation on variants of renewable raw materials, test them initially in small-scale adsorption experiments. The most promising materials are then analyzed in the next step. Often, a chemical treatment – like a combination acid and heat treatment – improves the adsorption capacity.

In a series of large-scale tests, selected bioadsorbents are characterized by their effectiveness to adsorb diclofenac (a pain killer) and metoprolol (a beta-blocker). These two molecules are suitable as test substances since they are often detected in ground and surface waters and, until now, are hardly degraded in sewage plants. From an economic perspective, a re-usable adsorptive material is the most promising. This is why we search for a renewable systems using different solvents and analyze and characterize the selected materials in great detail.

ITWM supplies simulation expertise

In parallel, a numerical adsorption model is being developed based on our institute's expertise with simulation tools for water supply and sanitation, which had already been proven in the EU's Nanopur project on drinking water preparation. BioSorb is now building on these findings. We use our high computing capacity and experience with simulation studies to provide the required expertise for multi-scale simulation, which evaluates the adsorbents.

The results are validated and verified in the final step. This step initially takes place using contaminated water, where we can test the effectiveness of the adsorbents without overlaying measurements. Subsequently, the adsorbents are introduced in practice-relevant waters, for example, the water from the sewage plant at Wuppertal-Buchenhofen.



MACHINE LEARNING WITH EXPERT KNOWLEDGE

1 *Workflow for the development of Greybox surrogate models from data and expert knowledge; adaptive sampling enables efficient data acquisition.*

2 *Two-dimensional parameter space of a toy example with a well-defined feasible range (green); this example demonstrates the efficiency of adaptive sampling for predicting operating windows.*

3 *The sequential development of the parameter space from Fig. 2 leads to feasible (green) and infeasible (red) simulation results and a corresponding model prediction for the operation window (blue), which improves with each iteration.*

4 *Visualization of the predicted operating window of a chemical plant*

In various research projects and in cooperation with industrial partners, we develop strategies to improve machine learning methods by including domain-specific expert knowledge. An important field of application is chemical process engineering.

Machine learning algorithms make it possible to derive patterns from data. The resulting models generalize the information contained in the data statistics in order to predict unknown results. However, it can be of decisive advantage to also consider the context of the data and to incorporate domain-specific expert knowledge in the models. This approach can take coherences into account which are insufficiently reflected by the pure data statistics.

The greybox approach

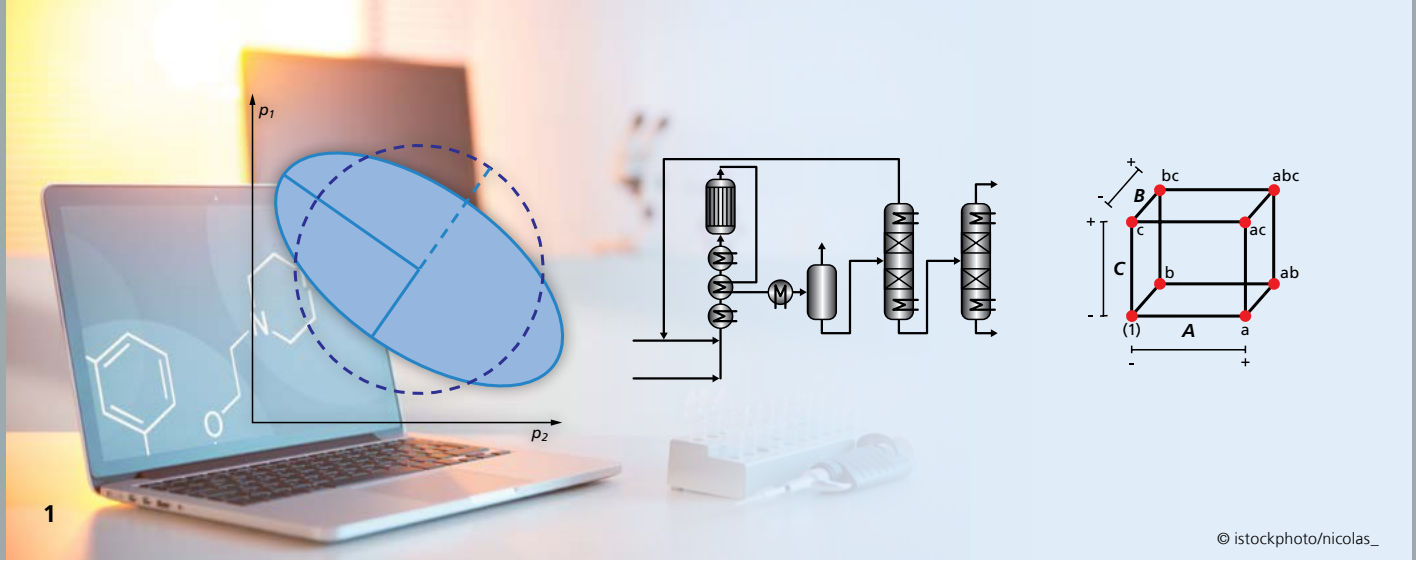
In industrial practice, data is often obtained from simulations since they are cheaper than experiments and free of measurement uncertainties. Solving optimization problems requires large amounts of such simulation data. Surrogate models, which can be evaluated faster than the original simulation, consequently bring a major speed advantage.

Since industrial simulations are based on physical laws, expert knowledge is already explicitly available. The challenge is to integrate it into a machine learning method in a suitable way. In this so-called "greybox" approach, knowledge-based models are combined with data-driven models to form a hybrid overall model.

Exploration of operating windows in chemical process engineering

Efficient data acquisition is crucial. Non-dynamic simulations of chemical plants can only be evaluated for process parameters for which the plant can be operated stationary. In a joint project with BASF SE, we are developing a method to determine these stationary operating windows with the aid of machine learning methods and greybox modelling.

With our novel strategy of adaptive sampling we are able to explore the parameter space sequentially in the most efficient way possible. For this purpose, a compromise must be found between the simulation effort and the expected information gain. The knowledge about the operating window then simplifies the optimization of process parameters by restricting the parameter space to be searched.



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MODEL-BASED EXPERIMENTAL DESIGN IN PROCESS ENGINEERING

In chemical process engineering, data are collected in experiments in order to calibrate physically motivated models. These experiments are always time- and cost-intensive. Therefore, their planning is about deriving as reliable models as possible from as few experiments as possible. In a cooperative project with BASF, we develop and implement methods that support this.

1 *Left: Scheme of a covariance ellipsoid to illustrate the confidence region of adjusted model paramaters*

Center: Scheme of a mini-plant with one tubular reactor and two distillation columns

Right: Statistical design of experiments for a linear model with three inputs

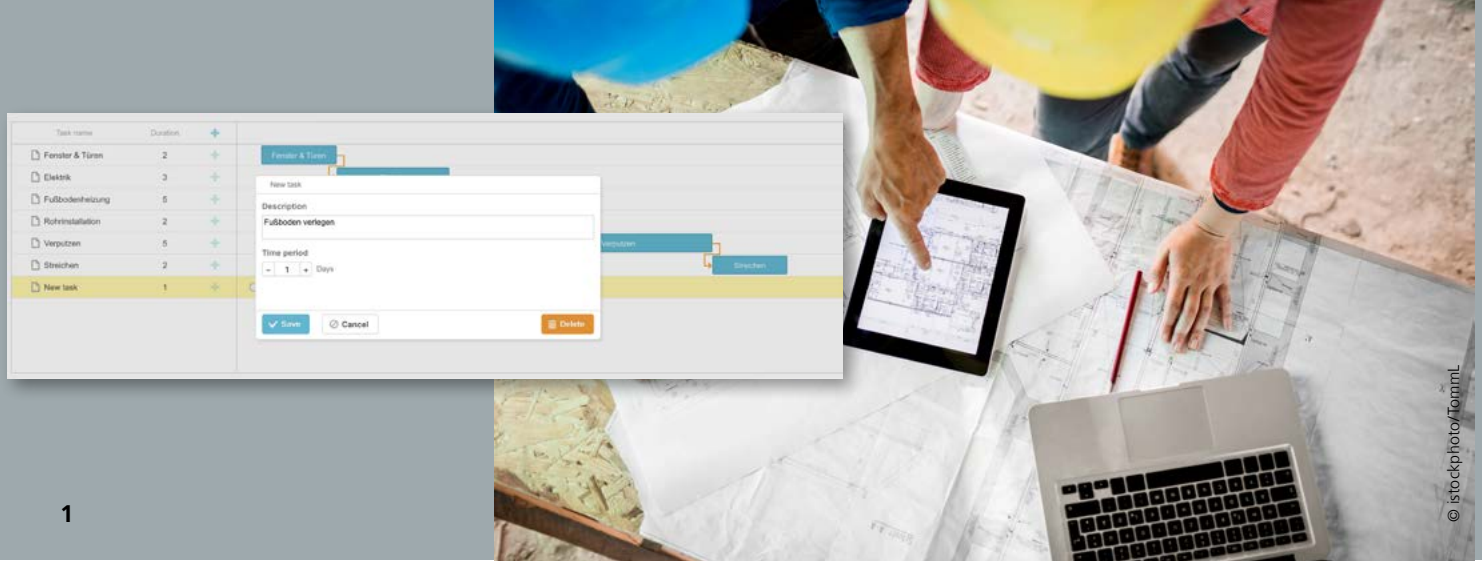
The reliability of model calibrations is influenced in two ways: On the one hand, the error bars of the estimated parameters, but also the prediction errors of the model are directly proportional to the measurement accuracy in the experiments. In other words, the more accurate the sensors, the more reliable the model prediction.

On the other hand, in order to calibrate successfully, it is crucial to consider correlations in the sensitivity of the models – especially with regard to the model parameters at the measurement points. This is illustrated in the following example.

Catalyst: Aging versus Temperature

Chemical reactions are generally faster at higher temperatures than at lower ones - this is why, for example, foods are cooled to prolong their shelf life. In chemical reactors, catalysts are often used to accelerate reactions. These catalysts age, so their effect decreases over time. Therefore, the reaction temperature is increased with increasing catalyst age in order to guarantee a constant quality of the reaction product. In this way, catalyst age and reaction temperature are closely related. It is not possible to calculate the separate effects of temperature and catalyst age on the end product. The experimental design proposes to run the reactor once at low temperatures and high catalyst age, and once at high temperatures and low catalyst age. With these two additional operating conditions, the effects can be separated and independently quantified.

The aim of the cooperation project with BASF is to transfer the concepts described above to complex models of pilot plants (Fig. 1). These are then calibrated to model parameters on the basis of their sensitivities, uncertainties are estimated (Fig. 2) and the corresponding experiments are planned. To this end, we solve large nonlinear optimization problems and make their results usable on interactive user interfaces.



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1

CONWEARDI – SMART PROCESSES IN CONSTRUCTION

1 *Planning assistance for construction sites*

In the project ConWearDi (Construction Wearables Digitization), we develop together with research partners and craftsmen a platform to enable the digitalization of services in the building industry with industry 4.0 technologies. The focus is on a tool for process planning.

The topic of digitalization is increasingly coming into focus. Construction companies in particular, which tend to be small or medium-sized enterprises, are still lagging far behind in the digital change. If you want to remain competitive in the future, you have to face digitalization and take advantage of opportunities that arise.

This is where ConWearDi comes in: The aim is to develop a web platform that enables the digital exchange of information between all those involved in construction. Building on this, services are developed to support the planning and implementation of construction site processes.

Web platform

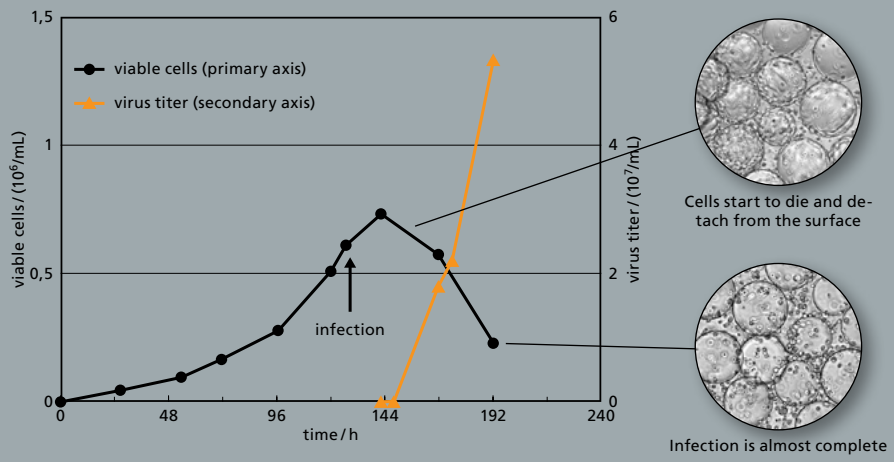
The platform connects (software) tools of different kinds. Examples are ERP systems, planning tools or machines and materials equipped with sensors. Wearables are also used, e.g. smart glasses, which record and process information in real time. As part of the project, we develop an application for process planning that is specially adapted to construction site processes and connected to the platform.

Construction site planning under uncertainty

The adherence to schedules across several construction projects is often only possible through a precise division of the work packages and an optimal use of the available resources. Changes in the course of the project (e.g. absence of employees) make it difficult for the planner to maintain an overview. In ConWearDi we develop models and algorithms that support the site planner in his tasks. An adequate consideration of the uncertainty of planning-relevant information plays an important role. For example, in many cases the feasibility of operations depends on the weather. In these cases, simulations help to develop suitable evasion strategies.

With the help of the resulting software, work packages can be automatically scheduled and optimized with regard to various goals. However, the final decision remains with the planner, who can interactively adapt the created plans (e. g. drag & drop) and is directly informed about the consequences of his decisions.

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung



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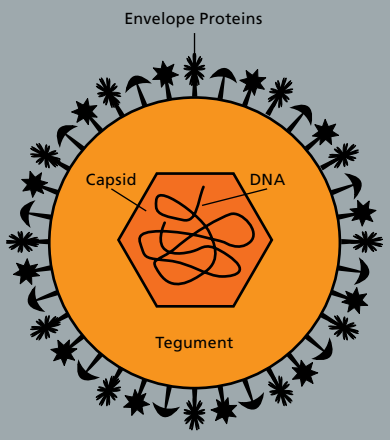


2

VIRUSES IN TUMOR THERAPY: HOW TO GROW THERAPEUTIC VIRUSES

Clinical studies with first generation oncolytic (cancer destroying) viruses are very promising. To ensure this new approach is available to all patients, we develop scalable and robust production methods for these viruses. As part of the Fraunhofer-Gesellschaft, our experts are researching these issues using mathematical methods within the framework of project TheraVision.

1 *Cell growth (black) and virus growth (orange). The images show the microcarriers the cells attach to, and the cells themselves.*

2 *Schematic representation of the herpes simplex virus*

When to infect and when to extract?

Preparation of the viruses consists of an upstream and a downstream process. Initially, special host cells are grown in the upstream process. At a certain time, these are infected with the virus. From this moment on, the viruses multiply in the host cells until the cells are destroyed and the viruses produced escape into the surrounding nutrient solution. After a certain period of time, the nutrient solution is extracted and fed into the downstream process where the virus is filtered out.

The aim of our project is a model-based optimization of the upstream process using experimental data. We have prepared a model that represents the cell and the growth of the virus as a function of controllable variables. The first variables to be optimized on the basis of the model are the infection and extraction points.

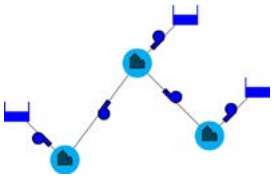
Parameter estimates and compromises

The model we use is a parameterized system of ordinary differential equations. Aided by the use of statistical methods (parameter estimation), we have identified the variables (growth and death rates) such that the model closely matches the experiments conducted at Fraunhofer ITEM.

When the model is constructed in this way, the optimal time of infection and extraction is determined using a special optimization method (multiple shooting). The focus is on several target aspects: the maximal achievable number of viruses, and the effectiveness and purity of the extracted solution. These aspects are either individually optimized or an optimally balanced compromise is sought between the targets (multi-criteria optimization).

NEWS

COpt2 – SAVING ENERGY IN THE DRINKING WATER INDUSTRY



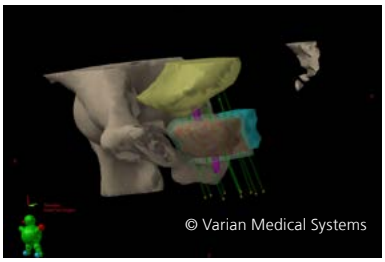
Complex networks in drinking water supply

The BMBF sponsored project, H2Opt, provides prototype software that supports energy efficient design and operation of drinking water plants. It results in energy and cost savings during planning and operations involving the drinking water supply. The software is in daily use at the energy company EWR, located in Worms, Germany. Launched in 2019, a follow-up project is to expand the prototype for the more complex water supply networks in Landau and Jockgrim. We simplify and improve workflows and develop new concepts to prevent water supply shortages. The project is funded by the European Fund for Regional Development (EFRE). Initially, the priority is the investigation of pumping operations because that is where an estimated 30 percent on average can be saved in energy costs.

COGNAC – ROBUST CAMPAIGN PLANNING FOR HARVESTS

The lighthouse project COGNitive AgriCulture (COGNAC) focuses on the design of an agricultural platform. The project is to deliver critical innovations in three areas: "Networked ecosystems", "Sensor systems", and "Autonomous field robots". A variety of applications have been realized as demonstrators. One case study is about robust harvest campaign planning, in which we review continuously updated ripening data and weather forecasts for the fields to be harvested. This allows us to plan ahead in personnel and equipment scheduling, which gives agricultural contracting firms a higher likelihood of meeting their customer appointments. Our robust models and algorithms reduce drying and fuel costs, while at the same time increase food quality and customer satisfaction.

DECISION SUPPORT FOR BRACHYTHERAPY



In collaboration with Varian Medical Systems, our multi-criteria decision support system has been embedded in the world's leading radiotherapy planning software for cancer patients. Our goal for next year is to make interactive planning available not only for external radiation therapies (IMRT, VMAT) but also for brachytherapy. This therapy directs the radiation source either on the immediate vicinity of the tumor or into the tumor itself, raising new questions that have to be solved, for example, regarding the optimal positioning of the catheter for directing the radiation.

Front, left to right: Johanna Schneider, Till Heller, Esther Bonacker, Dr. Katrin Teichert, Dr. Neele Leithäuser, Dr. Neil Jami, Dr.-Ing. Tino Fleuren, Dr. Cristina Collicott, Jasmin Kirchner, Dr. Sandy Heydrich, Dr. Elisabeth Finhold, Dr. Christian Weiß, Dr. Heiner Ackermann, Dr. Volker Maag, Dr. Michael Bortz, Prof. Dr. Karl-Heinz Küfer, Dr. Peter Klein, Dr. Gregor Foltin, Dr. Dimitri Nowak, Dr. Jan Schwientek, Dr. Tobias Fischer, Rasmus Schroeder, Dr. Dennis Heim, Dr. techn. Johannes Höller, Melanie Heidgen, Helene Krieg, Dr. Patricia Bickert, Dr. Martin von Kurnatowski, Dr. Raoul Heese, Andreas Dinges, Dr. Michal Walczak, Pascal Wortel, Dr. Sebastian Velten, Dr. Michael Helmling, Patrick Schwartz

FINANCIAL MATHEMATICS

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DR. ANDREAS WAGNER
HEAD OF DEPARTMENT

EXPERTISE IN CONVENTIONAL FINANCIAL MATHEMATICS, DATA SCIENCE, AND THE ENERGY INDUSTRY

Our application-oriented research provides the basis for the development, analysis and implementation of mathematical models for business enterprises. We rely on the latest findings of financial and statistical research. At the same time, we draw on a portfolio of successful projects with banks, insurance companies, energy suppliers, and manufacturing companies.

We cover all practice-relevant areas of financial mathematics – from modeling to the development of evaluation algorithms and their implementation – and maintain our own software libraries. Frequently, our projects result in software programs for use in company operations.

We assist companies to validate their data through mathematical modeling and to discover insights from the data using classical and modern statistical methods. The applications apply to the most diverse areas of controlling – from company-specific asset valuation such as leasing vehicles, to the detection of anomalies in accounting data. Our work involves a combination of classic statistical methods such as regression models and cluster analysis and modern machine learning methods.

The use of financial mathematical methods is increasingly important in the energy economy. We are familiar with the specific problems and characteristics of the energy markets and have experience with various models. We use current research results in developing algorithms that efficiently solve valuation problems and we also provide ready-to-use software packages that manage portfolio risk.

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MAIN TOPICS

- Financial economy
- Data science for controlling
- Energy industry

INTERACTIVE ANALYSIS FOR USED CAR WARRANTIES

Several insurers offer used car warranties: these are insurance policies against premature wear and tear or defects in vehicle components. These policies are important to owners wanting to reduce the risk of high cost maintenance after the expiration of a new car warranty. Of course, the suppliers of such insurance products have to worry about their own profitability.

