ITWM

Fraunhofer Institut
Techno- und
Wirtschaftsmathematik

Annual Report 2003

Imprint

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Annual Report 2003

Fraunhofer-Institut für Techno- und Wirtschaftsmathematik ITWM

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Fraunhofer Gesellschaft

Hier entsteht das Fraunhofer-Zentrum Kaiserslautern

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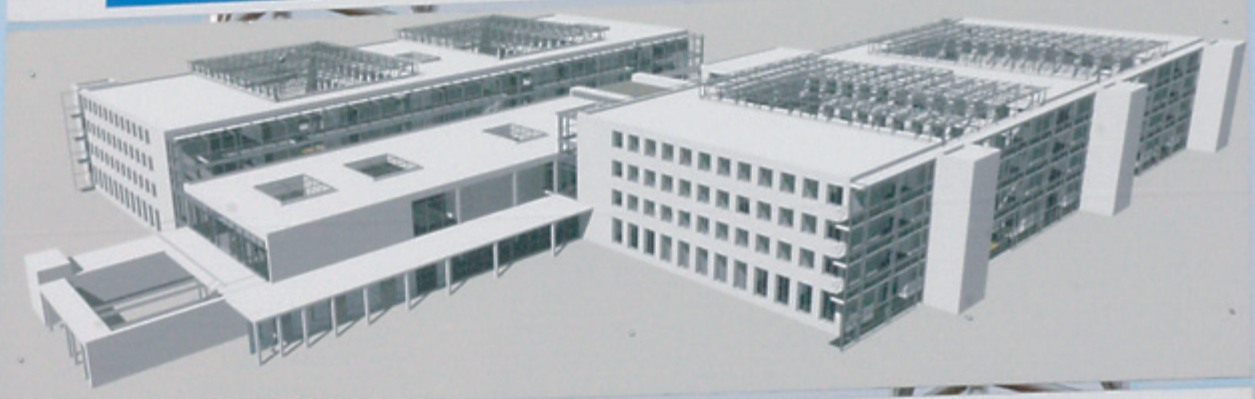

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Preface

The year 2003 was a difficult year for German economy. Additionally, the tense financial situation of the budgets both of the Länder and the Federal Government has lead to a decreasing funding of research projects. In spite of these difficult general conditions, the ITWM again was able to further increase its budget during its third year as a Fraunhofer Institute, finally concluding the financial year with a considerable balance brought forward. Decreasing public funding was compensated by growing profits from industrial cooperation projects and increased funding by the internal programs of the Fraunhofer-Gesellschaft.

In spite of the initiatives for innovation announced by the Federal Government, we don't see any basic change concerning the stagnant funding of research projects for the year 2004. We are again prepared for a hard time and will further increase our commitment to the acquisition of industrial projects. However, we are not able to hold out like that as a long-term solution. A permanent reduction of the public funding of research projects will have fatal consequences for Germany as a high-technology location.

Fraunhofer Institutes need an institutional base funding and a substantial participation in public funding of research projects for a successful and sustained technology transfer to economy. Adequate and continuous growth in both areas is a necessary condition for the functioning of the Fraunhofer model. The costs of the institutes concerning future-oriented basic and preliminary research cannot be covered by base funding alone. We therefore urgently need additional growth with respect to the public funding of research projects.

Higher economic profits imply more work for our employees, if these profits are not due to license income or royalties. However, this source is not very lucrative yet for the ITWM as a relatively young institute, so that a higher workload unfortunately is unavoidable. It is only due to the continuous commitment of our personnel, their creativity, and their persistent and strong identification with the objectives of our institute that we have been able to maintain the ITWM's high quality standard in the year 2003.

Besides, we have increasingly succeeded in reinforcing the basis for cooperation with long-standing industrial customers: individual departments initiate more and more projects of their regular customers together with other departments of the ITWM. This positive development is accompanied by a growing internal network between the individual departments of our institute, which is, e. g., expressed by the fact that the number of projects where different departments are cooperating has been strongly growing during the past two years. This cooperation has a positive effect on the general climate at the institute. We were afraid that the individual departments would seal off themselves more strongly against one another due to the introduction of budgeting and might develop egoisms with respect to project acquisition, which fortunately did not happen.

The ITWM has also been further integrated into the network within the Fraunhofer-Gesellschaft due to a large number of cooperation projects. We are cooperating with partners from the Information and Communication Group, but also with institutes from the research communities "production", "surface technology and photonics", "materials and components", and "microelectronics", which reflects the cross-sectional character and technological relevance of our main competence of mathematics. Its potential with respect to a further growth of our institute has by far not been exploited yet. One of the next steps on the path towards the use of this potential is the establishment of a new department of "Mathematical Methods for Dynamics and Durability". We are glad to announce that we have been able to win Dr. Klaus Dreßler for this new task as Head of Department. He has successfully concluded his PhD in industrial mathematics in Kaiserslautern and has achieved extensive experience concerning industrial projects.

The wide range of research projects of our institute includes a new and in our opinion visionary subject which has been defined at the ITWM by the term "Simulated Reality". One of the central IT problems is, let us say it in bold and simple words, the adequate representation of different systems, such as processes or products, by the computer. The Fraunhofer ITWM's priority here is mathemat-

ical modeling, optimization, and numerical simulation. On the other hand, the methods of virtual reality (VR) developed in computer science have created tools that allow for representations of real systems which are as exact as possible – according to the human visual perception capacities - and enable the user to interact with this virtual world. Up to now, technical simulation/optimization and virtual reality have been separated to a large extent due to the high complexity of most of the technically relevant problems. In particular, dynamic processes which are described by systems of partial differential equations could not yet be integrated into a VR-based simulation environment. It is a big challenge to overcome this separation, which will be met by the ITWM in cooperation with other institutes of the Information and Communication Group within the subject of simulated reality in the next few years. From the perspective of classical modeling and simulation, simulated reality offers new possibilities of interaction, design, visualization, and optimization which have never been known before. From the perspective of virtual reality, the transition towards simulated reality means that highly complex mathematical-scientific models can now also be accounted for. Based on modern hardware and software concepts, problem-adapted integrated working environments for planners, developers, and scientists will be generated in the following years which will allow for the interactive design of variations (virtual engineering) and for a systematic simulation-based optimization (reverse engineering) by integrated decision tools.

Especially reverse engineering will give decisive new impulses for the early computer-based support of product development and the respective production processes, which will result in shorter development processes and increasing product quality. We consider simulated reality as a forward-pointing contribution to a competitive value added by industry.

The regional basis of the ITWM could be further reinforced in 2003. A new structural element of the cooperation with small and medium-sized regional enterprises is the establishment of a "Mathematical Research Platform for Regional Enterprises". The Land Rhineland-Palatinate and the European Regional Development Fund support the ITWM with more than one million Euros for the establishment of such a platform. The platform consists of several research laboratories for the cooperative optimization of production processes, products, and planning methods of regional enterprises. The work is focused on pre-competitive research, so that companies are supported with respect to the handling of new technological challenges and their positions on the market are reinforced. The main subject is the field of IT, where the cycle "research – development – product" is continuously shortening and small and medium-sized enterprises are increasingly profiting from a direct technology transfer from research institutes. A successful development of these research laboratories is based on the ITWM's main competences: mathematical modeling, numerical simulation, optimization, and high performance computing.

The "Linux Networx Research Lab", which has been founded as a cooperation of the ITWM and the company Linux Networx, is firmly connected to the Research Platform.

The excellent development of our "Fraunhofer Chalmers Centre for Industrial Mathematics" in Gothenburg, which was founded in 2001 in cooperation with Chalmers Technical University, was a particularly positive aspect of the year 2003. The Centre has by far exceeded its economic objectives mentioned in the business plan, has increased the number of personnel as intended, and has dynamically expanded its research competences. The opening of the Swedish market is proceeding well, and the ITWM is cooperating in a number of industrial projects. This positive development has convinced the Board of Directors of the Fraunhofer-Gesellschaft to maintain a continuous support by the Gesellschaft in the form of a substantial funding of research projects up to the year of 2005.

The success of the FCC has encouraged the ITWM to further increase its activities in Europe. First steps towards the opening of the Italian market with a special focus on Sicily have been taken. The economic situation of Sicily and especially of the region of Catania has changed considerably since

1990. Main reasons are national and particularly European funds flowing into the region, which have lead to the establishment of many international high-tech companies. Simultaneously, applied mathematics has excellently developed in Catania, and intensive cooperation with the Department of Mathematics of the Technical University of Kaiserslautern has existed for more than 20 years now. On this basis, we see a good chance for the establishment of an ITWM competence center in Catania, which would also represent a perspective for other Fraunhofer Institutes with respect to an easier access to the Southern Italian economic market. However, several obstacles still remain to be overcome on the path towards this objective.

Let us return from Europe to Kaiserslautern, where the construction of our new building has come really close now. Thanks to the quick action of the Land Government, the threatening postponement of constructions for several years at the beginning of 2003 could be avoided successfully. The plans for the Fraunhofer Center are ready. The foundation stone will be laid in April 2004. From an architectonic as well as a functional point of view, it will be a forward-pointing building which will further increase the importance of the location of Kaiserslautern and of the region.

In a certain way, the new building has already "infiltrated" the present annual report, too. It has almost become tradition now that the ITWM annual reports use a "foreign" subject for illustration, in order to introduce the work of the ITWM to the reader more interestingly by way of association. This year, we have selected images taken at our building site. The earth formations, steel mountains, stone clusters, and palettes of material which we have found there are of impressive aesthetics in our opinion, and they are supposed to represent a small contribution for you to remain a little longer with one or another of our projects.

Let us convince you that mathematics at the ITWM has definitely left the ivory tower and is offering a wide range of innovative solutions for various practical problems. We hope that our work is interesting for you and that you might detect connections to your own research and development problems. If so, please let me invite you to think about cooperation with the ITWM.

I wish you a stimulating reading of our annual report!

Prof. Dr. Dieter Prätzel-Wolters, Director

Profile of the Institute

Computer simulations have currently become an indispensable tool for the design and optimization of products, services, and communication and working processes.

Real models are substituted by virtual models. As a raw material for the models and key technology for computer simulations, mathematics represents the foundation of the bridge towards this second world – the world of simulation – which has been established in almost every field of society and economy.

It is the mission and task of the ITWM to meet complex challenges in technology, logistics, communication, and finances by the application of modern mathematical methods and to further develop applied mathematics by innovative ideas, creating practical solutions in cooperation with industrial partners. Integral components of these solutions are consulting with respect to R&D problems, support with respect to the application of high performance computing technology, and the development of especially tailored software solutions.

The intention of the ITWM is not only to build the bridge between the real and the virtual world, but also to provide a connection between mathematical research at the universities and the practical application of the results. Therefore, the close cooperation with the Department of Mathematics of the University of Kaiserslautern is especially important for the ITWM.

Today, the ITWM is the spearhead of mathematics in industry and intends to strengthen and enlarge this position.