Our client is a European auto manufacturer that offers a variety of warranties that cover used car repair costs. An evaluation of these products reveals great differences in profitability over time and across different geographic regions. The first step is to analyze the background and cost drivers and predict the future development of costs. Fraunhofer ITWM was chosen as a partner because of its many years of actuarial experience and successful projects in the automotive sector.

Interactive data management

Over the course of the project, it became clear that customers had numerous other questions that could be answered with the available data. Based on R-Shiny technology, a web application was created that enables customers to work interactively with the data. We also developed new methods and models for further refining that data. Our client can exploit the hidden potential of the data significantly better now than ever before.

Fast anomaly detection thanks to machine learning

Our software helps customers merge data from various sources and automatically aggregate it to useful data sets. It also offers new opportunities for exploratory data analysis. Another innovative development is specific anomaly detection. This feature uses statistics and machine learning techniques to automatically search the data for conspicuous patterns. These patterns reveal aspects that, in turn, allow better workshop control, more efficient application review, more efficient contract design, and the optimization of internal processes.

Major aspects of the project are understanding the available data and predicting future costs. To this end, the decision maker has various actuarial methods available that can be adapted to fit the context. Comprehensive back-testing of historical data enables a reliable assessment of the forecasting quality.

MARKET TRANSPARENCY FOR OCCUPATIONAL PENSION SCHEMES

In 2018, the German legislator passed the Occupational Pension Strengthening Act a major reform package affecting occupational pensions. The main innovation is the introduction of the "social partner model" for bargaining parties. From now on employers only commit themselves to contribute premiums to the retirement provision institutions. Nowadays the guarantee of future pension entitlements is optional and employers no longer assume any liabilities beyond that. To support the members of the "Rentenwerk" in their striving for more transparency in the market of occupational pensions we apply our expertise in developing and establishing an accepted market model.

The reform in the area of occupational pensions opens new pathways and allows more flexibility in the development of products and services. The members of the "Rentenwerk," a consortium of five insurance companies under the lead management of Debeka, have created a new fund-based pension product. A fair assessment of competing plans requires a capital market model that is recognized industry wide as the basis for calculation.

PIA standard model is the benchmark for the industry

Debeka acknowledged our expertise in working with the "Produktinformationsstelle Altersvorsorge" (PIA) and commissioned us to develop a capital market model. One requirement for the model was to be in agreement with current industry standards. Fraunhofer ITWM already created an industry benchmark for stochastic capital market simulations with the PIA standard model for private pension plans. Using this established framework as the starting point, we have further developed the model and included aspects of particular relevance to fund products. For example, the new model can now show the effect of diversification on stock investments and differentiate between government and corporate bond funds.

More fairness thanks to improved information

The commission also included the implementation of the developed model in a software tool to simulate occupational pension schemes. Doing so we created a useful and versatile framework for the analysis and management of occupational pensions. It allows for better profit and loss assessments and an improved description of developments in the retirement period. The more detailed and standardized information supports the consortium in designing a fair company-specific pension plan to the benefit of all the bargaining parties.

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ASSET ALLOCATION AND PORTFOLIO OPTIMIZATION – BALANCE BETWEEN RISK AND RETURN

Asset allocation refers to the allocation of funds to various asset classes such as bonds, equities, real estate, currencies and precious metals. The EU's "Solvency II" Directive provides the framework for the necessary capital adequacy. On this basis, we have implemented a new approach to strategic asset allocation with R+V Lebensversicherung AG.

Many companies and individual investors are faced at least once a year with the question of how their existing capital could best be invested in the coming year. Here, the term »best« covers several areas where the respective objectives need to be aligned. Insurance companies, in particular, often strive to achieve the highest possible long-term return at a defined risk level. On the other hand, however, a given liquidity (i.e. availability of funds) should also be guaranteed within different time periods.

Strategic asset allocation mathematically and theoretically determines the long-term composition of a portfolio on a sound basis. Possible asset classes in the asset pool are

- shares
- bonds
- real estate
- financings

possibly broken down by region or risk profile.

In classic Markowitz portfolio optimization, only yield (mean value) and risk (variance) are taken into account. According to this, a so-called efficient portfolio exists if its return can no longer be improved without increasing the risk. The choice of asset allocation is based on a number of efficient portfolios. This gives the investor an overview and allows him to select a portfolio that matches his risk profile.

Under the name "Solvency II", the EU issued a directive in 2009 that has been binding for all insurance companies since 2016. Solvency II places particular demands on the company's capital resources and is therefore another important target function in asset allocation.


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Multi-stage solution

Together with R+V Lebensversicherung AG, we have implemented a new approach to strategic asset allocation. On the one hand, this takes into account the solvency ratio under the Solvency II regime. On the other hand, our approach allows other relevant portfolio features to be taken into account.

Our solution is multi-tiered. First, we determine all possible achievable risk-return profiles in the calculation kernel for given weight limits of the individual asset classes. We then optimize the solvency ratio for each of these profiles. This optimization also takes place offline in the calculation kernel. The calculated optimal portfolios are stored in a database.

The programming concept completely separates the visualization from the calculation kernel. This makes it possible to separate the time-consuming optimisation from the other work steps. In addition, the individual project parts are independent and reusable.

User-friendly visualization

The users interact completely via a graphical interface, which is implemented customer-friendly with the help of a web server and is completely separated from the calculation kernel. This allows users to quickly and easily analyse the results of the calculations in their daily work. The visualization shows all solvency ratio-optimal portfolios, incorporates additional constraints and shows variants. In this way, users can dynamically select a portfolio that meets their requirements and appears most suitable to them from the range of optimal portfolios. The program shows the composition of the portfolio and a number of other key figures, such as reallocation, diversification, value at risk and behaviour under stress scenarios. Users can also store their own portfolios in the database and compare them with each other or with the optimized portfolios.

Increased automation planned

Via the web interface, the user can also import further data sets with asset classes and weight limits and start optimizing the portfolios. The results can be exported to Excel for additional analysis. In the next project phase, the focus will be on optimizing further portfolio features. In addition, the entire process will be more automated so that a larger number of different data sets can be processed in parallel.

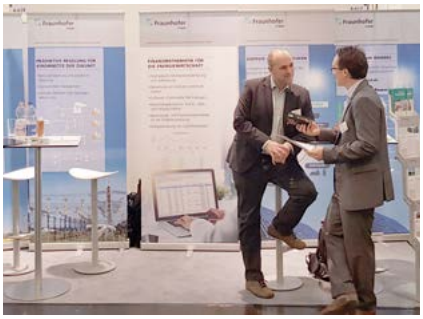
NEWS

WORKSHOPS WELL RECEIVED

Our joint workshop with the Product Information Center for Pension Plans (PIA) centered on the ALMSim® Path Generator. Our ALMSim Path Generator software enables the simulation of capital market scenarios and pension product contracts. The software supports insurance companies in the implementation of legal requirements. The models we have established have become the market standard and ALMSim is now used by more than 50 life insurance companies.

Our fraud assessment model is gaining wider acceptance in the pursuit of billing fraud in the healthcare sector. This also led to broad interest in our "Billing fraud in outpatient care – Claims calculation in R" workshop last November in Berlin.

COMMODITY RISK MANAGER AT E-WORLD



We have a strong profile in researching applications for the energy economy. In the ENets project, sponsored by BMBF, we develop assessment models for wind and photovoltaic systems. At e-World Energy & Water in Essen we presented our range of services in the energy sector, in particular the Commodity Risk Manager; this tool enables municipal electricity suppliers in particular to plan their electricity purchases on a long-term basis.

But we were not the only ones at the ITWM stand; our colleagues from the Green by IT Group and the department System Analysis, Prognosis and Control were also represented with current research projects.

OUTLOOK 2019

Our good reputation as a competent project partner serves us well, not only in the financial mathematics area, but also in data science. For example, we prepare business forecasts and identify unusual relationships. Our goal is to partner with a consortium of health insurance and associations to implement data-based anomaly detection. Working with industry and research, we successfully develop and market methods to promote flexibility in the power consumption requirements of industrial enterprises.

Front, left to right: Dr. Kerstin Dächert, Franziska Diez, Florian Schirra, Ria Grindel, Dr. Elisabeth Leoff, Renate Wegner, Dr. Andreas Wagner, Dr. Stefanie Schwaar, Wieger Hinderks, Dr. Jörg Wenzel, Dr. Robert Knobloch, Dr. Johannes Leitner, Robert Sicks, Simon Schürch, Philipp Mahler, Dr. Roman Horsky, Christian Laudagé

MATHEMATICS FOR VEHICLE ENGINEERING

DR. KLAUS DRESSLER
DIVISION DIRECTOR

DR.-ING. JOACHIM LINN
HEAD OF DEPARTMENT

COMPUTER AIDED DEVELOPMENT AND OPTIMIZED PRODUCTION IN THE AUTOMOBILE INDUSTRY

The department has experienced significant growth in recent years and, accordingly, has expanded the range of applications. For example, expanding from the simulation of cables and hoses, we also explore new fields of application in the area of the digital factory. Additionally, our VMC and USim tools, which were initially developed for load assumptions used in durability studies, are now widely used in the fields of energy efficiency, powertrains, and alternative drives as well as safety in Advanced Driver Assistance Systems and Autonomous Driving (ADAS/AD). Consequently, the department has re-organized these activities and created a new division: "Mathematics for Vehicle Engineering" (MF). The MF division consists of two departments: Dynamics, Loads and Environmental Data (DLU) and Mathematics for the Digital Factory (MDF); also, the Tire Simulation project group and a cross section unit called MF Technologies, which is responsible for testing and measuring systems.

The Dynamics, Loads, and Environment Data department continues to develop the simulation methods and tools for integrating environment data in variable use systems. This effort addresses the vehicle design attributes of durability, reliability, energy efficiency, and ADAS/AD. Subsequently, our system simulation activities center on vehicle-human-environment-interactions and the development of tire simulation models and methods for invariant system excitation. The development activities of the Mathematics for the Digital Factory department concentrate on software tools for the virtual genesis and development of products. Our software product IPS Cable Simulation, jointly created with FCC in Gothenburg, supports the virtual design, optimization, and safe assembly and operation of wiring, wiring harnesses, and hoses. Additionally, our IPS IMMA tool is a digital human model developed to facilitate virtual optimization of assembly installation processes.

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MAIN TOPICS

- Dynamic, load assumptions, and variable use
- Durability and reliability
- Digital environment data
- HMI and driving simulators
- Non-linear structural mechanics / IPS cable simulation
- Tire simulation – CDTire

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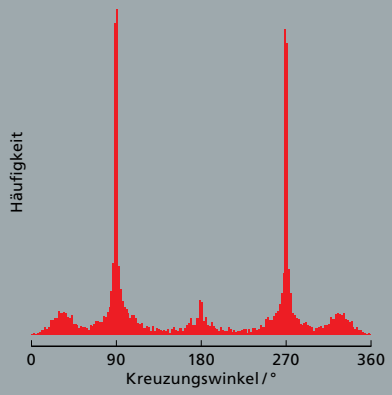

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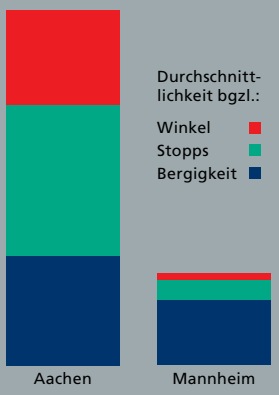


3

VMC® – STATISTICS-BASED SELECTION OF REFERENCE ROUTES AND REGIONS

1 *Section of the road network in downtown Mannheim with its famous square pattern*

2 *Histogram of the crossing angles in Mannheim. The amount of 90° and 270° angles here are quite exceptional.*

3 *Comparison of averages between Aachen and Mannheim, referencing a pool of 190 cities in Germany The larger the bar for a characteristic, the closer it is to the average. The angular distribution in Mannheim is particularly far from the average.*

Global geo-referenced data can play a major role in statistical validation of the assessment base and the estimation of fuel consumption as used for vehicle development: In view of the great variability of use in the automotive sector, statistical analysis of these data can be a valuable supplement to the current methods.

The software package Virtual Measurement Campaign VMC® enables the simulation of vehicle loads. To this end, VMC® combines information from the global road network with algorithms developed in the MF division. A key function of VMC® is the regional analysis. It gives users the option to select an individual region, like a city or a municipal district. After selecting the region, users can analyze different consumption and load variables that are relevant to that area.

Virtual urban district and real cities

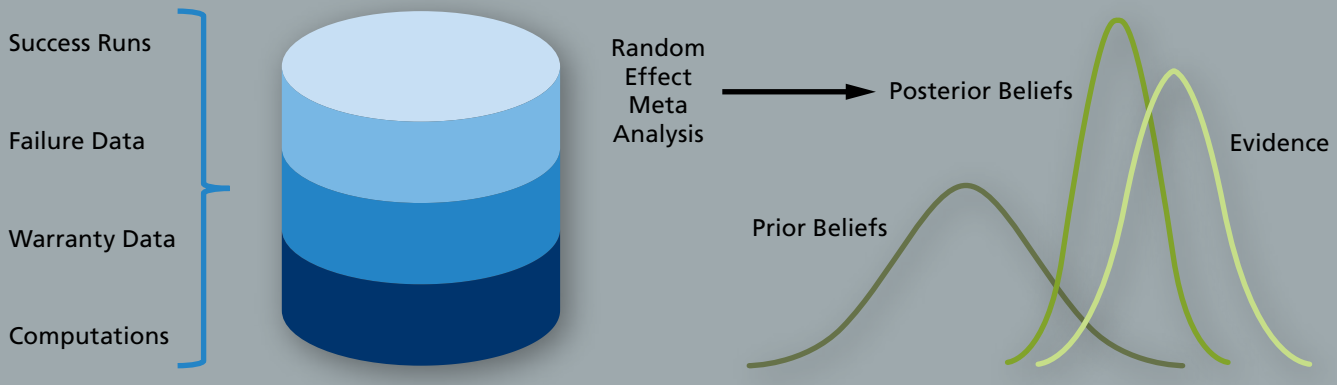
Last year, two of our research projects were tasked to expand the regional analysis. The core question to them was: What cities are particularly representative or above average for a specific area of application? Each project provided a different motivation for solving this problem: One involved the preparation of a representative virtual urban area for a vehicle simulator, while the other made a selection of suitable cities for an actual measurement campaign.

To compare two cities, we used various categories of characteristics. Which category a characteristic is assigned to is defined by how closely the characteristic relates to the expected load factor. For example, hilliness and curviness correlate quite directly with vehicle load and are assigned to the category of pseudo-load factors. Conversely, the appearance of the crossing angles in a city road network or the city's population density only indirectly affect the load, and so are placed in one of the other categories.

Appropriate criteria for each application

We developed pseudo-load factors using combinations of the various base measures established in VMC®. They can be simple measures, such as the stop event density, or more complex objects, such as the statistical hilliness distribution. To characterize the appearance of a road network, we used factors like the distribution of the crossing angles in the city. This process enables a statistically based selection of cities with a suitable formulation of criteria for the respective application.

VMC®



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JUROJIN – PUTTING PRIOR KNOWLEDGE TO USE

Safety critical components must not fail even in very demanding customer usage. Statistical testing of several hundred components without failure is necessary for even 99 percent reliability. A joint project with ZF applies prior knowledge from historical data sets to improve the predictive accuracy.

1 *Schematic process for the use of various sources of prior knowledge*

Attempts to reduce the high costs through longer test duration or greater load placement on just 5 to 10 components, makes the certification test less selective and only components that are substantially better than the requirement will pass. At the same time, all manufacturers have accumulated experience: thousands of similar components have been successfully produced in series for many years. The systematic use of historical data for the certification test was difficult in the past. A human had to assess how well each individual data set transferred over to the current component generation. Automation was never an option.

Prior knowledge from historical data sets

The joint project with ZF resulted in a process that we have implemented in Jurojin. It automatically generates a single individual knowledge model from any number of historical data sets. Bringing this prior knowledge into a smaller sample using Bayesian statistics, produces a level of quality that traditionally would have needed a much larger sample size. The design and planning of certification testing is significantly more efficient now. Our near term goal is to achieve a savings of 10 percent or more in the sample size.

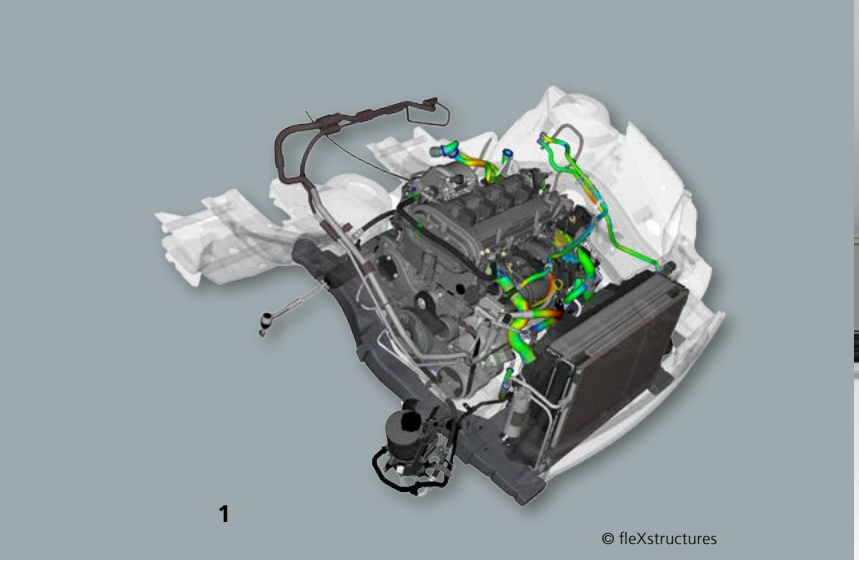
Random Effect Meta-Analysis

The new process can accommodate many types of historical data sets: whether the sample size is large or small, and no matter if there are just suspended items or all of the components have been tested until failure. The Random Effect Meta-Analysis we use automatically assigns the correct weighting to each data set (depending on sample size, consistency of the sample, and compatibility with other samples).

As the new, smaller size samples are also suitable for this format, the effect will be even greater in the coming years. Jurojin supports the entire process:

- ·Evaluates historical data and stores it in a database
- Combines many prior sources of knowledge in a Beta-distribution
- Uses the Beta-distribution for cost savings in the test plan

JUROJIN



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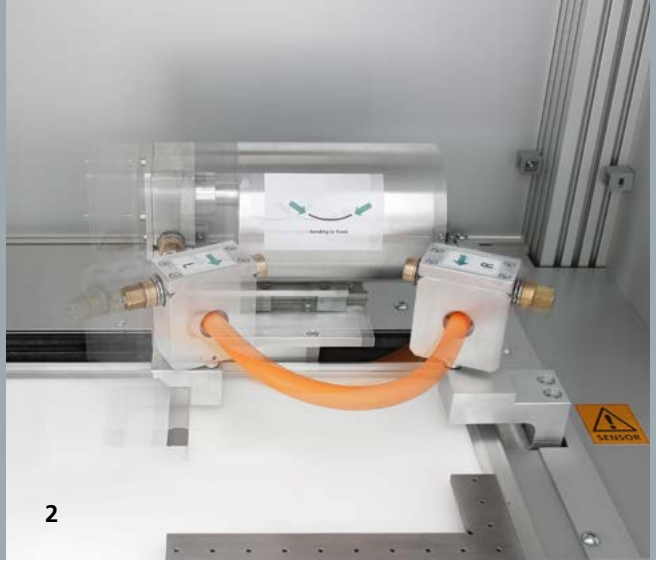


2

IPS CABLE SIMULATION AND MESOMICS® – SOFTWARE AND PARAMETERS FROM ONE PROVIDER

1 *Vehicle engine with cables and hoses*

2 *MeSOMICS bending test*

Cables are omnipresent. Looking into vehicles or other modern technical products, all contain moving cables and hoses which must not get damaged. Computer simulation helps to optimize the cable design and assembly, even before hardware prototypes are available.

However, to achieve realistic results, two essential requirements have to be fulfilled:

- The kinematical formulation and the computation of the mechanical equilibrium states, i. e. the cable deformation, must be physically correct.
- The simulation model has to include the mechanical properties of cables and hoses in a convenient way.

IPS Cable Simulation is developed by Fraunhofer ITWM and Fraunhofer Chalmers-Centre and fulfills both of the above criteria. Moreover, the computation is real-time capable and enables interactive simulation of cables and hoses.