Main Subjects

Transport Processes

- fluid-structure interaction
- grid-free methods
- radiation transfer and parameter identification
- continuum mechanical product and process design

Flows and Complex Structures

- microstructure simulation and virtual material design
- hydrodynamics
- complex fluids
- filling and casting processes
- structural optimization

Models and Algorithms in Image Processing

- surface inspection
- analysis of 3d microstructures
- image and sequence analysis

Adaptive Systems

- CAD for analog circuits
- monitoring and control
- biosignal processing and diagnosis support
- prognosis of material and product properties
- multiscale structure mechanics

Optimization

- internal logistics
- global logistics
- continuous optimization
- knowledge management and e-commerce

Financial mathematics

- option pricing
- credit risk and financial statistics
- credit derivatives
- portfolio optimization and interest rate models

Mathematical Methods for Dynamics and Durability

- Durability load data analysis and statistics
- Dynamics and fatigue simulation
- Functional performance optimization

Competence Center "High Performance Computing"

- molecular dynamics
- visualization
- parallelization
- benchmarking
- grid computing
- cluster computing

Fraunhofer Chalmers Research Centre for Industrial Mathematics

- material fatigue from a statistical point of view
- bioinformatics and system biology
- quality engineering
- financial and insurance mathematics

Customers and Cooperation Partners

For many years now, the ITWM has successfully cooperated with enterprises from many branches and of different sizes. In the year 2003, these were, among others:

- ABB, Västeras (Sweden)
- ADT AG, Weissbad (Swizerland)
- Alstom AG, Baden (Swizerland)
- Amaranth Advisors, New York (USA)
- aquinto AG, Berlin
- ARNOLD & RICHTER Cine Technik, Stephanskirchen
- Audi AG, Ingolstadt
- BASF AG, Ludwigshafen
- Bavarian State Ministry of Environment, Health and consumerism, Munich
- BMW AG, Munich
- BorgTec Systemhaus GmbH, Dresden
- Caparol, Ober-Ramstadt
- Carl Zeiss, Oberkochen
- City of Kaiserslautern
- Continental AG, Hannover
- Deutsche Apotheker- und Ärztebank, Düsseldorf
- Deutsche Bahn AG, Berlin
- Die Sprinter – Kurierdienst und Speditionsgesellschaft mbH, Mannheim
- Dresdner Bank AG, Frankfurt on the Main
- Elmo Leather AB, Svenljunga (Sweden)
- ESI-Group, Paris
- Eurofilters AG, Overpelt (Belgium)
- Fachhochschule Aschaffenburg
- Fachhochschule Landshut
- Faurecia, Sassenburg
- FCC Göteborg (Sweden)
- FE Design, Karlsruhe
- Freudenberg Vliesstoffe KG, Weinheim and Kaiserslautern
- FSM! GmbH, Landstuhl
- gbo AG, Rimbach
- GE Transportation Systems, Bad Dürkheim
- Gebrüder Gienanth-Eisenberg GmbH, Eisenberg
- Geratherm Medical AG, Geschwenda
- German Cancer Research Center, Heidelberg
- Gießereiinstitut, Technical University Bergakademie Freiberg
- Hager Electro GmbH, Ensheim
- Harvard Medical School, Boston (USA)
- HegerGuss GmbH, Enkenbach-Alsenborn
- hg.zwo GmbH, Kaiserslautern
- Hilti AG, Schaan (Liechtenstein)
- Hoffmann und Engelmann AG, Neustadt an der Weinstraße
- Hospital of the Johannes Gutenberg-University of Mainz
- Human Solutions GmbH, Kaiserslautern
- HypoVereinsbank, Munich
- i2t3 - Industrial Innovation Through Technological Transfer, Florenz (Italien)
- IBS Filtran GmbH, Morsbach
- Infineon Technologies AG, Munich
- Institut für Gießereitechnik GmbH, Düsseldorf
- Institut für spanende Fertigung, University of Dortmund
- Institut für Verbundwerkstoffe IVW, Kaiserslautern
- J. Wagner GmbH, Markdorf
- Johns Manville Europe GmbH, Bobingen
- Landesbank Baden-Württemberg, Stuttgart
- Landesbank Rheinland-Pfalz, Mainz
- Lehr- und Versuchsanstalt für Viehhaltung Neumühle, Münchweiler/Alsenz
- Linux Networx, Salt Lake City (USA) und Kaiserslautern
- m2k Informationsmanagement GmbH, Kaiserslautern
- MAGMA Gießereitechnologie GmbH, Aachen
- Mannesmann-Rexrodt AG, Lohr on the Main
- Massachusetts General Hospital, Boston (USA)
- MiniTec GmbH & Co KG, Waldmohr
- Mobotix AG, Kaiserslautern
- MSC/GAC, Buchenau
- müllers büro, Erzenhausen
- Odenwald-Faserplattenwerke GmbH, Amorbach
- OperaThing GmbH, Hürth
- Paul Wild GmbH, partu lapidaries GmbH, Kirschweiler
- proALPHA Software AG, Weilerbach
- Procter & Gamble, Schwalbach im Taunus and Cincinatti (USA)
- psb GmbH, Pirmasens
- Rhodia Acetow, Freiburg
- Roche Diagnostics, Mannheim
- Römheld & Moelle, Mainz
- Sandler AG, Schwarzenbach (Saale)
- SAP AG, Walldorf
- Schott Glas, Mainz
- Seidel GmbH, Marburg
- Siemens AG (Medical Solutions OCS), Heidelberg
- Steinbichler Optotechnik GmbH, Neubeuern
- Technical University of Dresden
- Technical University of Kaiserslautern
- Technische Werke Kaiserslautern
- tecmath AG, Kaiserslautern
- Tecnotessile Societa Nazionale di Ricerca tecnologica r.l., Prato (Italien)
- Tehalit GmbH & Co KG, Heltersberg
- Thomas Josef Heimbach GmbH & Co., Düren
- Ultrafilter international AG, Haan
- University of Freiburg
- University of Karlsruhe
- University hospital Tübingen
- University hospitals of Saarland, Homburg/Saar
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- Verkehrsverbundgesellschaft Saar mbH (VGS), Saarbrücken
- Verotec GmbH, Lauingen/Donau
- Volkswagen AG, Wolfsburg
- WestLB, Düsseldorf
- Westpfalz-Verkehrsverbund, Kaiserslautern

The Institute in Numbers

Budget

In 2003, not only the planning and the construction of our new institute center have been pushed forward, the ITWM has also continued to grow further. Difficult economic conditions and decreasing public funding have not been able to stop the increasing economic success of the ITWM in 2003. The ITWM is still showing two-digit growth rates. The operating budget has again increased by approximately 10 per cent to almost 8 million €.

However, profits from publicly funded projects were decreasing. Especially the funding provided by the BMBF (Federal Ministry for Education and Research) was nearly 30 per cent less than in the previous year. We are afraid that this tendency will be further reinforced in 2004. The decreasing funding by the BMBF could partly be compensated by financial means provided by the Land. Successful project proposals especially at the Ministry of Economy of Rhineland-Palatinate have resulted in 32 per cent of the operating budget still being covered by profits from public projects. The ITWM was also extraordinarily successful with respect to the internal programs and appears to be a particularly well sought-after partner for many institutes of the Fraunhofer-Gesellschaft.

However, even more successful again was the project acquisition in industry and economy, where the ITWM was able to further increase its profits. Returns increased by more than 14 per cent with respect to the previous year, covering 43 per cent of the operating budget. Especially in times of strong economic fluctuations, the ITWM's wide range of customers is invaluable. The continuous growth of economic profits in 2003 was only possible due to this background. Especially striking is the increasing demand of long-standing customers for the competences and the know-how of several departments.

Budget Development [Thousand €]	1999	2000	2001	2002	2003
Operating Budget	4550	5147	5866	7267	7912
Investments	382	244	756	878	563
Total	**4932**	**5391**	**6622**	**8145**	**8475**

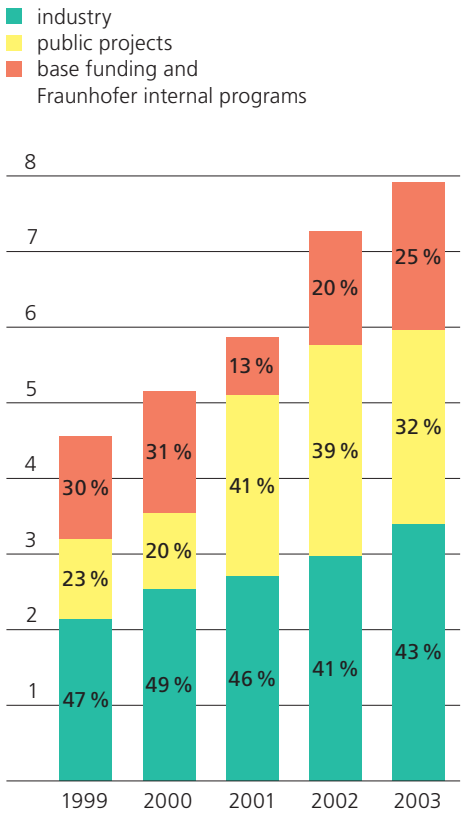
Personnel development

In 2003, the personnel quota of the ITWM increased by 11 per cent. Approximately 130 colleagues (76 scientists, 39 PhD students, and 14 colleagues in administration, EDP, and public relations) were working at the Fraunhofer ITWM in 2003, as well as 86 research assistants and trainees. One effect of this growth is that the offices which had been newly rented in 2002 will not be sufficient any longer, so that more offices will have to be rented again in 2004. Fortunately, this is possible without any problems at our location in the PRE-Park, so that extensive relocations can be avoided until the new institute center will be completed.

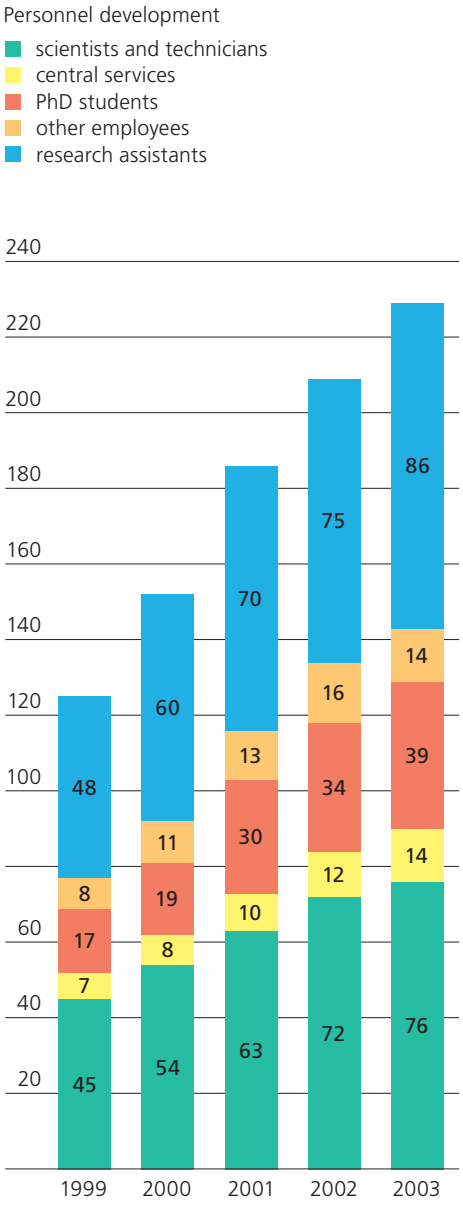
A large number of projects where different departments are cooperating indicate a positive future trend.