Fast computation of cable deformations

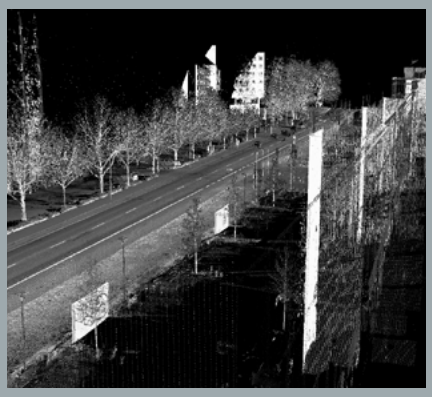
The kinematical model is based on discrete Cosserat curves, where curvatures and strains describe the local deformation. To compute the overall cable deformation, we use the fact that static equilibrium states correspond to local minima of the potential energy of the cable.

For industrial applications with IPS Cable Simulation, a linear constitutive model with effective stiffness values integrated over the cross section is particularly useful. It turns out to be very robust and allows efficient numerical computations. Furthermore, these effective stiffness can be determined directly from measurements.

Determine mechanical properties automatically

MeSOMICS is developed especially for this purpose. The highly automated measurement system comprises an innovative bending experiment under practically relevant curvatures, a torsion experiment and a computational determination of the tension stiffness. After inserting the specimen, the measurement and the evaluation of measurement results runs automatically. In addition, an optical monitoring ensures a reliable parameter identification. Finally, a full parameter set for IPS Cable Simulation is provided. Thus, customers are enabled to measure the mechanical properties of important cables within a few hours on their own.

1



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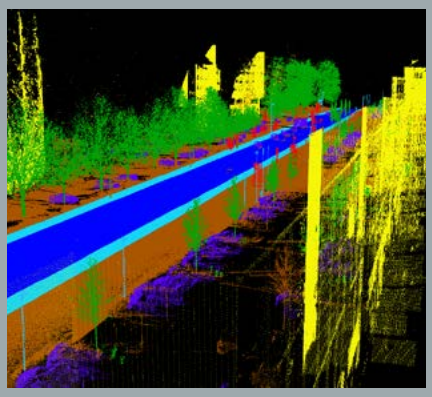


3

VMC® ROAD-AND-SCENE GENERATOR: DIGITAL ENVIRONMENTAL DATA FOR VEHICLE ENGINEERING

The development, evaluation, and validation of modern assistance and automation systems for passenger cars and commercial vehicles is more complex than ever before. The VMC® Software-Suite enables vehicle engineers to connect the real world to its digital twin.

1 *Picture of the real scene (Trippstadter Straße, Kaiserslautern)*

2 *Georeferenced 3D-laser scan of the environment*

3 *Automatic semantic segmentation and classification of the scanner data*

Since many years, we deal with the statistical analysis of geo-referenced data in order to support and improve the virtual evaluation of vehicles. While assistance and automation systems getting more and more complex, traditional testing and proving procedures are reaching their limits.

Current approaches such as the description of the logic of road networks often fail when capturing complex edge cases. However, these are omnipresent in reality, e. g., incomplete lane markings or damaged road surfaces. Even in the absence of lane markings, assistance systems have to ensure safe driving conditions. This must already be taken into account in the development process.

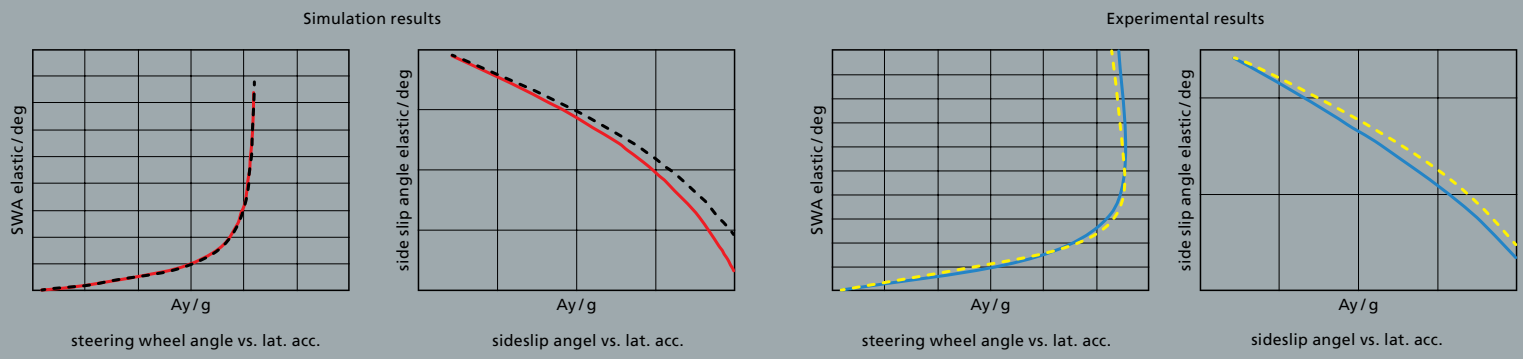
Real environment data as a basis

The "VMC Road-and-Scene Generator" is a software package that is currently developed at ITWM and enables the virtual development and evaluation of automation systems based on real environment data. Therefore, the process is as follows: Built on traditional statistical methods, we select a representative city, and then capture it using the institute's measuring car REDAR and save it as a 3D point cloud. We apply methods of machine learning and deep learning neuronal networks to analyze and classify the data; relevant objects such as vehicles, lanes, lane markings, buildings, etc. are automatically identified.

Automated data analysis and classification

This information provide a key component for a highly accurate sensor simulation since additional attributes can be made available for each object and each point, e.g., material properties, reflection and absorption characteristics depending on various electromagnetic wavelengths, etc. The data analysis and classification is highly automated leading to a highly efficient overall process.

VMC®



1

CDTIRE/3D: MODELLING TIRE VARIATIONS

1 *Qualitative comparison of tire size variation: 235/60 R 18 both axles (red/blue straight lines) vs. 235/55 R 19 front and 255/50 R 19 rear axle (black/yellow dotted lines).*

Simulation tools can shorten the time it takes for a product to reach series production with no loss in quality. Above all, they speed up the concept phase. Our department works together with various car manufacturers to improve the accuracy of simulation results in the early stages of development. Currently, a very promising new technology known as "morphing" is providing automotive manufacturers with access to data on many possible tire and wheel sizes in the earliest stages of planning – including, especially, some that do not yet physically exist.

The handling and performance of a passenger car is very dependent on the selection of tires. A new method uses the CDTire/3D model to predict the characteristics of a tire without having a physical prototype. Among the questions that arise in the early stages of development are the choice of tire and rim size, the optimal tire pressure, how much does changing tire specifications help in achieving the stated goals and how important is the vehicle itself.

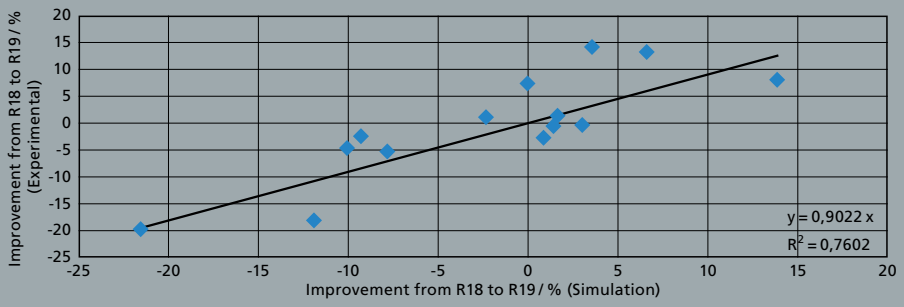
Geometric description of the tire

Fraunhofer ITWM develops the tire model CDTire/3D, which is used by the automotive industry in comfort, durability, and vehicle dynamics studies. A shell based discretization method combines the functional layers of a tire (like the cap plies, steel belts, and carcasses – each having defined material parameters), with their respective geometries. Modeling the elastic component for each fiber reinforced layer includes a nonlinear part that results from different tensile and compressive behaviors. The geometric description permits large deformations.

Separating material and geometric characteristics

The design assistant uses pressurized cross sectional geometry to parameterize the tire based on the construction properties of the functional layers. In effect, because the model strictly separates material and geometric properties, our method is able to modify an existing tire based on nominal specifications.

Our morphing algorithm adapts the geometric description and weight distribution of the reference tire to the specifications (tire width, tire cross section, rim diameter and width), without changing the material properties. For example, a 225/45 R17 (x7.5) tire size can be transformed into a 235/40 R18 (x8).



2

Internal pressure variation

The importance of tire inflation pressure as a factor influencing tire performance characteristics must also be mentioned. The compressed air acts as a force on the innerlinerof the tire and puts a strain on the structure, in particular, the load bearing elements of the spiral layers (steel belts, carcass and cap plies). The CDTire/3D tire model can apply gas pressure to the entire inside of the tire (using various gas models such as the ideal gas equation or the compressible Euler equation), to accurately describe and predict how is effected not only by size changes to an existing tire and rim, but also by variations in the internal pressure.

This method is used in the early stages of tire development – from a base tire – to study different tire and rim sizes. The prerequisite for this approach is that the materials, construction, and profile all remain the same.

Comparison of simulation and result

Our evaluation compared the predictions about varying tire size with the experimental results for the typical criteria of driving dynamics. The results showed only small differences between measured and predicted vehicle behavior (see Figure 1). The method is also useful in cases where not many measurements are available. Figure 2 shows the measured and simulated percentage improvement for each criteria used by a luxury vehicle manufacturer to assess vehicle handling. As is clearly shown, the predictions always reflect the same tendencies.

Morphing engineering in tire development has proven successful and its continued use in the future is assured. Planning for future projects includes a study of minor changes to the materials and construction.

2 *Comparison between simulated and measured improvement of key performance indicators when switching from 18'' to 19'' wheels*

NEWS

5TH INTERNATIONAL COMMERCIAL VEHICLE TECHNOLOGY SYMPOSIUM

The 5th International Commercial Vehicle Technology Symposium was held on the campus of TU Kaiserslautern on March 13–15, 2018. Attended by nearly 200 national and international experts and managers from scientific and business communities and supported by approximately 50 expert lectures and 15 poster presentations, the symposium provided a discussion forum for trends and technological developments in the commercial vehicle industry. Specifically, the topics ranged from energy and resource efficiency to safety, reliability and service life, automation, driver assistance, and autonomous driving.

EMMA-CC SYMPOSIUM

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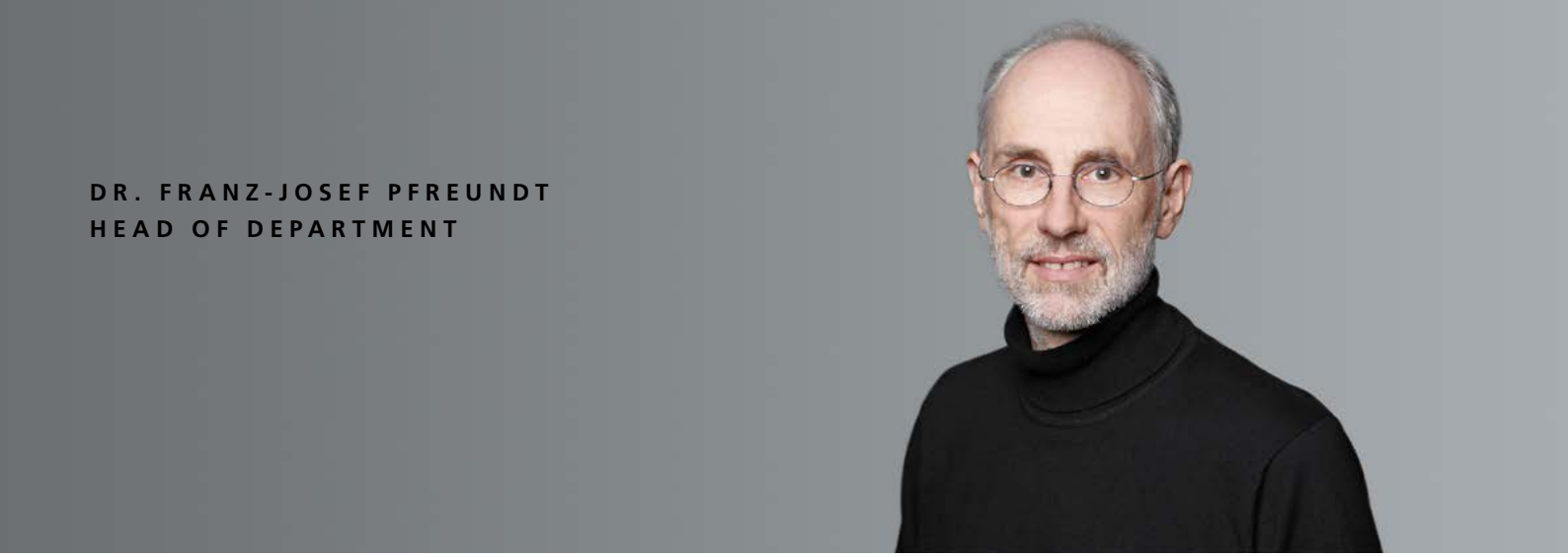
In April 2018, the results of the Fraunhofer project EMMA-CC (www.emma-cc.com) were presented by each of the research institutes involved. This symposium was complemented by highly respected speakers from industry and research who accepted our invitation and presented expert lectures which examined different areas of application and the industrial needs of digital human models from different perspectives. Speakers included Prof. Lars Hanson (SCANIA AB; University of Skövde), Dr. Sascha Wischniewski, Federal Institute of Occupational Safety and Health, Dr. Thomas Bär (Daimler AG), and Prof. Sigrid Leyendecker (University of Erlangen-Nürnberg).

4TH SYMPOSIUM ON DRIVING SIMULATION

4th Symposium on Driving Simulation was held at Fraunhofer ITWM on November 14, 2018. More than 50 participants actively discussed current challenges in the area of virtual development, testing, and verification of systems for autonomous vehicles. The practical relevance of the symposium was underscored by diverse live demonstrations of the simulation methods available at ITWM (static driving simulators, VR Lab, RODOS®, etc.).

Front, left to right: Tim Rothmann, Christine Biedinger, Björn Wagner, Canhui Wu, Dr.-Ing. Lilli Burger, Vanessa Dörlich, Dr. Jochen Fiedler, Dr. Michael Speckert, Dr.-Ing. Michael Roller, Dr. Klaus Dreßler, Thorsten Dahlheimer, Hannes Christiansen, Dr.-Ing. Michael Kleer, Thomas Stephan, Thomas Halfmann, Christine Rauch, Dr.-Ing. Joachim Linn, Steffen Polanski, Thorsten Weyh, Axel Gallrein, Dr. Fabio Schneider, Dr. Sascha Feth, Christoph Mühlbach, Jonathan Jahnke, Dr. Michael Burger, Simon Gottschalk, Benjamin Bauer, Marius Obentheuer, Thomas Jung, Tobias Ruhwedel, Dr. Stefan Steidel

COMPETENCE CENTER HIGH PERFORMANCE COMPUTING



DR. FRANZ-JOSEF PFREUNDT
HEAD OF DEPARTMENT

INNOVATION, DISRUPTION, AND A HOLISTIC APPROACH TO THE WORLD OF PARALLEL COMPUTING

The department has developed innovative world-class technologies for solving large data problems, specifically BeeGFS, Pre-Stack PRO and the Global Address Space Programming model (GPI) in addition to the Big Data framework called GPI-Space. In recent years, we have gained international attention by successfully combining these technologies with deep learning methods. At its core, it's always about the scalable automatic parallelization of big data problems. This is based on the concept of "Memory Driven Computing" which combines scalability and performance. In our machine learning projects, we are further developing industry-specific solutions based on this technology.

The aim of our involvement in EU-sponsored HPC research is to strengthen European technologies and improve the marketability of European HPC software products. In addition, our goal in co-design projects is to bring together microelectronics development and application development. We see a way to improve Europe's position in the fast-growing HPC/Big Data market in application-specific development of computer hardware.

The energy systems of the future will consist of millions of distributed Internet-of-Things (IoT) computers. These optimize the self-consumption of PV power, regulate the creation of local grids, control large and small power storage systems, and coordinate the energy flow in power grids. Our technologies and project solutions are developed to master this world of distributed computing. Our commitment is to create intelligent solutions that work to advance the energy transition.

Contact
franz-josef.pfreundt@itwm.fraunhofer.de
www.itwm.fraunhofer.de/en/hpc

MAIN TOPICS

- Scalable parallel programming
- Deep learning tools and applications
- Memory driven computing (GPI-Space)
- BeeGFS – parallel cluster file system
- Green by IT
- HPC in seismic

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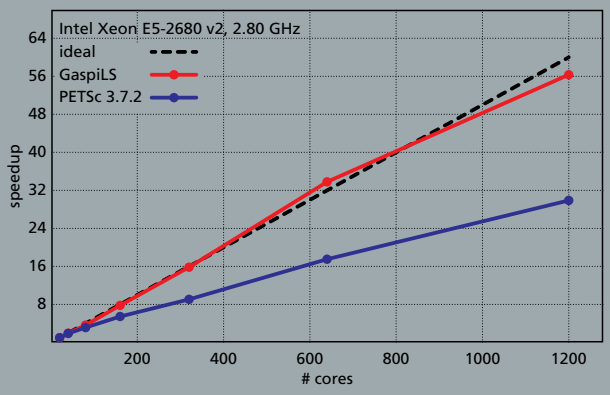


2

GaspiLS AND THE GPI-2 ECOSYSTEM: GPI-2 SCALABILITY AND PERFORMANCE MADE EASY

1 *GaspiLS provides scalability for FEM and CFD simulations*

2 *Performance plots: Scalability advantage of GaspiLS compared to PetSC. Jacobi preconditioned Richardson Method; 3-D Poisson equation (2d order FD discretization), cubic matrix (359^3)*

The distributed systems used in high performance computing require highly efficient and scalable applications. Scalability is a measure of the efficiency of a parallel implementation and ultimately indicates whether the available resources – for example, CPUs – are being efficiently used. The Competence Center High Performance Computing develops GPI-2, a parallel programming model that is ideal for implementing such applications.

GaspiLS is a library of scalable, iterative linear solvers developed to easily exploit the benefits generated by GPI-2 and make them available for immediate practical use in a multitude of applications. GaspiLS is ready for direct use with a variety of new or existing simulation programs ultimately solving linear systems.

HySCALA explores new areas of application and new markets for GaspiLS

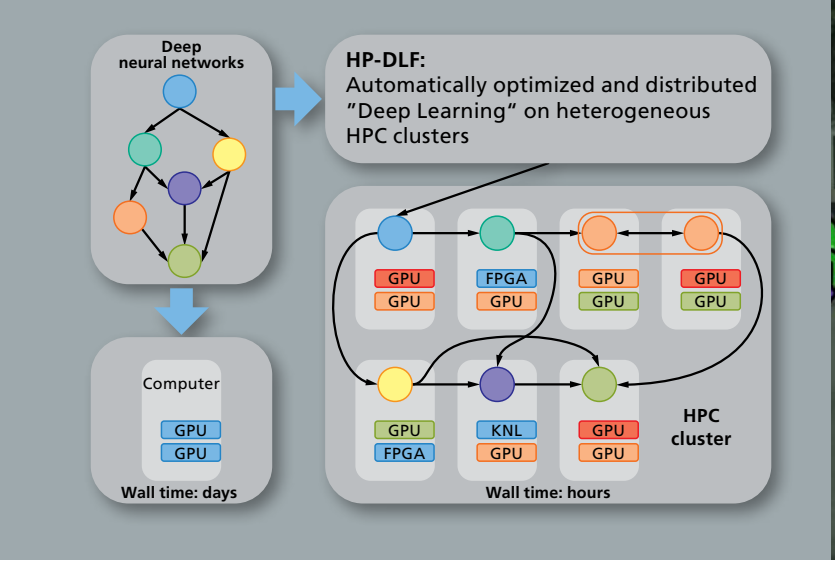
GaspiLS has already proven itself in several industry projects. Its further distribution is currently being promoted as part of the EU project HySCALA (Hybrid Scalable sparse matrix linear algebra for industrial applications).