Insofar, the ITWM is still looking optimistically forward into the future, and we expect two-digit growth rates also for 2004.

Operating Budget Development in Million €



Personnel development



Board of Trustees

Renowned representatives from science, economy, and politics could be won as members of the board of trustees, among which are:

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	Optimization	Prof. Dr. Stefan Nickel	+49 (0) 6 31/3 03-18 85
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	Mathematical Methods for Dynamics and Durability	Dr. Klaus Dreßler	+49 (0) 6 31/3 03-18 69

The Fraunhofer-Gesellschaft at a Glance

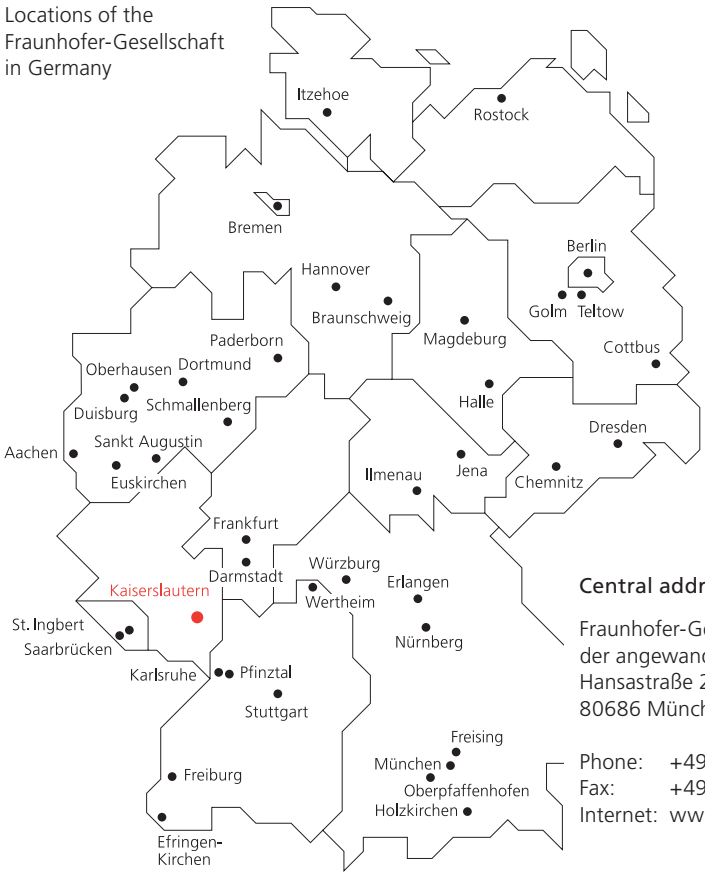
The Fraunhofer-Gesellschaft is the largest organization of applied research in Europe. As a non-profit organization, it currently maintains approximately 80 research units – including 58 institutes – at more than 40 locations throughout Germany. A staff of approximately 12,700 employees - mainly qualified scientists or engineers – works for the annual research budget of more than one billion Euros. More than half of industrial profits stem from projects with small and medium-sized enterprises.

The Fraunhofer-Gesellschaft deals with research and development projects for economy, the state, and the public sector. International cooperation is supported by Liaison Offices in the USA and in Asia.

Research areas of the Fraunhofer-Gesellschaft:

- material technology, component behavior
- production technology, manufacturing technology
- information and communication technology
- microelectronics, microsystem technology
- test engineering, sensor systems
- process engineering
- energy technology and constructional engineering, environmental and health research
- technical-economic studies, information transfer

Locations of the Fraunhofer-Gesellschaft in Germany



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Fraunhofer Group Information and Communication Technology

The Fraunhofer ICT Group is the largest European research alliance for information and communication technology (ICT), thus representing a coordinating body for industrial customers and media who are looking for an appropriate partner. The competences of the 17 member institutes are pooled in strategic alliances and marketed in common. This network allows for specific, branch-typical, and entire solutions from applied research: especially tailored IT solutions, competent technology consulting, as well as preliminary research for new products and services. Periodic economic summits provide a platform for the appropriate partners from industry and research.

An entire number of 2,000 employees of 17 institutes, as well as an annual budget of more than 190 million Euros turn the ICT Group into the largest research alliance in Europe. Therefore, the technologies in our ten research areas cover the entire value-added chain:

- e-business
- e-government
- medicine and life sciences
- traffic and mobility
- production
- digital media
- security
- culture and entertainment
- software
- communication systems and interdisciplinary applications

International Orientation - internal and external

We can still very well remember the images on German TV screens concerning the Green Card initiative of the German Government. Particularly many Indian women in their wonderfully colored sarees could be seen in front of computers. Their male colleagues in India and Eastern Europe were also target groups, so that soon we had a ridiculous discussion about whether we should support our own children or invite Indians to our country. However, it was exactly these computer experts who did not come in large numbers – real experts often had better offers from the USA. Now, it has become quiet about Indians with Green Cards and Eastern Europeans. But we really need them – especially a Fraunhofer Institute of the ICT Group such as the ITWM. However, you cannot order these experts like computers, because they are all human beings with their own history, with preferences and prejudices, with strengths and weaknesses. They must learn to live in a foreign atmosphere, must learn to interpret the smiles or bawling of other people, must know what is important in our society and what is not. In order to be successful in their professions here, these people need more than their expert knowledge and even more than a job or an adequate income. On this occasion, we would like to present to you some of our foreign colleagues – as human beings and a little also as scientists.

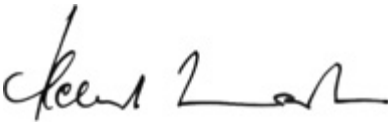
Let us begin with our probably most "exotic" colleague: Sudarshan Tiwari. He was born and grew up in a small Himalayan village, at the foot of the Lamjung Mountains in Nepal. I have visited the village, and it is really like paradise: a picturesque valley landscape, orange trees, rice, and water buffaloes in the village on the hills, but no streets and no electricity, and high up on the top of the ridge shining glaciers. The school is also "like paradise": the only sentence which the English teacher was able to say at our arrival in the language he is supposed to teach was "Welcome, we are a very poor school". It was also at this school where Sudarshan learned basic "mathematics"; with difficulties, because his father could only afford the schoolbooks of his older sons, so that the younger one had to jump two classes. However, he succeeded, and he subsequently went to secondary school in the vicinity and later on to the university in Katmandu. He studied mathematics there and did his Master – the best final exams in the whole country in all subjects. Now he is able to apply for a DAAD (German Academic Exchange Service) grant in Germany – his wife comes along, the newborn baby remains with the grandmother because they are afraid it might freeze in Germany. After two years, another Master in Industrial Mathematics in Kaiserslautern – and their daughter is born here in the Palatinate. The family returns to Nepal, already having applied for a PhD grant. Thus, after another four years, Sudarshan Tiwari does his PhD in Kaiserslautern about numerical methods in fluid dynamics, cooperating during this time with international experts in this area from the USA, Canada, and Europe. Being a good patriot, he then returns to Nepal, but the professors in Katmandu do not want a stronger competitor in their vicinity and send him to a college in a far-off valley. Had everything been in vain then? Even at the Indian Institute of Science in Bangalore, Sudarshan did not find a partner in mathematics with an expert knowledge in numerics. We had watched the situation from the distance of the ITWM, and when he apparently was not able to do anything for his country or for India, we gladly invited him to the ITWM. Since 1999 Sudarshan Tiwari has now been working at the ITWM, simulating airbag deployment and the formation of streaks in molten glass, and he is an important scientist in one of the most successful research groups.

Far less exotic because European, but nevertheless very typical for the colleagues at the ITWM from foreign countries, is the story of Teresa Melo. Having grown up in Lisbon, she is a real urbanite. She was educated traditionally by her family, who can certainly be

considered as being middle-class intellectuals. It is therefore not surprising that her father did not accept her wish to study archeology and, after fierce discussions, enforced his idea of mathematical studies for his daughter. Thus, Teresa studied mathematics at the University of Lisbon, focusing on operations research and statistics. She prepared her Master thesis about location optimization at the ERASMUS University in Rotterdam, finally doing her Master at the University of Lisbon. Afterwards, an EU grant enabled her to return to Rotterdam and to do her PhD about stochastic production planning. Private reasons take her to Aachen and, to be more exact, to the Jülich Research Centre, where I also made my first professional experiences 30 years earlier. After two years in the research group of "Systems Research and Technological Development" in Jülich, she comes to the ITWM to the department of "Optimization". Today, Teresa Melo is responsible for the subject of "Global Logistics and Traffic Planning" and develops tools for location decisions and for the planning of logistic processes in hospitals. Of course, she has contributed to the reinforcement of scientific relations of the ITWM to Portugal. The Iberian Peninsula is a source of excellent human resources in the field of mathematics; after their democratization, Spain and Portugal have returned to the scientific world full of energy and with high performance.

The last example stems from a group which presumably represents the largest group of colleagues from foreign countries at the ITWM, the Eastern Europeans. This group includes many different people, from the member of the Bulgarian Academy of Sciences and the engineer from Novosibirsk to the new PhD student from Poland. Monika Muszkieta is 25 years old and has been a PhD student in the department of "Models and Algorithms in Image Processing" since October 2003. She is in Kaiserslautern thanks to the international orientation of the department of mathematics of the Technical University of Kaiserslautern. The department is very actively cooperating in a European consortium "Mathematics for Industry", where Prof. Wojzek Okrasinski from Zielona Gora, which is situated between Berlin and Wrocław, is also participating. He came to Kaiserslautern several times in order to collect ideas for this area which had not been developed very far in Poland yet. Therefore, he suggested two of his best students to do their PhD in Kaiserslautern – Monika Muszkieta being one of these two. She visited high school in Glogow at the river Odra – her parents grow flowers and sell them to many places throughout Poland. However, she did not want to do that: "I simply couldn't imagine studying something different than mathematics." Therefore, she went to the University of Zielona Gora, which is 50 km from Glogow and also offers studies in industrial mathematics. Monika studied a simple model of a casting process, had an ERASMUS grant during the previous semester which took her to Kaiserslautern, and now intends to do her PhD on a subject from the field of image segmentation (How to identify "stains" on an almost clean surface?). A grant offered by the Fraunhofer-Gesellschaft to female PhD students is of decisive help here. Can you imagine a better contribution to the integration of Europe than the cooperation of young scientists within a Fraunhofer Institute?

These are three examples from an entire number of 39 foreign colleagues, human beings and scientists who are contributing to shape the image of the ITWM. Moreover, the institute does not only profit from their competence and their commitment, the community is also enriched by the culture of their mother countries which they bring with them. Of course, it is not easy for some of them to adapt themselves to the work within a Fraunhofer Institute, i. e. to the balance act between research and commerce and the succession of creative thinking and pressure due to the projects. German scientists coming from university have more or less the same problem; they are also not used to the direct connection between research work and profit. However, if the environment is characterized by this Fraunhofer spirit – which is the case for the ITWM to a very large extent -, excellent international teams are resulting. "Internal international orientation" complemented by "external international orientation" through the establishment of cooperation groups abroad: Maybe the ITWM will also be one of the institutes of the Fraunhofer-Gesellschaft leading the way here? At the moment, we are very lucky that this objective is so actively and competently supported by those people working in the central Fraunhofer administration who are responsible for international cooperation!