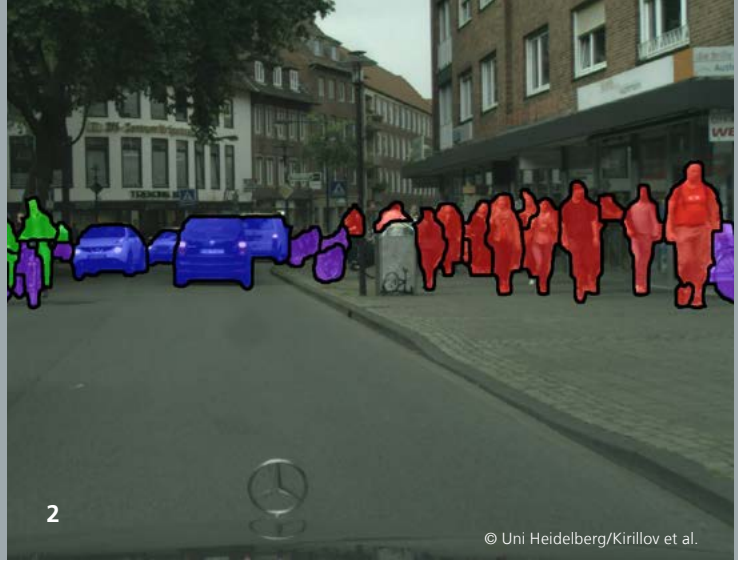
The aim is to analyze various, potential new market segments and fields of application for GaspiLS and to identify specific requirements for a competitive linear solver library. We are looking primarily for generic yet efficient preconditioners that allow us to reduce the number of iterations required for convergence of the iterative process and minimize the total run times. Presently, the focus is on the scalable implementation of efficient preconditioners that can be applied to a broad class of problems.

GaspiCxx for increased productivity

Within GaspiLS, we have factorized the implementation for the explicit management of communication resources required by the GPI-2 data transfer and used GaspiCxx to supply it to other applications. GaspiCxx defines an easy to use C++ interface. It delivers the full native GPI-2 performance. At the same time, the management of GPI-2 communication resources is fully transparent to the application.

This eliminates a large part of the implementation work normally required to develop GPI-2 applications. Development of GPI-2 applications and the exploitation of the advantages – like the good scalability – has never been so easy.





HPC FOR MACHINE LEARNING: HIGH PERFORMANCE DEEP LEARNING FRAMEWORK

Artificial neural networks have become established in many areas of machine learning in recent years. For example, they are at the leading edge of computer vision, speech and character recognition as well as machine translation. One reason for their success is the ability to create highly complex interrelationships between the raw data input and the classification (the labels) of the output data.

1 *HPC enables deep learning without storage limits.*

2 *Large amounts of data play a special role in autonomous driving.*

This often requires several million free parameters that have to be changed (i. e., learned) while training the network. Because of the large number of these so called weights, training a single neural network often takes several days or even weeks. Clearly, making these algorithms highly scalable through the use of supercomputers is highly desirable. In the ideal case, doubling the number of computers connected in parallel would halve the running time of the algorithm.

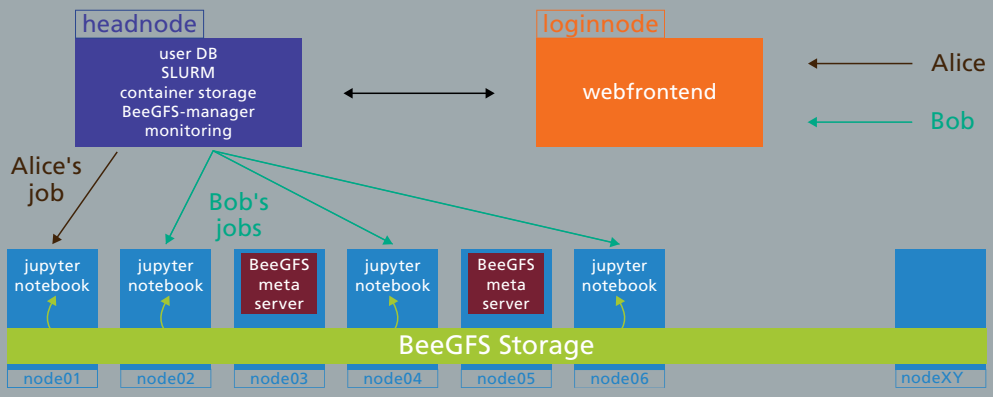
Small neural networks or fewer files?

Neural networks encounter an additional problem: they require a very large main memory. As a result, only relatively small neural networks can be trained on a single computer, or even the amount of data used for learning must be limited. Neither of these options is desirable because they reduce the capacity, i. e., the learning ability of the network. Rather, it is more desirable to train networks of twice the size with twice the number of computers. This is called "weak scalability" in the jargon of parallel computing.

High degree of scalability with GPI Space

Enabling both weak as well as strong scalability in the training of neural networks is the subject of the BMBF project "High Performance Deep Learning Framework, (HP-DLF)." A particular focus is placed on enabling the construction of neural networks of any size and ensuring easy access to existing and future high performance computing systems. No prior knowledge of parallel computing is required on the part of the user. Our in-house runtime system GPI-Space manages everything. When represented in the form of a special graph, a so-called Petri net, algorithms can be automatically and dynamically parallelized.

GPI-SPACE



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HPC FOR MACHINE LEARNING: CARME

1 *Simplified scheme of the most important system components and their connections*

Machine learning has an increasingly higher priority in both scientific and industrial enterprises. This is evident from the investment in new, above all, GPU-based hardware – from simple desktop computers to high performance computing clusters. Computing clusters are used in Data Analysis (DA) and highly complex Machine Learning (ML) systems to process and simulate very large amounts of data – to include even the human brain.

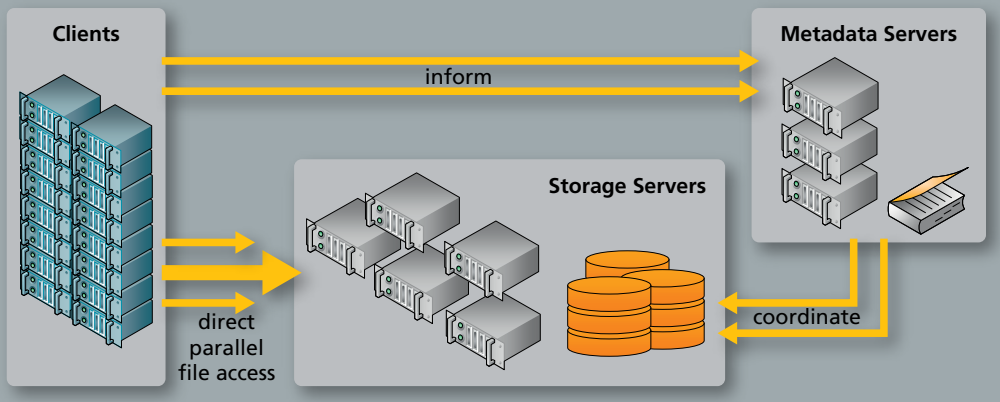
Machine learning in HPC clusters presents certain challenges. The procurement of the individual hardware components is the least of these challenges. The biggest questions arise subsequent to that acquisition:

- How to manage existing resources?
- How to make an application scalable to several GPUs?
- How to solve the challenge of data storage and continuous upload to the program?
- How to train users to effectively use the hardware?

The answers to these questions begin with our open-source software stack Carme. The basic concept is to combine the world of machine learning and data analysis with the world of HPC systems. We achieve this using established ML and DA tools with HPC back ends. Specifically, we use a variety of HPC and ML technologies. Some of these technologies are developed in this department, for example, the highly reliable parallel file system BeeGFS for fast data links.

Carme combines the worlds of machine learning and HPC clusters. ML is a steady and fast growing field of technology. This new agility challenges data centers to provide very different applications for single users. It is not enough to have one user interface for the user; rather there must also be a guarantee of a seamless integration of this surface in existing and emerging clusters. To make clusters attractive to ML and DA users, an intuitive software environment must be provided to the clusters. Interactive management of the cluster is essential in the development of ML applications. Users must have the opportunity to use tools they are familiar with on a complex HPC cluster, making it easier for them to migrate to and use the cluster.

www.open-carme.org



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BeeGFS – THE FILE SYSTEM FOR BIG DATA AND AI

The success of current AI technologies such as neural networks is based on the increased power of today's processors – mostly GPU´s – but, above all, on the availability of very large amounts of data. For example, new medical devices, autonomous vehicles, and genome analyses supply ever more fine resolution data in quick succession forming the basis for future AI solutions. Developed at ITWM and distributed by ThinkparQ, the parallel file system BeeGFS (also known as Fraunhofer Parallel File System – FhGFS) helps in mastering the large data volumes with a very flexible software solution.

1 *BeeGFS architekture*

BeeGFS is a parallel file system where storage capacity as well as read and write speeds grow linearly with the number of linked storage units. As a pure software solution, it can be flexibly installed both on existing hardware and on the latest, superfast flash-memory systems. In addition to very good scalability, our system development team attaches great importance on easy handling and a high degree of flexibility for a variety of potential use cases.

BeeGFS on NVMe

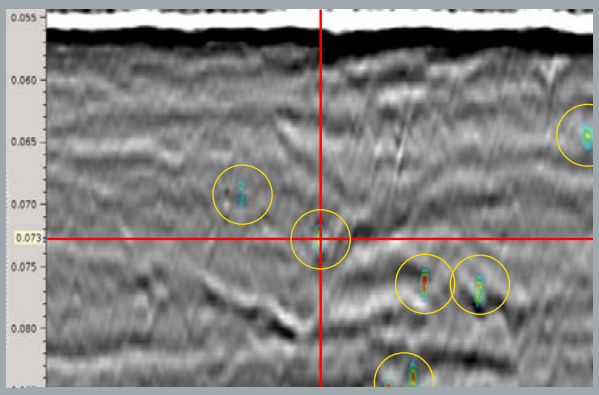
Training deep neural networks (Deep Learning) demands that existing data be provided several times very quickly to the computing units. Most external storage systems are hardly suitable for this task, so the data is cached directly to the computer servers on fast local systems (NVMe). Since these have relatively small capacities, the need arises for data to be distributed on several units in parallel.

The BeeGFS software system is specially optimized for high speed requirements even with a large number of files and this ability is its biggest strength. BeeGFS can be installed directly on the computer servers and is scalable to high I/O rate of 1 TByte/sec and more. Japanese AI researchers were convinced: BeeGFS is now successfully deployed on the two major Japanese AI systems TSUBAME 3.0 (HPE) and AI Bridging Cloud Infrastructure (ABCI, Fujitsu).

Open-source license

The software is distributed with an open-source license and source files are provided on the BeeGFS website. A spin-off of Fraunhofer ITWM, ThinkparQ, supplies worldwide commercial support for BeeGFS and manages further development from a customer perspective. The joint development team also successfully applies its extensive knowledge in several EU funded projects that focus on the use of BeeGFS on future Exascale computing systems.

BeeGFS®
developed by Fraunhofer



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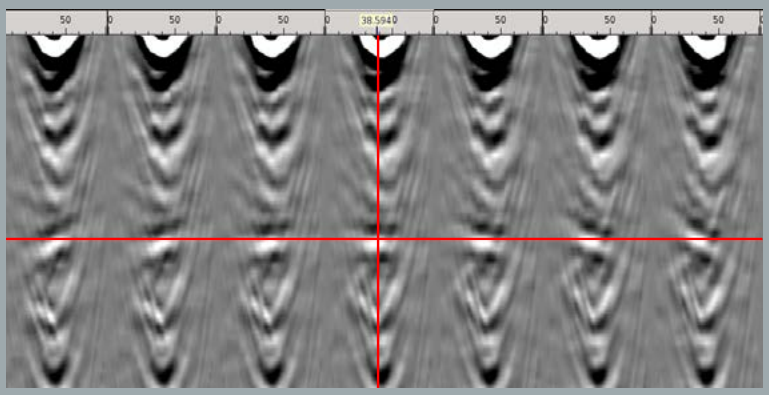


2

BOULDER-DETECTION MIT MACHINE LEARNING

1 *Subsurface image computed from seismic data; colour spots show locations of high probablity for the presence of boulders*

2 *Illumination representation of part of the subsurface at which a boulder was identified; the cross-hair points into the symmetry center of the identified pattern and indicates the lateral position of the boulder at 73 m depth*

Piles of windmills of offshore windparks must be firmly coupled into the subsurface layers deep below the sea-floor. Large boulders, that would be obstacles for the planting process of such piles, must be identified in the phase of defining the exact locations of windmills. Seismic data sets acquired for site-planning of windparks for the purpose of assessing subsurface stability conditions have limited frequency content. We developed a new methodology for object identification below seismic wavelength (here: 1 m) from such data by means of machine learning methods.

Key to this methodology is the preprocessing of the data by a prestack migration method that highlights the weak-amplitude diffractions contained in the seismic data.

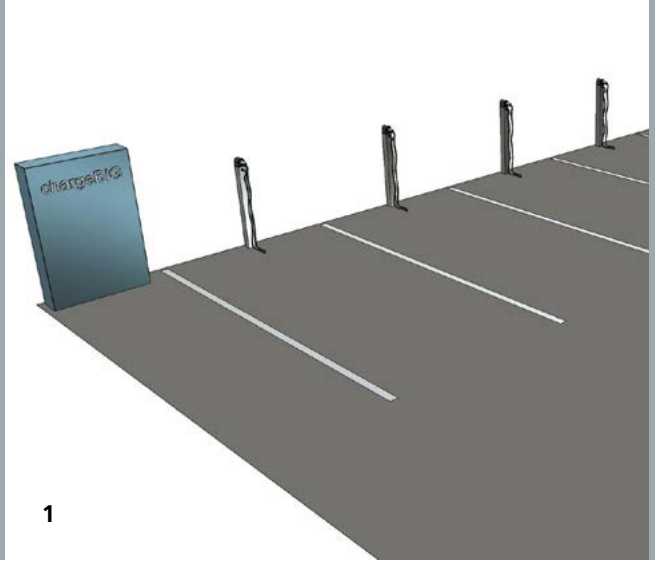
Pattern recognition in seismic sections

Together with colleagues from Fraunhofer IWES and sponsored by BMWI we developed a process that maps the seismic data into a domain in which diffraction responses show a typical pattern. The task of finding such patterns, thus to localize the associated diffracting objects, is similar to the task of assigning pixels of photos to object classes, which constitutes a problem that can successfully be solved with the help of deep neural networks (DNNs).

Here, however, we are dealing with a high-dimensional problem, as even for 2D seismic, i. e. 2D subsurface images, illumination-direction and velocity-variation contribute two additional dimensions. Further, the Earth's subsurface is not accessible so that the networks cannot be trained with the ground truth for real data; rather, we have to rely on training solely based on synthetic data generated and perturbed towards the appearance of real data.

Benefit for the user: reduced amount of data

Our results demonstrate that transfer learning from synthetic to real data works and that our DNNs that consist of a large number of convolutional layers offer the necessary complexity for computing the probability for the existence of diffracting objects of 1m scale length even in noisy data. After application of this automated process, the user is left with the task to further interpret the seismic data only in those areas that are marked by high probablility values.



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chargeBIG – A NEW CHARGING INFRASTRUCTURE FOR ELECTRIC DRIVE VEHICLES

The chargeBIG project is a joint development effort with MAHLE Group and the Eliso company to create a new kind of charging infrastructure for electric drive vehicles. The resulting system is to be cost efficient, highly scalable, and will contribute to stable grid operations. The goal is the large scale electrification of parking garages by placing a charging option at every parking space of a parking garage as cheaply as possible.

1 *Rendering of the chargeBIG charging infrastructure; the charging towers are connected to the chargeBIG central.*

2 *Left: Charging towers with charging plugs, right: Prototype of the chargeBIG central for 18 charging points*

Conventional technologies are very expensive and car park operators often decide against complete electrification. Instead, they install charging stations for electric cars only at a few designated spaces; with the disadvantage of finding that the charging station is often blocked by already fully charged vehicles.

Charging infrastructure for all parking spaces

The vision of chargeBIG: In place of expensive components at a few parking spaces, the necessary technical components are combined at a central location and just one tower with a charging cable is needed for each parking space. In effect, the requirements at each parking space are reduced to a minimum. The centralized concept provides substantial savings, both in manufacturing costs as well as current maintenance expenses, with the benefit of low-cost electrification of as many parking spaces as possible.

A parking garage as an actual lab

In joint development with ITWM, MAHLE has already developed a chargeBIG prototype with 18 charging points. This serves as a blueprint for a demonstrator with 108 charging points to be installed in a MAHLE parking garage in Stuttgart. The garage is a real laboratory for testing the effectiveness of grid operations. In addition to the charging infrastructure, we installed a storage battery system, a DC-DC fast charging station (i. e., a station for charging an e-vehicle directly with DC current from a stationary battery), and a dedicated photovoltaic system.

The Amperix energy management system developed by Green by IT Group optimizes component usage with a view towards increasing local self-sufficiency, reducing peak loads (peak shaving), and the adoption of flexible electricity prices. The chargeBIG project is funded by the Immediate Action Program "Saubere Luft" of the Federal Ministry for Economic Affairs and Energy (BMWi). As part of the accompanying scientific research, ITWM is also analyzing and evaluating the project's contribution to the reduction of nitric oxide (NOX) emissions in the city of Stuttgart.

NEWS

EPEEC: EUROPEAN JOINT EFFORT TOWARDS A HIGHLY PRODUCTIVE PROGRAMMING ENVIRONMENT

The aim of the project launched in October is to develop a parallel programming environment for heterogeneous supercomputers. We are adding application-specific data compression algorithms to GPI, the parallel programming model, in order to better support machine learning and loosen the requirements for consistency. Today's programs rely on a consistent view of global attributes, which presents a limiting factor for scalability and requires synchronization between parallel computer nodes. GPI enables EPEEC to meet these challenges in achieving exascale computing.

AMPERIX® SUPPORTS ENERGY SELF-SUFFICIENCY

In the Schoonschip community, a water estate north of Amsterdam, 30 houses form an energy unit/microgrid that generates most of its electricity itself using solar energy and stores the energy itself using heat pumps and batteries. The houses are interconnected with each other, but also have a shared connection to the municipal power grid. The power supply inside of the microgrid is coordinated by our Amperix® energy management system. In addition to controlling the battery storages, we also implement the sector coupling with controlling the heat pumps.

AUTOMATED DATA ANALYSIS USING MACHINE LEARNING: DEEP TOPOLOGY LEARNING (DETOL)

Although Deep Learning methods are established in many sectors, intensive training is still required. Artificial neural networks demand huge amounts of data and enormous processing power to complete this task. The aim of the DeToL project, launched last June, is to substantially simplify and accelerate the design process of Deep-Learning solutions by means of automated, data-driven design algorithms.

One of the core aspects in DeToL is the development of the central software framework for distributed parallelization of the massive compute load. Our distributed runtime system GPI-Space forms the basis on which the individual modules are implemented. Here we focus on the algorithmic realization of the parallelization of the partial modules for reinforcement learning, genetic algorithms, graph embeddings, early stopping, meta learning and pruning. (See page 91)

Front, left to right: Sabine Müller, Kalun Ho, Dr. Somnath Madzumdar, Dr. Rui Machado, Dr. Alexandra Carpen-Amarie, Avraam Chatzimichailidis, Dr. Abel Amirbekyan, Dr. Dimitar Stoyanov, Peter Michael Habelitz, Dr. Tiberiu Rotaru, Valentin Tschannen Dr. Matthias Balzer, Sebastian Schumb, Kai Krüger, Frauke Santacruz, Dr. Norman Ettrich, Matthias Klein, Javad Fadaieghotbi, Bernd Lörwald, Dominik Loroch, Mikita Vedzeneyeu, Dr. Valeria Bartsch, Dr. Franz-Josef Pfreundt, Dr. Mirko Rahn, Delger Lhamsuren, Dr. Alexander Janot, Bernd Lietzow, Dr. Martin Kühn, Ricard Durall Lopez, Raju Ram, Lukas Ristau, Dr. Peter Labus, Christian Mohrbacher, Matthias Deller, Dr. Dirk Merten, Dr. Dominik Straßel, Julius Roob, Dr. Roman Iakymchuk, Dr. Alexander Klauer, Philipp Reusch, Dr. Janis Keuper, Patrick Reh

MATERIALS CHARACTERIZATION AND TESTING

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PROF. DR. GEORG VON FREYMANN
HEAD OF DEPARTMENT

NON-DESTRUCTIVE TESTING WITH MILLIMETER, TERAHERTZ AND OPTICAL WAVES

Quality control in industrial production processes is not only important for safety-relevant components, e. g. in aviation industry and medical technology but also supports resource-saving production by avoiding defective parts. Contact-free and non-destructive measurement allows further use of tested parts in the production process.

At the Materials Characterization and Testing department, we develop non-destructive and contact-free measurement methods which are optimized for application in production lines and enable reliable control of the production process. Our Terahertz layer thickness measurement systems are able to investigate thickness and material parameters of each individual layer. Our pipeline inspection systems check the wall thickness directly at the extruder. Our FMCW radar-based inspection system reliably detects defects in composite materials. Chemometric evaluation methods determine the composition of materials quickly and reliably from spectral data.

Our scientists, engineers and technicians use technologies ranging from optical coherence tomography (OCT) in the visible spectral range to time domain spectroscopy in the terahertz frequency range and electronic system concepts in the millimeter wave range for tailor-made customer solutions. The competence of our employees includes a detailed understanding of the process in such a way that application and evaluation software clearly presents the key target parameters and appropriate technological solutions can be identified for the respective application.