Prof. Dr. Helmut Neunzert

Looking Back at the Year 2003

February 20	Meeting of the Board of Trustees: ITWM as the top leader of the ICT Group
March 17	Appointment of Prof. Helmut Neunzert as Fellow of the Royal Society of Edinburgh
May 2nd	Installation of a Linux cluster with a performance of 400 Gigaflops at the Linux Networx Research Lab of the ITWM
June 5	Establishment of a mathematical Research Platform for regional enterprises
October 27	Start of construction of the Fraunhofer Center at the location Trippstadter Straße

The year 2003 was characterized for the ITWM by increased public presence. The institute presented its products, for example, during 16 fairs and conferences, among which were such renowned events as “MEDICA” and “FILTECH”, both in Düsseldorf, “SuperComputing” in Phoenix, “Control” in Sinsheim, “Sensor” in Nuremberg, or “HUSUMwind”.

Additionally, the ITWM organized several workshops, for example, on the subjects of location optimization or software tools for medical technology, as well as a Fraunhofer expert conference on hospital logistics focused on “patient transports”.

However, what is especially striking – apart from a generally increased presence in the media - is that reports about the institute were shifting their focus from events towards projects and contents. Already five ITWM products were presented in the monthly Fraunhofer media service. A small insight into individual news about the institute can be found on the next page.

news items

**Kaiserslautern,
18. Februar 2003**

ITWM bestes Institut in der Fraunhofer-Gruppe “Information und Kommunikation”

Großes Lob aus der Münchner Zentrale der Fraunhofer-Gesellschaft gab es für das Institut für Techno- und Wirtschaftsmathematik bei der diesjährigen Kuratoriumssitzung: Das ITWM hatte 2002 die höchsten Wirtschaftserträge innerhalb der Fraunhofer-Gruppe “Information und Kommunikation”, in der ein

**Kaiserslautern,
8. Mai 2003**

Mathematik überwacht Schwingungen

Kraftwerke sichern unseren Energiebedarf. Egal ob diese Energie nun aus Wind, Wasser, Kohle oder einem anderen Rohstoff gewonnen wird, das Prinzip ist immer das gleiche: Aus Primärenergie wird elektrischer Strom gewonnen und dafür braucht man einen Generator, also eine rotierende Ma-

elektrische Energie umwandelt.

**Kaiserslautern,
4. Juni 2003**

Mathematik für regionale Unternehmen

Das Fraunhofer-Institut für Techno- und Wirtschaftsmathematik ITWM erhält vom Land Rheinland-Pfalz und dem europäischen Fond für regionale Entwicklung eine Förderung von über einer Mio. Euro für den Aufbau einer “mathematischen Forschungsplattform für regionale Unternehmen”. Davon werden in den nächsten zwei Jahren vor allem kleine

**Kaiserslautern,
20. Oktober 2003**

Fraunhofer ITWM liefert individuelle Lösungen für Filtrationsprobleme

Filter werden in vielen Bereichen der Industrie und des täglichen Lebens eingesetzt, um Menschen vor toxischen oder allergenen Stoffen zu schützen und die Funktionsfähigkeit von Maschinen zu erhalten. Sie müssen an ihren jeweiligen

d.h. Reinraumfilter müssen

A special interest of the ITWM has always been the support of trainees in sciences, mainly, of course, in mathematics. This commitment is expressed by the institute's participation in university events, such as the "Day of Mathematics", the "TechnoDay", and "Science and Technology for Schoolgirls" by the organization of workshops and talks, as well as by a long-standing cooperation with regional secondary schools, e. g., with respect to the handling of practical problems in mathematics during the so-called pupils' modeling weeks, the counseling of school working groups in mathematics, the organization of visits of school classes at the ITWM, and the acceptance of pupils as trainees at the ITWM. An offer which has been readily accepted: in the year 2000, the ITWM had only 5 trainees, a number which had grown to 28 last year.

Two of these trainees, Stephan Martin, student of business mathematics at the Technical University of Kaiserslautern (1st semester), and Jenny Metzger, who is taking her final exams at the St. Franziskus-Gymnasium in Kaiserslautern, are talking here about their experiences during the trainee program.

What gave you the idea of participating in a trainee program at the ITWM?

Jenny: My teachers, who already had contact with the ITWM, told me about it.

Stephan: I found the address of the ITWM via links on the homepage of the Technical University of Kaiserslautern, and I already knew something about the institute from the newspapers.

Which motivation did you have for such a trainee program?

Jenny: I had thought about maybe studying mathematics; mainly, however, I was interested in the subject. I had already been to the modeling weeks in Lambrecht before, and that was really fun.

Stephan: I could hardly imagine what mathematicians do in their "real" job, since we only know it from school and from the perspective of our teachers, and I wanted to know like Jenny how it is in reality.

Were your expectances fulfilled?

Jenny: Yes, completely.

Stephan: During my trainee program, I did project work where I had to describe and develop the subjects of the institute at school level. So I was able to take a comprehensive look inside almost all current projects of all the departments – that was great.

How were you taken care of?

Jenny: Really well! I was always able to ask anything, and I never had the impression of getting on anybody's nerves. People were really very nice and I was completely integrated.