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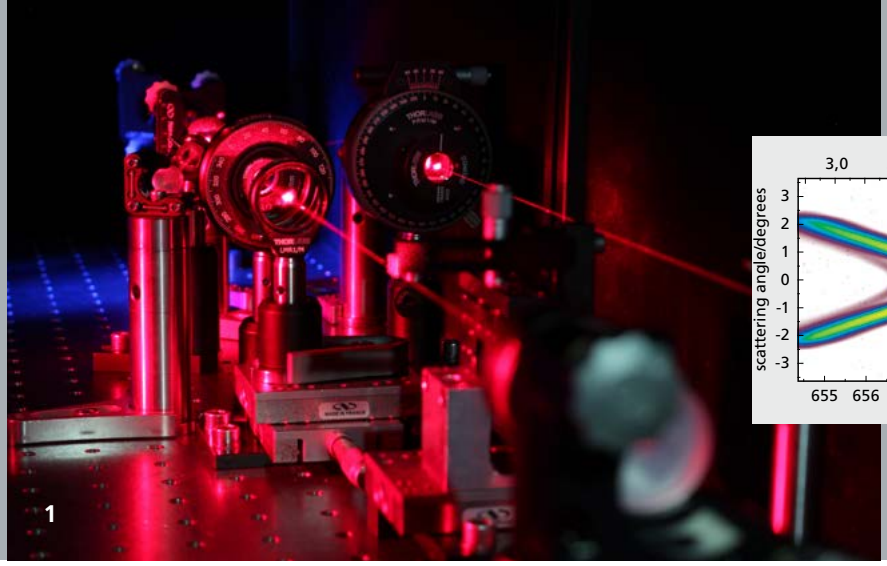
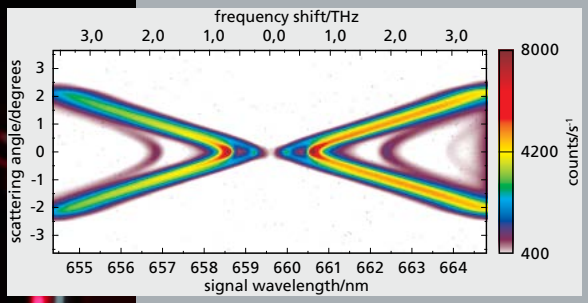
MAIN TOPICS

- Non-destructive testing
- Layer thickness measurements
- Chemical analysis





1 2

QUILT – QUANTUM OPTICS IN THE TERAHERTZ SPECTRAL RANGE

1 *Experimental setup to verify photons generated by quantum optics*

2 *Angular spectrum recorded in the context of the project as indirect proof of quantum optical generation of terahertz photons*

Fraunhofer has a flagship project known as QUILT to conduct research on imaging processes in the terahertz spectral range based on quantum optics. "Schrödinger's Cat" has developed from a thought experiment to an exciting and practical reality. With our first experimental successes achieved in 2018, we are breaking new ground in the field of terahertz research.

Classical imaging in the visible spectral range benefits from the wide availability of good detectors. Whether in digital cameras, PCs, or smartphones: the majority of households own several optical imaging systems with millions of detectors.

Imaging difficulties using terahertz waves

However, imaging in the terahertz spectral range is still a major technical challenge. Often, we are forced to rely on scanning methods since only a single or just a few detectors can be operated. In practice that means the scenes to be recorded are scanned with a single detector and these traces, subsequently, have to be put together.

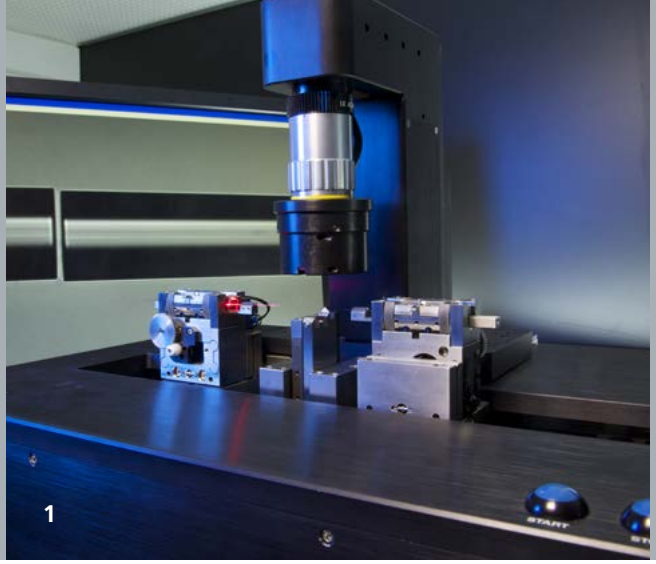
Quantum optics provides a solution

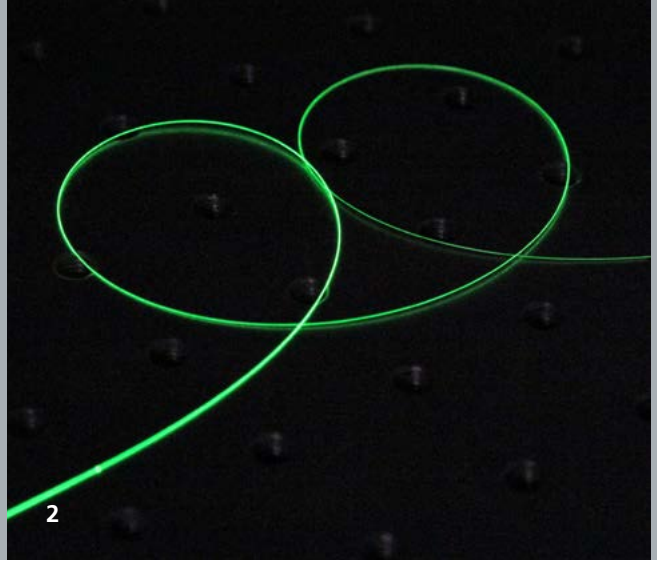
Using the phenomena of quantum optics, we can transfer the properties of photons (light particles) to other photons. If we succeed in transferring the properties of difficult detectable photons over to the easier to detect photons, for example, those in the visible range, we can identify them and avoid the detector availability problem.

Initial success

Inspired by outstanding basic research on the subject of quantum optics, the aim of our flagship project is to transfer these concepts to the terahertz spectral range. The first experimental challenge was to generate suitable photon pairs, something we achieved last year.

The next steps mean entering into uncharted scientific territory. The interaction of photons in the terahertz range with visible photons must be verified. For this, we take advantage of the good detectability of visible photons to indirectly detect and utilize terahertz waves. If this step succeeds, a new access to the terahertz spectral range and its many applications will be made possible.





SLAPCOPS – LASER CONCEPT FOR TERAHERTZ MEASUREMENT SYSTEMS

Time-resolved measurement of signals in terahertz time domain spectroscopy requires two variable laser pulses with a time delay between them. Until now, a mechanical displacement unit or two light sources achieve the necessary time delay. We have built a laser system working without a mechanical positioning unit and just one laser. Introducing the SLAPCOPS system.

1 *Fiber splicing device connecting two fiber ends; the connection process is a basic prerequisite for implementing fiber lasers.*

2 *Characteristic green glow of an active fiber, representing a key component of the SLAPCOPS laser system*

The majority of systems developed and in use now in the department are based on ultrashort pulsed lasers in conjunction with optical delay units. These two components are necessary to record processes on a scale of picoseconds. (One second consists of a trillion picoseconds, a time scale that currently cannot be achieved with electronic systems). Terahertz pulses are electromagnetic pulses lasting one picosecond, which enable a thickness analysis of multi-layer coatings like automobile paint, in a non-contact and non-destructive manner – a fundamental advantage over other technologies.

Lower costs, higher measurement rates

Ultrashort pulsed lasers and delay units continue to dominate the cost of many terahertz measurement systems. Our researchers have found an innovative approach while working on a PhD project that combines these two components into a single, less expensive device.

In addition to the cost advantage, much faster measurements are possible with the new measuring device. The new method also provides a high degree of flexibility that facilitates uncomplicated solutions to a variety of measurement problems. The patented invention also permits the measurement of very thick layers or even walls in a single measurement, which was not readily feasible with conventional terahertz systems. The optical systems currently in use can supply approximately 50 measurements per second, whereas the SLAPCOPS system enables more than 1000 measurements per second.

International scientific success

The scientific success of SLAPCOPS is already assured by presentations at international conferences and several publications in prestigious journals. To protect our established know-how in this area, we have filed intellectual property applications and several patents have been granted.

FLEXIBLE PIPE INSPECTION WITH TERAHERTZ TECHNOLOGY

1 *Pipe inspection system for testing wall thickness during production*

2 *The pipe being inspected for wall thickness at four selectable positions*

Improved quality and efficiency: An inline control check of pipe-wall thickness during extrusion enables the optimization of the production process. Early in 2018, we supplied a newly developed pipe control system to a global market leader, marking a milestone in the history of coating thickness measurement.

In addition to non-contact coating-thickness measurement of multi-layer paint coatings, recent developments in wall-thickness measurement during the pipe extrusion process have proven to be a promising application for terahertz technology. Our inline measuring system enables the customer to test the pipe-wall thickness directly after the extrusion of the plastic and to readjust the settings so as to optimize the production quality and efficiency.

Simultaneous measurement on four channels

The project launched with ambitious requirements for the early phase. The previous system, designed for a single sensor, had to be expanded for the simultaneous measurement of four channels allowing for four positions around the pipe to be checked at the same time. This requirement posed challenges for the integrated fiber optics as well as the collection and evaluation of measurement data.

The mechanical design had to feature the required flexibility to freely select these four positions and handle numerous different pipe diameters. The symmetrical arrangement of the system and the integrated monitor arm allow it to be installed and operated from either side of the production line.

Expansion to other market segments

The intuitive user interface – designed according to customer requirements – allows for convenient operation via a touch screen. A customer-specific interface to the manufacturer's plant control system guarantees optimal integration of the measuring system.

We provide our system with application-specific adjustment capability; we offer our system not only to pipe manufacturing companies, but also to hose producers. Because these two markets are so diverse, we see good opportunities ahead for additional customer-specific implementations.

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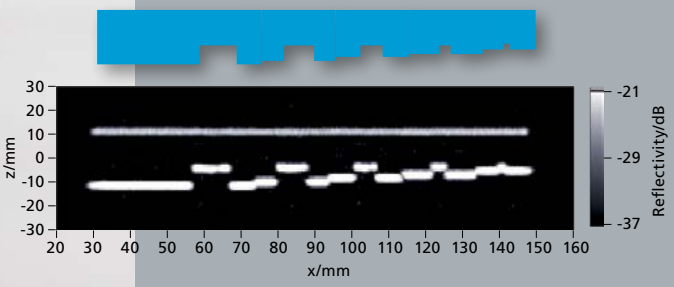

2

HANDHELD TERAHERTZ SENSOR FOR MOBILE USE

The special properties of terahertz waves include the ability to penetrate electrical insulators such as ceramics, glass, and plastics. This ability has an advantage over the established methods based on x-rays, ultrasound, or thermography, which all have limitations, especially, when assessing modern fiber reinforced plastics. A solution is now available in the form of the mobile, terahertz handheld scanner, which can also examine structures in hard to access places and detect defects in plastics.

Overcoming the limits of ultrasound systems

Many applications demand measuring methods that are suitable for rapid and mobile use. Often, ultrasound is chosen for this reason. Water and gel are common coupling media to minimize the high losses when passing from air to a material. However, this is not possible for ceramics and foams. Fortunately, terahertz-measuring systems are non-contact, require no coupling medium and can even be used to examine hollow structures.

Innovative handheld scanners

The handheld scanner is a complete terahertz system for non-destructive on-site testing. Thanks to its compact, lightweight design, it is easily transported and ideal for use with non-movable samples as well as in various location within the production. Single-sided sample access is sufficient as the system operates in reflection. The housing of the sensor protects from dust and spray water, which facilitates use in a manufacturing environment. An integrated touch screen ensures ease of operation and a clear display of all measurements.

When the handheld scanner is moved over a sample, it continuously records A-scans (thickness profiles) while the position sensor simultaneously registers the location. By linking these two data readings, the associated B-scans are created (spatially resolved cross sectional images). The position sensor corrects for uneven movements of the scanner.

Pipe inspection during production

The handheld scanner is already in use in some production settings, for example, to inspect pipes directly after extrusion and to ensure a real-time process control. In this case, ultrasound cannot be used because of the high pipe temperatures and the plastic core present inside the pipe. Another example is the post-welding inspection of pipe insulation.

1 *Handheld terahertz sensor, consisting of a computer and measuring head. No other device is required for operation, only a power outlet and the right power cord.*

2 *A B-scan of a stepped wedge with flat bottom holes made of PE (bottom) and schematic cross section (top). Diameters of the holes range from 2 to 10 mm; always set at 2 mm increments. Step height is 1 mm.*

NEWS

TALENTA GRANT FOR NINA SCHREINER

The Fraunhofer TALENTA speed up program supports female scientists who wish to pursue a position with management or technical responsibilities. Our PhD candidate Nina Schreiner demonstrated the motivation and potential to meet all requirements: She is doing research in the field of terahertz measuring systems and plans to complete her doctorate next summer. After that is done, she will become the head of the topic area "Radar-based thickness measurements". The support program is goal oriented and lasts for two years, giving her the time and freedom to become accustomed to the leadership role.

ALTERNATIVE SYSTEM CONCEPT: INCOHERENT QUASI TIME-DOMAIN SPECTROSCOPY (IQTDS)

Although the terahertz technology has developed well beyond its infancy, not all technical options for implementing system concepts have been exhausted. In our efforts to minimize system costs, we recently realized a novel concept in the field of optical terahertz measuring systems that does not require a laser source. The initial results are very promising, so further testing and integration in measuring systems is expected soon. One patent has already been registered.

SHORTER EVALUATION, GREATER STABILITY

Very short measuring and evaluation times are essential when using measurement systems for inline quality control of production. A joint project between the Materials Characterization and Testing department and the CC High Performance Computing achieved great success in measuring coating thickness: The improved evaluation software enables evaluation times of less than 1 ms for four-layer coatings with commercially available notebooks. Originally, the evaluation time was in the second range. The parallel use of several sensors or the use of new measuring methods such as SLAPCOPS can significantly increase the measuring rate up to 1,000 thickness measurements per second.

Combined with better stability, the improvement in the measuring time allows real time evaluation of recorded signal data and creates the potential to open up further fields of application for terahertz measurement technology and to further expand the Materials Characterization and Testing department.

Front, left to right: Samuel Weber, Shiva Mohammadzadeh, Dr. Daniel Molter, Caroline Cappel, Nina Schreiner, Ute Rein-Rech, Dmytro Kharik, Oliver Boidol, Mirko Kutas, Michael Kocybik, Carsten Matheis, Prof. Dr. Georg von Freymann, Dr. Joachim Jonuscheit, Jens Klier, Marie-Therese Braun, Sebastian Bachtler, Stefan Weber, Andreas Keil, Ph.D., Claudia Busch-Crolly, Dr. Fabian Friederich, Björn Haase, Alexander Theis, Tobias Pfeiffer, Dominik Gundacker

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Master thesis, Bundeswehr University Munich, Dept. of Electrical Engineering and Information Technology

Bergner, Tim
Network Flows and Packing Problems with Bundle Constraints
Master thesis, University Kaiserslautern, Dept. of Mathematics

Biedinger, Christine
Automatic usage modeling for automotive applications
Doctoral thesis, University Kaiserslautern, Dept. of Mathematics

Boidol, Oliver
Digitale Phasenregelung eines Ultrakurzpuls-Lasers
Master thesis, University of Applied Sciences Konstanz, Dept. of Electrical Engineering and Information Technology

Diehl, Maximilian
Long Term Stability of the Balance Sheet of a Life Insurer
Master thesis, University Kaiserslautern, Dept. of Mathematics

Föhst, Sonja
3D Image Analysis of Capillary Vessels in Mouse Organs
Doctoral thesis, University Kaiserslautern, Dept. of Mathematics

Gilberg, Dominik
Continuum models for bi-disperse granular material flows capturing the process of size segregation
Doctoral thesis, University Kaiserslautern, Dept. of Mathematics

Hertrich, Christoph
Scheduling a Proportionate Flow Shop of Batching Machines
Master thesis, University Kaiserslautern, Dept. of Mathematics

Hofmann, Tobias
Phase-field methods for deformation and degradation processes in lithium-ion batteries
Doctoral thesis, University Kaiserslautern, Dept. of Mechanical and Process Engineering

Jouahri, Omar
Konzeptionierung, Aufbau und Programmierung eines vollautomatisierten Charakterisierungsaufbaus für Terahertz-Antennen
Master thesis, University of Applied Sciences Saarbrücken, Dept. of Engineering Sciences

Kranz, Robert
Positionsbestimmung mittels einer inertialen Messeinheit zur 3D-Terahertz-Bildgebung
Master thesis, University Kaiserslautern, Dept. of Mechanical and Process Engineering

Küsters, Ferdinand
Switch Observability for Differential-Algebraic Systems / Analysis. Observer Design and Application to Power Networks
Doctoral thesis, University Kaiserslautern, Dept. of Mathematics

Lehne, Niklas
Simulation und Modellierung nicht-Newtonschen Fluidverhaltens mit der Finite Pointset Method
Master thesis, University Kassel, Mathematics and Natural Sciences

May, Karl Henrik
Design, Setup and Characterization of an Electronic Teraherertz Measurement System Featuring Sensor Fusion
Diploma thesis, University Kaiserslautern, Dept. of Physics

Merkert, Dennis
Numerical Homogenization for Linear Elasticity in Translation Invariant Spaces
Doctoral thesis, University Kaiserslautern, Dept. of Mathematics

Pelz, Philipp
Verlässlichkeit von Regressionsgewichten bei der Modellanpassung von Fließbildsimulationen an Betriebsdaten
Master thesis, TU Berlin, Institute for Chemical and process engineering

Reinbold, Christian
Computation of the GITfan using a massively parallel implementation
Master thesis, University of Applied Sciences Konstanz, Dept. of Mathematics and Physics

Ritter, Juliane
Optimization of Distillation Systems
Master thesis, University Kaiserslautern, Dept. of Mathematics

Suchde, Pratik
Conservation and Accuracy in Meshfree Generalized Finite Difference Methods
Doctoral thesis, University Kaiserslautern, Dept. of Mathematics

Tien Ha Chu
Inspection Simulation Enhancement using Realistic Camera Model And Image Registration
Master thesis, University Kaiserslautern, Dept. of Computer Science

Yeromenko, Ivan
Nonparametric Estimation of the Spherical Granulometry Distribution
Master thesis, University Kaiserslautern, Dept. of Mathematics

TALKS

Ackermann, Heiner
Einschnittoptimierung im Sägewerk
GOR Tagung Entscheidungstheorie und Praxis, Kaiserslautern, March

Ackermann, Heiner; Diessel, Erik
Playing Dominos to Optimize Production Plans
OR 2018: International Conference on Operations Research, Brüssel (B), September

Ackermann, H.; Dinges, A.; Diessel, E.
Coping with hard problems in practice – An efficient algorithm for a packing problem in sawmills
13th Symposium on Future Trends in Service-Oriented Computing, Hasso-Plattner-Institut, Potsdam, April

Ackermann, Heiner; Ewe, Hendrik; Kopfer, Herbert; Schröder, Michael
Production Scheduling – Learning from other Industry Sectors
Intern. Workshop: "Mathematical Methods in Process Engineering: Digitization in the Chemical Industry", Kaiserslautern, September; Pro3-Seminar „Digital Methods in Product and Process Development", Kompetenznetz Verfahrenstechnik Pro3 e.V., Kaiserslautern, April

Andrä, Heiko
Direkte numerische Simulation von Materialeigenschaften auf 3D-Bilddaten von porösen Materialien und Verbundwerkstoffen
68. Heidelberger Bildverarbeitungsforum, 3D+ Bildanalyse und –visualisierung, Heidelberg, March

Andrä, H.; Hofmann, T.; Niedziela, D.; Rau, S.; Steiner, K.
Multi-scale simulation methods for bulk material handling of ceramic process
93. DKG-Jahrestagung und Symposium Hochleistungskeramik, Keynote Prozesssimulation, Messe München, April

Angermann, M.-C.; Meiers, D.; von Freymann, G.
A simple model mimicking the white beetles
EOS Topical Meeting on Waves in Complex Photonics Media, Anacapri (I), June

Angermann, M.-C.; Rothammer, M.; Zollfrank, C.; von Freymann, G.
Cellulose-based photoresist for Two-Photon-Lithography
DPG Frühjahrstagung 2018, Berlin, March

Angermann, M.-C.; Rothammer, M.; Zollfrank, C.; von Freymann, G.
Towards a cellulose-based photoresist
SPIE Photonics West 2018, San Francisco (USA), January/February

Asprion, Norbert; Ritter, Juliane; Böttcher, Roger; Bortz, Michael
Model-based Design of Experiments Using a Flowsheet-Simulator
28th European Society of Computer-Aided Process Engineering (ESCAPE), Graz (A), June

Aßmann, R.; Vogel, M.; Chumak, A. V.; Hillebrands, B.; von Freymann, G.
Spin-Wave Optics in Magnetization Landscapes
DPG Frühjahrstagung 2018, Berlin, March; Joint European Magnetic Symposia 2018; Mainz, September

Bauer, M.; Keil, A., Matheis, C., Jonuscheit, J., Moor, M.; Denman, D.; Bramble, J.; Savage, N., Friederich, F.
Volume Inspection Of Composite Structures In Aircraft Radomes With FMCW Terahertz Radar At 100 And 150 GHz
43rd International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW THz-2018), Nagoya (J), September

Bauer, Maris
Plasmonic and thermoelectric terahertz detection with broadband antenna-integrated alGan/Gan hEMts and graphene FEts
9. THz Frischlingetreffen, Kaiserslautern, March

Bauer, M.; Keil, A.; Matheis, C.; Jonuscheit, J., Moor, M.; Denman, D.; Bramble, J.; Savage, N.; Friederich, F.
Radome Inspection with FMCW Terahertz Radar at 100 and 150 GHz«
11. UK-Europa-China-Konferenz zu Millimeterwellen und Terahertz-Technologien UCMMT, Hangzhou (CHN), September

Boidol, Oliver
FPGa basierte Regelung eines ECOPS THz- TDS Systems
9. THz Frischlingetreffen, Kaiserslautern, March

Bortz, Michael
Aus anderen Branchen lernen: Beispiele für den industriellen Nutzen von Digitalisierungsansätzen
ERWAS - Anwenderworkshop H2Opt „Software zur Anlagenoptimierung bei Trinkwasserversorgung – Ergebnisse der Fördermaßnahme ERWAS, Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V., Dechema, Frankfurt, June

Bortz, Michael
Enhancing the efficiency of flowsheet simulation by surrogate models
Jahrestreffen der ProcessNet-Fachgemeinschaft "Prozess-, Apparate- und Anlagentechnik" PAAT 2018, Köln, November

Bortz, Michael
Experimental Design in a Multicriteria Optimization Context: An Adaptive Scheme
9th Vienna International Conference on Mathematical Modelling MathMod 2018, Wien, February

Bortz, Michael
Flowsheet simulation and optimization supported by machine learning methods
ProcessNet-Jahrestagung, Aachen, September

Bortz, Michael
From Data to Models, from Models to Data - a Mathematical Perspective
Summerschool für Reaktionstechnik und Katalytik, Dechema-Haus, Frankfurt, August

Bortz, Michael
Grey Box: Integration von Anwendungswissen in Lernverfahren
Fraunhofer-Symposium »Netzwert« 2018, München, February

Bortz, Michael
Supporting Flowsheet Simulation by Machine Learning
International Workshop: "Mathematical Methods in Process Engineering: Digitization in the Chemical Industry", Kaiserslautern, September

Bortz, Michael; Weiß, Horst
Digital Methods in Product Development at BASF
Pro3-Seminar „Digital Methods in Product and Process Development", Kompetenznetz Verfahrenstechnik Pro3 e.V., Kaiserslautern, April

Burger, Michael
Bayesian Road Roughness Estimation
5th European Conference on Computational Optimization - EUCCO 2018, Trier, September

Burger, Michael
Digitale Umgebungsdaten für die Fahrzeugentwicklung – Entwickeln, Testen und Prüfen von Fahrerassistenzsystemen unter Berücksichtigung realistischer Nutzungsszenarien
Workshop SCT2018 - Scientific Computing und Verkehr – Die Mobilität der Zukunft, Heidelberg, October

Burger, M.; Carlqvist, C.; Ekevid, T.; Steidel, S.; Weber, D.
Multiphysics Simulation of Construction Equipment
Commercial Vehicle Technology, Kaiserslautern, March

Burger, Michael; Speckert, Michael
Modellierung von Straßenunebenheiten als Anregung von Fahrzeugen
DVM Fortbildungsseminar 'Zuverlässigkeit und Probabilistik', Ingolstadt, November

Burger, Michael; Speckert, Michael
VMC® Geo Referenced Data for Vehicle Development
Kick-Off Workshop ASAM OpenSCENARIO, Kaiserslautern, November

Burger, M.; Speckert, M.; Dreßler, K.
Nutzungsspezifische Vorhersage von Beanspruchung und Energieverbrauch
SIMVEC – Simulation und Erprobung in der Fahrzeugentwicklung, Baden-Baden, November

Burger, Michael; Speckert, Michael; Müller, Roland; Weiberle, Daniel
Model-Based Identification Of Road Profiles and Road Roughness Indicators Using Vehicle Measurements
Commercial Vehicle Technology, Kaiserslautern, March

Calabrese, F.; Bäcker, M.; Gallrein, A.
Advanced methods for tire handling analysis, characterization and parameterization with CDTire
Tire technology EXPO 2018, Hannover, February

Calabrese, F.; Bäcker, M.; Gallrein, A.
How to handle the brunch of potential tire/wheel sizes in the early vehicle development process
Symposium SAE BRASIL de Testes e Simulações, Sao Paolo (BR), September

Calabrese, Francesco; Dusini, Luca; Bäcker, Manfred; Gallrein, Axel
Managing the variety of potential tire / wheel sizes in the early vehicle development process
International Munich Chassis Symposium, München, June; VI-grade Users Conference, Lainate (I), May

Cappel, Caroline
Schnelle cW-Terahertz-Schichtdickenbestimmung mit Hilfe einer GP-GPu
9. THz Frischlingetreffen, Kaiserslautern, March

Cesarek, Peter; Dörlich, Vanessa; Linn, Joachim; Diebels, Stefan
Modeling of inelastic bending of cables using constitutive laws for cosserat rods
6th European Conference on Computational Mechanics (ECCM 6); 7th European Conference on Computational Fluid Dynamics (ECFD 7), Glasgow (GB), June

Danielsson, P.-O.; Ekevid, T.; Kumar, M.; Rothmann, T.; Wilhelmsson, M.
Articulated Hauler Load Simulations
Commercial Vehicle Technology, Kaiserslautern, March

Dobrovolskij, D.; Schladitz, K.
Local 3D Fiber Orientation Analysis for Fiber Reinforced Composite Materials
4th International Congress on 3D Materials Science (3DMS 2018), Helsingør (DK), June

Diez, Franziska
The Evolution of Yield Curves in 2 Factor Hull White Models
ICA, World Congress of Actuaries, Berlin, June

Diller, Rolf; Hauth, Jan
Modelling and assessment of spectroscopic data by Bayesian estimation methods
BioComp-Symposium, Klostermühle Alsenz, December

Dobrovolskij, Dascha
Simulation of Ultrasound Scattering Effects in a Polycrystalline Titanium Based on 3D Full-field X-ray Microscopy
Materials Science and Engineering 2018. Darmstadt, September

Dreßler, K.; Pena Vina, E.; Rothmann, T.
Environmental Data for vehicle engineering - Pointcloud based scenarios
VI-grade Users Conference, Lainate (I), May

Ecke, N. C.; Höller, J.; Niedermeyer, J.; Klein, P.; Schlarb, A. K.
Simulation hybrider Tribocompounds mittels homogenisierter Materialmodelle
59. Tribologie-Fachtagung, Göttingen, September

Edelmann, B.; Menstell, P.; Ohser, J.; Osterroth, S.; Steiner, K.
Modeling and simulation of protein transport processes in chromatographic media using experiments and confocal laser scanning microscopy
ACHEMA, Frankfurt, June

Edelmann, B.; Menstell, P.; Ohser, J.; Osterroth, S.; Schwämmle, A.; Steiner, K.
Modeling and Simulation of Protein Transport Processes in Chromatographic Media
Mathematical methods in process engineering - digitization in the chemical industry, Kaiserslautern, September

Eifler, Matthias; Hering, Julian; von Freymann, Georg; Seewig, Jörg
3D printing of material measures for areal surface texture
SPIE Photonics Europe, Strasbourg (F), April

Eimer, M.; Borsche, R.; Siedow, N.
A local time stepping method for district heating networks
ECMI 2018, Budapest (Ungarn), June

Ellrich, F.; Klier, J.; Weber, S., Molter, D., Jonuscheit, J.; von Freymann, G.
Terahertz thickness determination for industrial applications: challenges and solutions
SPIE Photonics West 2018, San Francisco (USA), January/February

Ellrich, F.; Molter, D.; Jonuscheit, J.; von Freymann, G.
Fiber-coupled THz systems for industrial applications
SPIE Photonics West 2018, San Francisco (USA), January/February

Ettrich, Norman
High Performance Computing of Seismic Data
DGMK Workshop "Digital Oil Field, Where are we? Where are we going?", Hannover, November

Fend, Chiara; Moghiseh, Ali; Stephani, Henrike; Weibel, Thomas
Object Detection on Supermarket Shelves with a Deep Network
European Machine Vision Forum 2018 – EMVA, Bologna (I), September

Fraundorfer, W.; Kuhnert, J.; Pena Vina, E.; Weyh, T.
Auslegung von mobilen Schwimmbrücken und Arbeitsplattformen
Commercial Vehicle Technology, Kaiserslautern, March

Friederich, Fabian
Millimeter-wave imaging solutions for non-destructive testing
SPIE Photonics West 2018, San Francisco (USA), January/February

Friederich, Fabian
Non-destructive radome inspection
8th International ‚Workshop on Terahertz Technology and Applications, Kaiserslautern, March

Friederich, F.; May, K. H.; Baccouche, B.; Matheis, C.; Bauer, M.; Jonuscheit, J.; Moor, M.; Denman, D.; Bramble, J.; Savage, N.
Radome Inspection with Terahertz Waves
ECNDT 2018, Göteborg (S), June; 10th Internat. Symposium on NDT in Aerospace, Dresden, October

Gospodnetic, Petra
Inspection 4.0–Let's make it agile
European Machine Vision Association Business Conference, June

Gospodnetic, Petra
Understanding the World Through Images
UWC, Birkenfeld, January 2019

Gospodnetic, P.; Banesh, D.; Wolfram, P.; Petersen, M.; Hagen, H.; Ahrens, J.; Rauhut, M.
Ocean Current Segmentation at Different Depths and Correlation with Temperature in a MPAS-Ocean Simulation
IEEE VIS 2018, October

Gospodnetic, P.; Spies, M.; Rauhut, M.
Image based surface microgeometry modeling for complex surfaces
12th European Conference on Non-Destructive Testing (ECNDT 2018), Göteborg (S), June

Gottschalk, Simon; Burger, Michael
Reinforcement Learning in order to control biomechanical Applications
ECMI 2018 - The 20th European Conference on Mathematics for Industry, Budapest (H), June

Gramsch, Simone
Maschinelles Lernen in der Textilindustrie
Hofer Vliesstofftage, Hof, November

Gramsch, Simone
Simulation of spunbond and meltblown processes for filter media production
Filtech 2018, Köln, March

Gramsch, Simone; Kramer, Stephan
Modellierung und Simulation von Vliesstoffen und Batterien – Physik am Fraunhofer ITWM
jDPG Berufsvorbereitungsseminar, Mainz, October

Grindel, Ria
MLMC for stochastic delay differential equations in a biochemical setting

European Consortium for Mathematics in Industry (ECMI), Budapest (H), June

Heidgen, M.; Schneider, J.
Optimierung der ambulanten medizinischen Versorgung im ländlichen Raum (HealthFaCT)
GOR-Arbeitsgruppe „Health Care Management", Augsburg, February

Heller, Till
A combinatorial exchange model for the future electricity market
22nd Workshop on Future Research in Combinatorial Optimization FRICO 2018, Chemnitz, August

Helmling, M.; Ackermann, H.; Jami, N.; Schneider, J.; Küfer, K.-H.
Business Continuity Planning for Supply Chain Disruptions – How to assess the risk of catastrophic supply disruptions in a supply chain: A bi-objective modelling approach
OR 2018: International Conference on Operations Research, Brüssel (B), September

Hering, J.; Eifler, M.; Hofherr, L.; Ziegler, C.; Seewig, J.; von Freymann, G.
Two-photon laser lithography in optical metrology: calibration
SPIE Photonics West 2018, San Francisco (USA), January/February

Hering, J.; Waller, Erik H.; von Freymann, G.
Additive Manufacturing of Three-Dimensional Surfaces
MICOS 2018, Kaiserslautern, March

Hering, J.; Waller, Erik H.; von Freymann, G.
Three-dimensional µ-Printing: An enabling Technology
International Conference on Photo-Excited Processes and Applications, Vilnius (LT), September

Hietel, Dietmar; Andrä, Heiko; Arne, Walter; Steiner, Konrad
Modeling and simulation of glass fiber processes and composites
IGS 2018, Aachen, October

Hietel, D.; Arne, W.; Feßler, R.; Schnebele, J.; Wieland, M.
Fiber-Fluid Interaction: Modeling, Analysis, Simulation and Optimization
GFC 2018, Dornbirn (A), September

Hietel, D.; Iliev, O.; Manvelyan, D.; Mohring, J.; Shklyar, I.; Schmeißer, A.
Charakterisierung der Stochastik in Vliesstoffen und deren Einfluss auf seine funktionalen Eigenschaften
Symposium Textile Filter 2018, Chemnitz, April

Hietel, D.; Iliev, O.; Manvelyan, D.; Mohring, J.; Shklyar, I.; Schmeißer, A.
Study of the influence of the filter media heterogeneity on filter performance
Filtech 2018, Köln, March

Hinderks, Wieger
A structural Heath-Jarrow-Morton framework for consistent intraday, spot, and futures electricity prices
Commodity and Energy Markets Association Annual Meeting, Rom (I), 2018, June

Hinderks, Wieger
Pricing German Energiewende products: intraday cap/floor futures
International Ruhr Energy Conference, Essen, September

Hofmann, Tobias
Phase-Field Methods for Deformation Processes in Lithium-Ion Batteries
Promotionsvortrag, Kaiserslautern, January

Hofmann, T.; Zausch, J., Andrä, H.; Müller, R.
Electro-chemo-mechanical simulation of 3D-microstructures for lithium-ion batteries
15th Symposium on Modeling and Experimental Validation of Electrochemical Energy Devices MODVAL, Aarau (CH), April; European Conference on Computational Mechanics ECCOMAS, Glasgow (GB), June; Physics & Mechanics of Random Media: From Morphology to Material Properties, International Workshop in Honor of Dominique Jeulin, Ile d'Oleron (F), June

Hofmann, T.; Zausch, J.; Latz, A.; Biebl, F.; Glatt, I.; Wagner, C.
Battery analysis with BatteryDict and BEST
GeoDict User-Meeting, Nagoya (J), November

Hohmann, R.; Leithäuser, C.
Shape optimization of liquid polymer distributors
ECMI 2018, Budapest (H), June

Höller, Johannes
Adjusting substance property data in an industrial context
International Workshop: "Mathematical Methods in Process Engineering: Digitization in the Chemical Industry"

Horsky, Roman
Risikomanagement: Modellierung von Versicherungsprodukten
Symposium »Netzwert«, München, February

Iliev, Oleg
ExaDUNE: Flexible PDE Solvers, Numerical Methods and Applications: Toward exascale computation of UQ using MLMC
Invited talk RICAM Collquium, Linz (A), January

Iliev, O.; Prill, T.; Gavrilenko, P.
Reactive Flows in Porous Media: PoreChem Software Tool
Research seminar Corning, St. Petersburg, November; Kaiserslautern, September

Iliev, Oleg; Prill, Torben; Greiner, Robert; Votsmeier, Martin
Simulation of Filtration in a Catalytic Filter Wall
InterPore, New Orleans (USA), May

Iliev, O.; Prill, T.; Nessler, Katie; Printsypar, G.; Lakdawala, Z.; Greiner, R.; Votsmeier, M.; Mikelic, A.
On pore scale simulation of reactive flow
Invited talk Digital Core Workshop, Qingdao (CHN), July; Workshop Multiscale and Model Reduction Methods, Yakutsk (RUS), August; Digitalization in the chemical industry, Kaiserslautern, September

Iliev, Oleg; Prill, Torben; Printsypar, Galina; Nessler, Katie
Computational modeling of functionalized membranes' performance
Aachen Membrane Koloquium, Aachen, November

Iliev, Oleg; Vabishchevich, Petr
Computational identification of adsorption and desorption parameters for pore scale transport in periodic porous media
Multiscale methods and Large-scale Scientific Computing, Moscow (RUS), August

Jonuscheit, J.; Weber, S.; Klier, J.; Molter, D.; von Freymann, G.
Berührungslose, robotergestützte Schichtdickenmessung im industriellen Umfeld
DGZFP Jahrestagung, Leipzig, May

Jonuscheit, Joachim
Available Current Instrumentation for THz
European Microwave Week 2018, Madrid (E), September

Jonuscheit, Joachim
Bildgebende Verfahren zur Detektion von Gefahrstoffen
Seminar VS 10.06 Detektion von Explosivstoffen, CCG-Gesellschaft, Pfinztal, November

Jonuscheit, Joachim
Künftige Entwicklungen der Terahertz-Technik zur zerstörungsfreien Prüfung von Verbundmaterialien
DGZFP Seminar Zerstörungsfreie Prüfung an GFK und GFK-Klebeverbindungen, Wittenberge, August

Jonuscheit, Joachim
Schichtdickenmessung im industriellen Umfeld mittels Terahertz-Technik
18. Stuttgarter Branchentreff: Farbe – Lack – Oberfläche, Stuttgart, November

Jonuscheit, Joachim
Terahertz-Aktivitäten am Fraunhofer ITWM
DGZFP-Seminar, Fachausschuss Mikrowellen- und Terahertzverfahren, Würzburg, November

Jonuscheit, Joachim
Terahertz-Technik und Auswertemethoden zur Dickenmessung
220. Sitzung des DGZFP-Arbeitskreises, Stuttgart, February

Jonuscheit, Joachim
Zerstörungsfreie Prüfung keramischer Bauteile mit Terahertz-Messtechnik
Deutsche Keramische Gesellschaft DKG FA 3 "Verfahrenstechnik", Mettlach, May

Jonuscheit, J.; Klier, J.; Molter, D.; Weber, S.; von Freymann, G.
Contact-free, robot-assisted coating thickness measurement in the industrial environment
ECNDT 2018, Göteborg (S), June

Jörg, C.; Cherpakova, Z.; Letscher, F.; Dauer, C.; Schulz, J.; Eggert, S.; Fleischhauer, M.; Linden, S.; von Freymann, G.
Waveguides for Quantum Optics: 3D-Micro-Printing and Topological Insulators
Universidad Autonoma de Barcelona, Barcelona (E) Juni

Jörg, C.; Dauer, C.; Letscher, F.; Fleischhauer, M.; Eggert, S.; von Freymann, G.
Transitions between States in Topological Waveguide Systems by Local Time-Periodic Driving
Nanop 2018, Rom (I), October

Jörg, C.; Letscher, F.; Dauer, C.; Pelster, A.; Eggert, S.; Fleischhauer, M.; von Freymann, G.
Driving Transitions between States in Topological Systems
DPG Frühjahrstagung 2018, Erlangen, March

Jouahri, Oumar
Konzeptionierung, Aufbau und Programmierung eines vollautomatisierten Charakterisierungsaufbaus für Terahertz-Antennenmodule
9. THz Frischlingetreffen, Kaiserslautern, March

Kabel, Matthias
Poroelastic behavior of rocks using Digital Rock Physics
Computational Techniques and Applications Conference (CTAC 2018), Newcastle (AUS)

Kabel, Matthias; Frizen, Felix
Automatic derivation of material laws for simulating structural components
MOR Seminar, Stuttgart, February

Kabel, M.; Kirsch, R.; Osterroth, S.; Rief, S.
A Two-Scale Approach for the Computation of Flow through Pleated Filters based on Real Image Data
FILTECH 2018 Conference, Köln, March

Kabel, M.; Kirsch, R.; Osterroth, S.; Rief, S.; Staub, S.
A two-scale simulation approach for predicting the lifetime of pleated filters with embossing
GeoDict User Meeting 2018, Kaiserslautern, September

Kabel, M.; Kirsch, R.; Osterroth, S.; Rief, S.; Staub, S.
Including filter media heterogeneities in the simulation of filtration processes
AFS Filtcon, Prior Lake (US), April

Kabel, M.; Kirsch, R.; Osterroth, S.; Rief, S.; Staub, S.
Simulation of flow and filtration characteristics in consideration of production-related media deformation
European Conf. on Fluid Particle Separation FPS 2018, Lyon (F), October

Kabel, M.; Kirsch, R.; Osterroth, S.; Rief, S.; Staub, S.
Simulationsgestützte Standzeitanalyse von gefalteten Filtermedien mit inhomogener Materialverteilung
Jahrestreffen der ProcessNet-Fachgruppe „Mechanische Flüssigabtrennung", Merseburg, February

Kabel, M.; Köbler, J.; Fritzen, F.
Fast and Memory Effcient Two-Scale Simulations of Components by Combining Reduced Order Models and Composite Voxel on the Micro-Scale
6th European Conference on Computational Mechanics (ECCM 6), Glasgow (GB), June

Keil, Andreas; Friederich, Fabian
Quantification of Liquids with Terahertz Waves
43rd International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW THz-2018), Nagoya (J), September

Keil, A.; Schreiner, N. S.; Friederich; F.
Thickness Measurements with Multistatic Sparse Arrays
43rd International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW THz-2018), Nagoya (J), September

Keuper, Janis
Introduction to Deep Learning
Gastvortrag Fraunhofer IIS, February

Keuper, Janis
Large Scale ML on HPC Systems
Gastvortrag TU Dresden, May

Kirsch, R.; Osterroth, S.; Rief, S.
Build-up of internal cake in layered filtering media
Filtech, Köln, March

Kirsch, R.; Osterroth, S.; Rief, S.
Uniformity of media face velocity as an additional criterion for the computer-aided rating of pleated filters
FPS, Lyon (F), October

Klier, J.; Kharik, D.; Zwetow, W.; Gundacker, D.; Weber, S.; Molter, D.; Ellrich, F.; Jonuscheit, J.; von Freymann, G.
Four-channel terahertz time-domain spectroscopy system for industrial pipe inspection
43rd International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW THz-2018), Nagoya (J), September

Köbler, J.; Kabel, M.; Andrä, H.; Müller, R.; Schneider, M.; Staub, S.; Welschinger, F.
Efficient multiscale methods for viscoelasticity and fatigue of short fiber reinforced polymers
10th European Solid Mechanics Conference ESMC, Bologna (I), July

Köbler, J.; Welschinger, F.; Schneider, M.; Andrä, H.; Kabel, M.; Müller, R.
Efficient multiscale methods for computing the effective viscoelastic and fatigue response of short fiber reinforced thermoplastics
EUROMECH Colloquium 597 on Reduced Order Modeling in Mechanics of Materials, Bad Herrenalb, August

Kolano, M.; Boidol, O.; Molter, D.; Weber, S.; von Freymann, G.
Single-laser polarization-controlled optical sampling system for THz-TDS
43rd International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW THz-2018), Nagoya (J), September

Korn, Ralf
European Actuarial Journal
ICA, World Congress of Actuaries, Berlin, June

Korn, Ralf
Gemeinsam gegen das Risiko: Geschichte und Prinzipien der Versicherungsmathematik
Tag der Mathematik, Kaiserslautern, June

Korn, Ralf
Ist Altersvorsorge trotz Nullzins möglich?
Nacht, die Wissen schafft, Kaiserslautern, April

Korn, Ralf
Optimal Portfolios with Stress Scenarios: A Worst-Case Scenario Approach
ICA, World Congress of Actuaries, Berlin, June

Korn, Ralf
Yield Curves, Measure Transformation, and Applications in Chance-Risk Classification of German Pension Products
Hannover-Zürich-Workshop on Insurance Mathematics, Hannover, November

Kranz, Robert
Implementierung einer positionsmessenden Sensorik in ein Terahertz-Messsystem für die bildgebende Terahertz-Prüfung
9. THz Frischlingetreffen, Kaiserslautern, March

Krieg, Helene; Schwientek, Jan; Nowak, Dimitri; Küfer, Karl-Heinz
Optimal pump series design via semi-infinite programming
16. EUROPT Workshop on Advances in Continuous Optimization 2018, Almeria (E) Juli

Krüger, Jens
Cloud Nutzung am Fraunhofer ITWM–Praktische Erfahrungen: Nutzen–Spot Markt und Kosten –Sicherheit Verbindung von On Premise und Cloud Computing am Safeclouds.eu Beispiel
Arbeitskreis Strategie und Organisation des ZKI-Vereins, Berlin, November

Küfer, Karl-Heinz
Optimizing yields in gemstone cutting - mathematics as a driver of process innovation
GOR Tagung Arbeitsgruppe Optimierung, Regenstauf, April

Küfer, Karl-Heinz; Bortz Michael
Industrial Applications of Multicriteria Decision Support Systems
GOR Tagung Entscheidungstheorie und Praxis, Kaiserslautern, March; Dagstuhl-Seminar „Personalized Multiobjective Optimization: An Analytics Perspective", Wadern, January

Kuhnert, Jörg
MESHFREE simulations in fluid and continuum mechanics
NAFEMS CFD, Wiesbaden, November

Kuhnert, Jörg
MESHFREE simulations of fluid structure interaction
NAFEMS DACH, Bamberg, May

Kurnatowski, M. von; Meier, J.; Thonemann, N.; Babutzka, J.; Bortz, M.
Modeling, multi-criteria optimization and life cycle assessment in electrochemical process engineering
PAAT, Jahrestagung Process-Net-Fachgemeinschaft „Prozess-, Apparate- und Anlagentechnik, Köln, November

Küsters, Ferdinand
Switch observability for differential-algebraic systems
KI-Regelungstechnik, Kaiserslautern, March 2018

Labus, Peter
HP-DLF: Scalable Deep Learning for Supercomputers
High Performance Computing for AI (Workshop at Leibniz-Rechenzentrum), München, October

Laudage, Christian
Severity Modeling of Extreme Insurance Claims
European Actuarial Journal Conference, Leuven (B),September

Leithäuser, C.; Siedow, N.; Hübner, F.; Bazrafshan, B.; Vogl, T. J.
Experimental Validation of a Mathematical Model for Laser-Induced Thermotherapy
ECMI 2018, Budapest (H), June

Leithäuser, Neele
Multikriterielle Optimierung und Entscheidungsunterstützung in der Erntekettenlogistik
EULOG 2018: Fachtagung Entscheidungsunterstützung in der Logistik, Linz (A) October

Leoff, Elisabeth
Particle Filtering for Truncated Noise Densities
International Conference on Computational and Financial Econometrics, Pisa (I), December

Linn, Joachim
Dynamical Simulation of Human Motion in Car Assembly by Optimal Control of a Biomechanical Digital Human Multibody Model
Human Modeling and Simulation in Automotive Engineering, Berlin, October

Meier, C.; Durville, D.; Brüls, O.; Gerstmayr, J.; Linn, J.
Modeling and Discretization Approaches for Slender Continua and their Interaction
6th European Conference on Computational Mechanics (ECCM 6); 7th European Conference on Computational Fluid Dynamics (ECFD 7), Glasgow (GB), June

Mohammadzadeh, Shiva
Design of a Quasi-Optical Terahertz Line-Scanner
9. THz Frischlingetreffen, Kaiserslautern, March

Mohring, J.; Heidenbluth, M.; Brüggeman, T.
Effizienter FW-Betrieb durch dynamische Netzsimulation
AGFW-Symposium Zukunft Fernwärme, Kaiserslautern, March

Molter, Daniel
Berührungslose Schichtdickenmessung im industriellen Umfeld mit Terahertz-Messtechnik
11. Fraunhofer Vision-Technologietag, Jena, October

Molter, Daniel
Vibration compensation for layer thickness measurements in industrial environments
8th International ,Workshop on Terahertz Technology and Applications, Kaiserslautern, March

Molter, D.; Weber, S.; Pfeiffer, T.; Klier, J.; Bachtler, S.; Ellrich, F.; Jonuscheit, J.; von Freymann, G.
Interferometry-aided terahertz time-domain spectroscopy for robust measurements in reflection
43rd International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW THz-2018), Nagoya (J), September

Müller, O.; Moghiseh, A.; Stephani, H.; Rottmayer, N.; Huang, F.
Application of Deep Learning for Crack Segmentation on Concrete Surface
Forum Bildverarbeitung, Karlsruhe KIT und Fraunhofer IOSB, November

Muttray, A.; Reinhard, R.; Rutrecht, H.; Hengstenberg, P.; Tutulmaz, E.; Geißler, B.; Hecht, H.
Simulatorkrankheit: Diagnostik, Auswirkungen auf das Leistungsvermögen und Gegenmaßnahmen bei schlafmedizinischen Untersuchungen
Wissenschaftliches Symposium „Fahrsimulation in der Schlafmedizin – ein Update für Forschung und Praxis", 26. Jahrestagung der Deutschen Gesellschaft für Schlafforschung und Schlafmedizin (DGSM), Nürnberg, October

Muttray, A.; Reinhard, R.; Rutrecht, H.; Hengstenberg, P.; Tutulmaz, E.; Geißler, B.; Hecht, H.
Zur Wirkung von Simulatorkrankheit auf die Reaktionszeit bei PKW-Fahrsimulationen
58. Wissenschaftliche Jahrestagung 2018 der deutschen Gesellschaft für Arbeitsmedizin und Umweltmedizin e.V. (DGAUM), München, March

Nowak, Dimitri
Multicriteria optimization in the water distribution sector
OR 2018: International Conference on Operations Research, Brüssel (B), September; International Workshop: "Mathematical Methods in Process Engineering: Digitization in the Chemical Industry"

Nowak, D.; Krieg, H.; Bortz, M.
Surrogate Models for the Simulation of Complex Water Supply Networks
CCWI-WDSA 2018, Kingston, Ontario (CDN), July

Obentheuer, Marius; Roller, Michael; Björkenstam, Staffan; Berns, Karsten; Linn, Joachim
Comparison of different actuation modes of a biomechanical human arm model in an optimal control framework
Internat. Conference on Multibody System Dynamics, Lissabon (P), June

Ohser, Joachim; Schladitz, Katja
Mikrostrukturanalyse anhand von 3D-Bilddaten
68. Bildverarbeitungsforum, 3D+ Bildanalyse und -visualisierung, Heidelberg, March

Pena Vina, E.; Kleer, M.; Dreßler, K.
Virtual validation of autonomous vehicles in a 3D Pointcloud
SIMVEC – Simulation und Erprobung in der Fahrzeugentwicklung, Baden-Baden, November

Pfreundt Franz-Josef
Memory Driven Computing
HPC Summit Ljubliana (SLO)

Pfreundt, Franz-Josef
BeeGFS & BeeOND – Use Case Examples & Mapping Capabilities to Customer Requirements
HP CAST 30, Frankfurt, June

Pfreundt, Franz-Josef
BeeGFS & BeeOND – Use Cases and Examples
HP CAST 31, Dallas, November

Pfreundt, Franz-Josef
Deep Learning on HPC Systems
HPC Statustagung, October

Phutane, U.; Roller, M.; Björkenstam, S.; Leyendecker, S.
Investigating human thumb models via their range of motion volumes
GAMM, Wien (A), January

Phutane, U.; Roller, M.; Leyendecker, S.
Optimal control simulations of two finger grasping
GAMM, Wien (A), February

Rahn, Mirko
A directory/cache for leveraging the efficient use of distributed memory by task-based runtime systems
EASC2018, Edinburgh, April 2018

Rahn, Mirko
Abstract memory for task based systems – Attempts, limitations, learnings

Intertwine Exascale Application Workshop, Edinburgh, April

Rahn, Mirko
GASPI – Scaling in Dynamic Environments
SIAM PP18, Tokyo (J), March

Rein, Markus; Mohring, Jan
Stability preserving model order reduction for district heating networks
ECMI 2018, Budapest (H), June

Reinhard, René; Faust-Christmann, Corinna; Lachmann, Thomas
Preconditions for virtual reality avatar effects on real life behavior
51st Conference of the German Society for Psychology (DGPs), Frankfurt a. M., September

Reinhard, R.; Kleer, M.; Dreßler, K.
Effects of Individual Reactions to Driving Simulators on Emergency Braking Reaction Times
DSC, Antibes (F), September

Reinhard, R.; Kleer, M.; Dreßler, K.
The role of individual reactions to driving simulators in the design of simulator studies
4th Symposium Driving Simulation SDS, Kaiserslautern, November

Roldan, D.; Godehardt, M.; Höhn, S.; Redenbach, C.; Schladitz, K.
Reconstruction of porous structures from FIB-SEM: influence of image resolution
Materials Science and Engineering 2018. Darmstadt, September

Rösch, Ronald
Blick über den Tellerrand der klassischen Oberflächeninspektion
Seminar Inspektion und Charakterisierung von Oberflächen mit Bildverarbeitung, Karlsruhe, December

Rösch, Ronald
Innovative Verfahren zur Inspektion von industriellen Oberflächen
11. Fraunhofer Vision Technologietag, Jena, October

Rotaru, Tiberiu
Application Example Running on Top of GPI-Space Integrating D/C
Intertwine Exascale Application Workshop, Edinburgh (GB), April

Rothammer, M.; Zollfrank, C.; Heep, M.-C.; von Freymann, G.
A Cellulose-Based Photoresist for Direct Laser Writing
Materials Science & Engineering, MSE, Darmstadt, September

Sandmann, K.; Leyendecker, T.; Burger, M.; Speckert, M.
Ableitung von feldrelevanten Lastkollektiven mittels Stochastischer Verkehrssimulation
DVM – Effiziente Auslegung und Absicherung in der Betriebsfestigkeit, Stuttgart, September

Sarishvili, Alex
Maschinelles Lernen für die Charakterisierung und Visualisierung der Mehrkanal-EEG-Signale frühgeborenen Kinder
Tagung rlp_vernetzt ERLEBNIS KI, Kaiserslautern, August

Scherpelz, M.; Plieske, M.; Gottwald, A.; Halfmann, T.; Weyh, T.
Einsatz von virtuellen Messkampagnen bei der Getriebeentwicklung
Commercial Vehicle Technology, Kaiserslautern, March

Schladitz, K.; Prill, T.; Redenbach, C.; Roldan, D.; Godehardt, M.; Höhn, S.; Kühnert, J.-T.
Multi-scale analysis, modelling, and simulation of a nano-porous membrane
Physics and mechanics of random structures: from morphology to material properties, International workshop in honor of Dominique Jeulin, Île d'Oléron (F), June

Schneider, Fabio; Linn, Joachim
Simulation-based load data analysis for cables and hoses in vehicle assembling and operation
Commercial Vehicle Technology, Kaiserslautern, March

Schneider, F.; Linn, J.; Dreßler, K.
Virtual assembly of slender flexible structures in automotive engineering
Workshop on "Math for the Digital Factory", Limerick (IRL), March

Schneider, F.; Bilger, F.; Linn, J.; Dreßler, K.
Digitale Absicherung und simulationsbasierte Lastdaten dynamisch beanspruchter Hochvoltleitungen
SIMVEC - Simulation und Erprobung in der Fahrzeugentwicklung, Baden-Baden, November

Schneider, Johanna
HealthFaCT: Optimization of medical care in rural environments
IBOSS-ECMath Workshop, Berlin, October

Schneider, Johanna
Simulationgestützte Standortoptimierung am Beispiel der Rettungswache Nierstein
GOR Tagung AG "Health Care Management", Augsburg, February

Schneider, J.; Schröder, M.
Simulation-based location optimization of ambulance stations
OR 2018: International Conference on Operations Research, Brüssel (B), September

Schreiner, Nina
High-resolution FM cW Millimeter-Wave and terahertz thickness Measurements
9. THz Frischlingetreffen, Kaiserslautern, March

Schreiner, N., Sauer-Greff, W.; Urbansky, R.; Friederich, F.
Multilayer Thickness Measurements Below the Rayleigh Limit Using FMCW Millimeter and Terahertz Waves
Kleinheubacher Tagung, Miltenberg, September

Schreiner, N.; Sauer-Graff, W.; Urbansky, R.; Friederich, F.
Multilayer thickness inspection with millimeter-waves
SPIE Photonics West 2018, San Francisco (USA), January/February

Schreiner, N.; Sauer-Graff, W.; Urbansky, R.; Friederich, F.
All-electronic High-resolution Terahertz Thickness Measurements
43rd International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW THz-2018), Nagoya (J), September

Schröder, M.; Schneider, J.
Simulationsgestützte Optimierung von Rettungswachenstrukturen
33. Notfallmedizinische Jahrestagung der agswm, Baden-Baden, March

Schwientek, Jan
Optimization of Distillation Sequences
Internat: Workshop: "Mathematical Methods in Process Engineering: Digitization in the Chemical Industry"

Seidel, Tobias
Wie trifft man Entscheidungen, wenn man gar nicht weiß, was man will?
Fraunhofer Talent Take Off – Vernetzen, Femtec, Berlin, May

Siedow, N.; Leithäuser, C.
Mathematical Modeling for Laser-Induced Thermotherapy in Liver Tissue
ECMI 2018, Budapest (H), June

Siedow, N.; Leithäuser, C., Hübner, F.; Bazrafshan, B.; Vogl, T. J.
MR Thermometrie und Simulation bei ablativen Verfahren
19. Frankfurter Interdisziplinäres Symposium für Innovative Diagnostik und Therapie, Frankfurt/Main, September

Speckert, M.; Lübke, M.; Wagner, B.; Anstötz, T.; Haupt, C.
Representative Road Selection and Route Planning for Commercial Vehicle Development
Commercial Vehicle Technology, Kaiserslautern, March

Staub, Sarah; Andrä, Heiko; Orlik, Julia; Steiner, Konrad
Simulative Charakterisierung technischer Textilien – Anwendungspotenziale für Smart Textiles und Drucktechnologien
Digitaldruck zur Funktionalisierung textiler Materialien, Bayern Innovativ, Nürnberg, November

Staub, S.; Andrä, H.; Rief, S.
Microstructural modeling and simulation of heat transfer in wood fiber based insulating materials
International Conference on Porous Media, New Orleans (USA), May

Staub, S.; Orlik, J.; Andrä, H:
Computational Homogenization for Embossing of Thin Fibrous Structures based on FEM-FFT Coupling

TEACHING ACTIVITIES

World Congress of Computational Mechanics, New York (USA), July

Straßel, Dominik; Keuper, Janis
Carme – An Open Source Framework for Multi-User, Interactive Machine Learning on Distributed GPU-Systems
ISC High Performance, Frankfurt, June; High Performance Computing for AI (Workshop at Leibniz-Rechenzentrum), München, October

Suchde, Pratik
A Meshfree Generalized Finite Difference Method for Surface PDEs
7th Conference on Finite Difference Methods: Theory and Applications, Lozenetz (BG), June; 13th World Congress on Computational Mechanics (WCCM2018), New York (USA), July

Suchde, Pratik
Conservation and Accuracy in Meshfree Generalized Finite Difference Methods
Verteidigung Promotion, Kaiserslautern, February

Suchde, Pratik
Meshfree Methods for Fluid Flows and Surfaces.
University of Luxembourg, September

Teichert, K.; Süss, P.; Walczak, M.
Targeted multi-criteria optimization in IMRT/VMAT planning using knowledge based model creation
EURO 2018, Valencia (E), July

Telatar, E.; Reinhard, R.; Humayoun, S.; Ebert, A.; Lachmann, T.
Comparison of Object Perception in Head Mounted Display and in Desktop Monitor for Congruent and Incongruent Environments
60. Tagung experimentell arbeitender Psychologen TeaP

Theis, Alexander
Design and optimization of an FMCW Terahertz system for thickness measurements and imaging applications
9. THz Frischlingetreffen, Kaiserslautern, March

Vogel, M.; Chumak, A.V.; Aßmann, R.; Waller, E.H.; Langner, Vasychuka, P., Hillebrands, B.; von Freymann, G.
Spin-wave control in optically induced thermal gradients
Core-to-Core, Kaiserslautern, May; Nano-Magnonics, Kaiserslautern, February

von Freymann, Georg
3D µ-printing: An enabling technology
Technion, physics colloquium, Haifa (ISR), April

von Freymann, Georg
3D printed photonic quantum simulators
SPIE Photonics Europe, Strasbourg (F), April

von Freymann, Georg
Terahertz Applications
P&G Ignite Days, Kronberg, January

von Freymann, Georg
Wave-transport in optically induced materials
MRS Spring Meeting, Phoenix (USA), April

Wagner, Andreas
Chancen-Risiko-Klassifizierung von Altersvorsorgetarifen
Versicherungsforum, Köln, March

Wagner, Andreas; Oktoviany, Prilly
A stochastic price model for the German secondary balancing power market
Commodity and Energy Markets Association Annual Meeting, Rom, June; 6th Internat. Symposium on Environment and Energy Finance Issues (ISEFI), Paris (F), May; European Consortium for Mathematics in Industry (ECMI), Budapest, June

Walczak, M.; Heese, R.; Seidel, T.; Bortz, M.
Chemical process design aided by grey-box modelling
EURO 2018, Valencia (E), July

Waller, E. H.; von Freymann, G.
Direct laser written metal and metal-composite micro-structures
SPIE Photonics Europe, Straßburg (F), April

Waller, Erik H.; von Freymann, Georg
Metal- and Metal-composite microstructures via direct laser writing
SPIE Photonics West 2018, San Francisco (USA), January/February

Weiss, C.; Ackermann, H.; Hertrich, C.; Heydrich, S.; Krumke, S.
Planning Modern Pharmaceutical Production
OR 2018: International Conference on Operations Research, Brüssel (B), September

Wieland, M.; Arne, W.; Feßler, R.; Marheineke, N.; Wegener, R.
On Dry Spinning Processes In Airflows
ECMI 2018, Budapest (H), June

Wirsen, Andreas
Mathematische Modellierung in den Lebenswissenschaften: Anwendungsbeispiele aus Medizin und Biotechnologie
9. Biotech-Tag der TH Bingen, Bingen, October

Wortel, Pascal
Robust buffer allocation using a network flow based algorithm
EURO 2018, Valencia (E), July

Wortel, Pascal; Helmling, Michael; Velten, Sebastian; Weiss, Christian
Scheduling with Prefabrications
OR 2018: International Conference on Operations Research, Brüssel (B), September

Zausch, Jochen
Battery models and simulations for computer-aided electrode and cell design
IQPC Conference "Battery Cell Technology for EVs", Berlin, December

Zausch, J.; Hofmann, T.; Latz, A.
Advanced Battery Simulation Cases with the „Battery and Electrochemistry Simulation Tool" BEST
GeoDict User-Meeting 2018, Kaiserslautern, September

Andrä, Heiko
Kontaktmechanik
University Kaiserslautern, Winter term 2018/19

Andrä, Heiko
Höhere Mathematik in der Anwendung
DHBW CAS, Summer term 2018 und Winter term 2018/19

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

Bortz, Michael
Datenauswertung und Versuchsplanung
University Kaiserslautern, Summer term 2018

Bortz, Michael
Modellierung, Simulation und Optimierung in der Verfahrenstechnik
University Kaiserslautern, Winter term 2018/19

Burger, Michael
Optimal Control of ODEs and DAEs
University Mannheim, Winter term 2018/19

Dreßler, Klaus
Durability Load Data Analysis
University Kaiserslautern, Summer term 2018

Friederich, Fabian
Millimeterwellen und Terahertz Technologien
University Kaiserslautern, Summer term 2018, Winter term 2018/19

Kabel, Matthias
Analysis 1 für Wirtschaftsingenieure
University of Applied Sciences Kaiserslautern, Winter term 2018

Kabel, Matthias
Analysis 2
University of Applied Sciences Kaiserslautern, Summer term 2018

Kleer, Michael
Robotik 1
University of Applied Sciences Kaiserslautern, Winter term 2017/18, Summer term 2018

PARTICIPATION IN FAIRS AND CONFERENCES

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

Küfer, Karl-Heinz
Theory of Scheduling Problems
University Kaiserslautern, Summer term 2018

Küfer, Karl-Heinz
Probability and Algorithms
University Kaiserslautern, Winter term 2018/19

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

Rau, Sebastian
CAE
Baden-Wuerttemberg Cooperative State University (DHBW) – Center for Advanced Studies (DHBW CAS), Summer term 2018

Rau, Sebastian
Simulationstechnik
Baden-Wuerttemberg Cooperative State University (DHBW), Mannheim

Schöbel, Anita
Professur für Angewandte Mathematik
University Kaiserslautern, Dept. of Mathematics

Staub, Sarah; Andrä, Heiko
Höhere Festigkeitslehre und Werkstoffmechanik
Baden-Wuerttemberg Cooperative State University (DHBW) – Center for Advanced Studies (DHBW CAS), Summer term 2018

Steidel, Stefan
Analysis 3
University of Applied Sciences Kaiserslautern, Winter term 2018/19

von Freymann, Georg
Professur für Optische Technologien und Photonik
University Kaiserslautern, Dept. of Physics

Aachen Membrane Koloquium
Aachen, November, Lecture

AC² user meeting
Garching, November, Lecture

ACHEMA 2018
Frankfurt/M., June, Exhibitor, Lecture

AFS-Filtcon
Prior Lake (USA), April, Lecture

AGFW-Symposium
Kaiserslautern, March, Lecture

AnugaFoodTec
Köln, March, Exhibitor

Auftaktveranstaltung Offene Digitalisierungsallianz Pfalz
Kaiserslautern, August, Exhibitor

bonding Firmenkontaktmesse
Kaiserslautern, November, Exhibitor

carhs – Human Modeling and Simulation in Automotive Engineering
Berlin, October, Lecture

chassis.tech plus 2018
München, June, Lecture

Control 2018
Stuttgart, May, Exhibitor

Core-to-Core
Kaiserslautern, May, Lecture

DGZfP Jahrestagung
Leipzig, May, Lecture

DGZFP Seminar Zerstörungsfreie Prüfung an GFK und GFK-Klebeverbindungen
Wittenberge, August, Lecture

Digital Core Workshop
Qingdao (CHN), July, Lecture

DPG Frühjahrstagungen 2018
Erlangen, Berlin, March, Lecture

DSC 2018 Driving Simulation Conference
Antibes (F), September, Lecture

EAGE 2018
Kopenhagen (DK), June, Exhibitor, Lecture

ECCOMAS – ECCM – ECFD
Glasgow (GB), June, Lecture

ECMI
Budapest (H), June, Lecture

ECNDT 2018
Göteborg (S), June, Lecture, Poster

ees – Part of The Smarter E Europe 2018
München, June, Exhibitor

21. Energietag Rheinland-Pfalz
Bingen, August, Exhibitor

Energy Storage Europe
Düsseldorf, March, Exhibitor

EOS Topical Meeting on Waves in Complex Photonics Media
Anacapri (I), June, Lecture

EUCCO – European Conference on Computational Optimization
Trier, September, Lecture

EUROMECH Colloquium 597 on Reduced Order Modeling in Mechanics of Materials
Bad Herrenalb, August, Lecture

6th European Conference on Computational Mechanics ECCOMAS
Glasgow (GB), June, Lecture

European Conference on Fluid Particle Separation FPS 2018
Lyon (F), October, Lecture

European Microwave Week 2018
Madrid (E), September, Lecture

10th European Solid Mechanics Conference – ESMC
Bologna (I), July, Lecture

European Symposium on Computer Aided Process Engineering – ESCAPE 28
Graz (A), June, Lecture

E-World Energy & Water 2018
Essen, February, Exhibitor

8. Fachtagung Smart Grids und Virtuelle Kraftwerke
Wanderath, March, Exhibitor

Filtech
Köln, March, Exhibitor, Lecture, Poster

FISI 2018
Frankfurt/M., September, Lecture

Forschung in Kaiserslautern: Ein Blick in die digitale Zukunft
Kaiserslautern, October, Exhibitor

Fraunhofer-Symposium »Netzwert« 2018
München, February, Lecture

Fraunhofer-Vision Technologietag
Jena, October, Exhibitor, Lecture

GAMM
München. March, Lecture

GeoDict User Meeting
Kaiserslautern, September, Lecture

Global Fibers Congress
Dornbirn, September, Lecture

Gordon Research Conference: Flow and Transport in Permeable Media
Newry (USA), July, Poster

Hannover Messe
Hannover, April, Exhibitor

Hofer Vliesstofftage
Hof, November, Exhibitor, Lecture

HP CAST 30
Frankfurt/M., June, Lecture

HP CAST 31
Dallas (USA), November, Lecture

ICA – World Congress of Actuaries 2018
Berlin, June, Lecture

IFAC Symposium on Control in Transportation Systems
Savona (I), June, Lecture

IMSD 2018 – International Conference on Multibody System Dynamics
Lissabon (P), June, Lecture

IMSE – 15th International Conference on Integral Methods in Science and Engineering
Brighton (GB), August, Lecture

3rd International Advanced School on Magnonics
Kiew (UA), September, Poster

43rd International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW THz-2018)
Nagoya (J), September, Lecture

AWARDS AND PRIZES

International Conference on Photo-Excited Processes and Applications
Vilnius (LT), September, Lecture

International Glass Fiber Symposiums
Aachen,October, Lecture

10th International Symposium on NDT in Aerospace
Dresden, October, Lecture

12th International Topical Meeting on Nuclear Reactor Thermal-Hydraulics, Operation and Safety (NUTHOS-12)
Qingdao (CHN), October, Lecture

8th International Workshop on Terahertz Technology and Applications
Kaiserslautern, March, Exhibitor, Lecture, Poster

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

InterPore
New Orleans (USA), May, Lecture

IQPC Conference „Battery Cell Technology for EVs"
Berlin, December, Lecture

ISC High Performance 2018
Frankfurt/M., June, Exhibitor, Lecture

Jahrestreffen der ProcessNet-Fachgruppe „Mechanische Flüssigabtrennung"
Merseburg, February, Lecture

Joint European Magnetic Symposia 2018
Mainz, September, Lecture

Kleinheubacher Tagung
Miltenberg, September, Lecture

MACSI – Math for the Digital Factory
Limerick (IRL), March, Lecture

Mathematical methods in process engineering – Digitization in the chemical industry
Kaiserslautern, September, Lecture

MICOS 2018
Kaiserslautern, March, Lecture

ModVal 2018
Aarau (CH), April, Poster

MRS Spring Meeting
Phoenix (USA), April, Lecture

MSE 2018 – Materials Science & Engineering
Darmstadt, September, Lecture

Multiscale methods and Large-scale Scientific Computing
Moscow (RUS), August, Lecture

Nano-Magnonics Workshop 2018
Diemerstein, February, Lecture, Poster

Nanop 2018
Rom (I), October, Lecture

Okinawa Summerschool
Okinawa (J), September, Poster

P&G Ignite Days
Kronberg, January, Lecture

ProZell Industrietag
Frankfurt/M., September, Poster

rlp_vernetzt Zukunftsmesse — ERLEBNIS KI
Kaiserslautern, August, Exhibitor, Lecture

SAE – Simpósio SAE BRASIL de Testes e Simulações
Sao Paolo (BR), September, Lecture

SC 18 – Supercomputing 2018
Dallas (USA), November, Exhibitor

SDS – 4th Symposium Driving Simulation SDS
Kaiserslautern, November, Exhibitor, Lecture

SEG International Exposition 2018
Anaheim (USA), October, Exhibitor

SES 2018
Madrid, October, Lecture

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

SPIE Optics&Photonics
San Diego (USA), August, Poster

SPIE Photonics Europe
Straßburg (F), April, Lecture

SPIE Photonics West 2018
San Francisco (USA), January/February, Lecture

15th Symposium on Modeling and Experimental Validation of Electrochemical Energy Devices MODVAL
Aarau (CH), April, Lecture

Symposium Textile Filter
Chemnitz, April, Exhibitor, Lecture

Tag der Mathematik
Kaiserslautern, June, Exhibitor

45. Tagung des DVM-Arbeitskreises Betriebsfestigkeit: Effiziente Auslegung und Absicherung in der Betreibsfestigkeit
Ingolstadt, November, Lecture

Technion physics colloquium
Haifa (IL), April, Lecture

9. Terahertz-Frischlingetreffen
Kaiserslautern, March, Lecture, Poster

Tire Technology Expo 2018
Hannover, February, Lecture

ToCoTronics 2018
Würzburg, July, Poster

11. UK-Europa-China-Konferenz zu Millimeterwellen und Terahertz-Technologien UCMMT
Hangzhou (CHN), September, Lecture

Universidad Autonoma de Barcelona
Barcelona (E) June, Lecture

VI-grade Users Conference
Lainate (I) Mai, Exhibitor, Lecture

Workshop Multiscale and Model Reduction Methods
Yakutsk (RUS), August, Lecture

fleXstructures GmbH gemeinsam mit Bereich Mathematik für die Fahrzeugentwicklung
SUCCESS 2018 – Technologiepreis
Investitions- und Strukturbank Rheinland-Pfalz (ISB) und Ministerium für Wirtschaft, Verkehr, Landwirtschaft und Weinbau Rheinland-Pfalz
November

Grau, Tobias
Jahrgangsbester im Ausbildungsberuf »Fachinformatiker Fachrichtung Systemintegration«
IHK Pfalz
November

Obermayr, Martin; Dreßler, Klaus; Vrettos, Christos; Eberhard, Peter
Outstanding Paper Award 2018
Computers and Geotechnics
April

Osterroth, Sebastian
Fraunhofer ICT Group Dissertation Award (3. Preis)
Fraunhofer-Verbund IUK-Technologie
September

Schunk, Dominic
Preis für herausragende Leistungen in der Berufsausbildung
IHK Pfalz
November

ThinkParQ GmbH gemeinsam mit BeeGFS-Gruppe des Competence Center High Perfomance Computing
HPCwire Best HPC Storage Product or Technology Award anlässlich der Supercomputing 2018 für »Paralleles Dateisystem BeeGFS«
HPCwire
November

von Freymann, Georg
Landespreis für junge Unternehmen in Baden-Württemberg mit der Firma Nanoscribe (1. Preis)
Land Baden-Württemberg
November

von Freymann, Georg; Molter Daniel; Klier, Jens; Weber, Stefan
3. Preis Die Oberfläche: Dickenmessung von Lackschichten mit Terahertz-Strahlung
Fraunhofer IPA
June

OWN EVENTS

AGFW-Symposium Zukunft Fernwärme
Kaiserslautern, March

Career Night mit Fraunhofer _ Escape-Room
Kaiserslautern, December

Festakt zum Auftakt der 2. Phase des Leistungszentrums »Simulations- und Software-basierte Innovation«
Kaiserslautern, April

Gaspi Tutorial
HLRS, July; LRZ, May

GaspiLS Tutorial
AAC Nanjing (CHN), November

Gesundheitstag
Kaiserslautern, August

Herbstschule und Themenkonferenz der Felix-Klein-Akademie
Kaiserslautern, September

International Science Campus for Women
gemeinsam mit Fraunhofer-Zentrale, Kaiserslautern, March

International Workshop »Mathematical Methods in Process Engineering: Digitization in the Chemical Industry«
Fraunhofer ITWM, Kaiserslautern, September

8th International Workshop on Terahertz Technology and Applications
Fraunhofer ITWM, Kaiserslautern, March

5. Internationales Commercial Vehicle Technology Symposium
Kaiserslautern, March

Intertwine Application Workshop
Edinburgh, April

KL-Regelungstechnik: Seminarreihe zu Regelungsthemen, mathematischen Methoden und technische Umsetzung
Kaiserslautern, ganzjährig, einmal im Monat

Mathe-Camp des Felix-Klein-Zentrums für Mathematik
Kaiserslautern, March

Moderne Methoden im Machine Learning/Deep Learning
Diverse Orte, Feb, March, April, July, October, November

Nacht, die Wissen schafft
Kaiserslautern, April

Pro3-Seminar: Digital Methods in Product and Process Development
Kaiserslautern, April

Seminar Einführung in maschinelles Lernen in der Verfahrenstechnik
Kaiserslautern, November

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

Seminar: Statistische Methoden in der Betriebsfestigkeit
Kaiserslautern, July

Strategisches Netzwerktreffen mit Alumniveranstaltung
Kaiserslautern, December

Symposium »Emma-CC – Digitale Menschmodellierung für ergonomische Arbeitsplätze«
Kaiserslautern, April

Talent School der Felix-Klein-Akademie
Kaiserslautern, August

9. Terahertz-Frischlingetreffen
Fraunhofer ITWM, Kaiserslautern, March

Workshop »Optimal stopping in radiation therapy«
Kaiserslautern, May

Workshop 3D FIB-SEM Imaging & Analysis
Karlsruhe, KIT Campus Nord

Workshop: Abrechnungsbetrug in der ambulanten Pflege – Schadenshochrechnung in »R«
GKV-Spitzenverband, Berlin, November

Workshop: Altersvorsorge Vergleichsrechner
Kaiserslautern, May

Young Researchers Symposium
gemeinsam mit Innovationszentrum Applied System Modeling for Computational Engineering (ASM-4CE) und TU-Nachwuchsring, Kaiserslautern, June

Lecture series »Blick über den Tellerrand«
Fraunhofer-Zentrum Kaiserslautern

Pohl, Walter
Universität Wien
Was können wir von der Völkerwanderung lernen?
January

Amunts, Katrin
Universität Düsseldorf
Gehirn, Computer und Erkenntnis
February

Kreiter, Sebastian
TRON gGmbH Mainz
Neuer Therapieansatz: Impfstoffe gegen Krebs
March

Buhlmann, Britta
Museum Pfalzgalerie Kaiserslautern (mpk)
Physiognomien mit Geschichte
April

Friauf, Eckhard
TU Kaiserslautern
Wie Neurobiologen helfen, unser Gehirn besser zu verstehen
May

Seefried, Elke
Universität Augsburg
Zukünfte. Eine Geschichte der Zukunftsforschung
June

Sonar, Thomas
TU Braunschweig
Der Prioritätsstreit zwischen Leibniz und Newton
August

Preckel, Franzis
Universität Trier
Hochbegabung: Grundlagen und neue Forschungsergebnisse
September

Kusch, Martin
Universität Wien
Ist Wissen relativ? Eine Einleitung in den Relativismus
October

Tetens, Holm
Freie Universität Berlin
Verträglichkeit/Unverträglichkeit von Schöpfungsglaube und Naturwissenschaft
November

Graf von Wallwitz, Georg
München
Wie viel Mathematik braucht die Bildung?
December

GUESTS

Alexandrov, Vassil
(Centro Nacional de Supercomputacion, Barcelona (E))
On Latest Advances in Hybrid Monte Carlo and quasi-Monte Carlo Methods for Linear Algebra
April

Arnold, Martin
(Martin-Luther-University Halle-Wittenberg)
Numerik für Mehrkörpersysteme
February

Esche, Erik
(Technische Universität Berlin)
MOSAICmodeling – A Fully Equation-oriented, Collaborative Tool for Modeling, Simulation, and Optimization in Chemical Engineering
November

Griso, Georges
(University Pierre und Marie Curie, Paris (F))
Decomposition of thin structures
April, November

Grützner, Thomas
(University Ulm)
Thermische Prozesstechnik@Uni Ulm: Forschung und Entwicklung an einem Uni-Start-Up
June

Jenkins, David
(University of Newcastle NSW (AUS))
Understanding coke formation and quality by analysis of physico-chemical processes
October

Khoromskij, Boris
(Max-Planck-Institute for Mathematics in the Sciences, Leipzig)
Tensor Numerical Methods in Scientific Computing: Theory and Practice
February

Knackstedt, Mark
(Australian National University Canberra (AUS))
Digital Materials Design
September

Koci, Petr
(University of Chemistry and Technology, Prag (CZ))
Multi-Scale Modeling of Catalytic Filters
September

Leyendecker, Sigrid
(Friedrich-Alexander-University Erlangen-Nürnberg)
Cosserat rod modeling
June

Leyffer, Sven
(Laboratory for Advanced Numerical Simulations am Argonne National Laboratory (USA))
Derivative-Free Mixed-Integer Optimization
October

Maday, Yvon
(University Pierre und Marie Curie, Paris (F))
Reduced basis method for convection diffusion equation
December

Margenov, Svetozar
(University of Sofia (BG))
Numerical Methods for Fractional Diffusion Problems
December

Nentwich, Corina
(University Ulm)
Surrogate modeling for phase equilibria in process simulation and optimization
August

Noroozi, Sooran
(University of Laval, Quebec (CDN))
Modellierung und Simulation von String-Modellen
June – November

Repke, Jens-Uwe
(Technische Universität Berlin)
Experimental Investigations of Liquid Film on Micro-Structured Packing Sheets
November

Schwartz, Alexandra
(Technische Universität, Darmstadt)
Mathematische Programme mit Kardinalitätsrestriktionen und verwandte Problemklassen
February

COLLABORATION IN BOARDS, EDITORSHIPS

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- DFG-Programm »Materials for Additive Manufacturing - Bewertung der Prozessfähigkeit teilkristalliner Theroplaste im Fused Deposition Modeling mittels eines mikroskaligen Berechnungsansatzes« (Reviewer)
- Heat and Mass Transfer (Reviewer)

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- Journal of the Science of Food and Agriculture (Reviewer)
- Materials Characterization (Reviewer)
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- Science, Science Advances (Reviewer)
- Phys. Rev. Lett., Phys. Rev. Appl, Phys. Rev. X (Reviewer)
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EDITORIAL NOTES

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This annual report is also available in German language.

Editing Ilka Blauth
Steffen Grützner
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Layout Gesa Ermel

Photography Gesa Ermel, Fraunhofer ITWM

Printing Kerker Druck GmbH, Kaiserslautern

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