Stephan: I was very well taken care of; it was very pleasant and, above all, very personal! I didn't feel like a trainee at all. The atmosphere was very relaxed and informal, and I never had to make coffee or do the photocopying.

What else was good?

Jenny: I got in touch with many new software programs. My work was not for the waste paper basket and neither invented only to keep me occupied. The results which I had produced were really used afterwards! I was able to work very independently and didn't have to sit with somebody only watching.

Stephan: The broad insight into the other research groups. Everybody was willing to explain everything to me, and people really answered my questions.

What was less good in your opinion?

Jenny: I can't think of anything at the moment.

Stephan: I once had to change to another department where people were a little bit unprepared; maybe there was an internal communication problem and the transition should be improved.

Does or did the trainee program have any influence on your choice of profession?

Jenny: Not yet up to now. However, I did find it very helpful for orientation. I am still searching and haven't decided yet. Maybe I'll do computer science or medicine after my final exams.

Stephan: Directly after the trainee program and my work as research assistant at the ITWM I studied something different, but I have decided for mathematics now and I have not regretted it yet. I know what to expect and I can imagine more than without the trainee program.

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Manuela Hoffmann, Katharina Parusel, Ingeborg Woltmann, Dr. Marion Schulz-Reese, Brigitte Williard

Not on the picture: Myrjam Schröer, Dr. Renate Tobies, Martin Vogt

Transport Processes

The movement of filaments in an air flow, the refueling process of a motor vehicle, the radiative transfer through glass, the dose deposition in radiation therapy, the convective cooling of a floodlight, and the gas flow through a network of pipelines: these are examples for projects concerning transport processes which will be presented in the following. The modeling of such processes is based mathematically on transport equations, i. e. on partial (integro-)differential equations.

The Department of Transport Processes is working on technical and scientific models for the examples characterized above, and on the development of efficient algorithms for the numerical solution of these models. On this basis, the department offers solutions for its clients from very different industrial branches, ranging from studies with respect to design, construction, and optimization proposals to the development of software concepts and tools.

During the financial year of 2003, which again was a very successful one, the department has been able to further improve its profile with respect to contents and methodology concerning the following main subjects:

- fluid-strukture-interaction
- grid-free methods
- radiative transfer and parameter identification
- continuum mechanical product and process design

The last one of the subjects listed above additionally shows the range of complexity of the application problems which are dealt with. Available competences are joined together and new fields of subjects are generated. Hence, almost all the colleagues of the department are participating in varying teams in the solutions developed for this subject. The research work concerning industrial contract research is complemented and supported by basic research, which is essentially based on a number of PhD projects (currently eleven) within the department.

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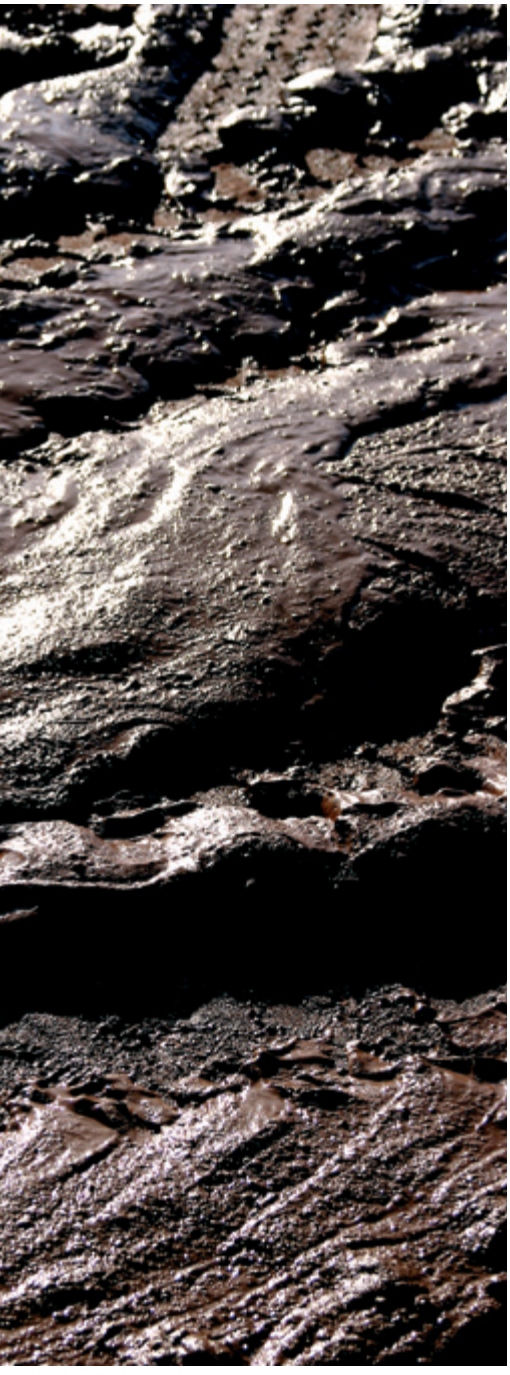
Dr. Robert Feßler, Dr. Norbert Siedow, Markus von Nida, Christian Schick
Dr. Teodor Grosan, Bhaskare Subra Annadata, Dr. Sudarshan Tiwari, Serguei Antonov, Nicole Marheineke

not on the picture: Eka Budiarto

Fluid-Structure Interaction



Generally speaking, "fluid-structure interaction" means the interaction of flows and 3d objects. The respective research at the ITWM is mainly focused on objects whose extension can be reduced in the model by one or more dimensions, i. e. mass points (e. g., droplets and particles), line shape objects (e. g., filaments), and planar objects (e. g., sheets of paper). The dynamics of the structures is always described by Newtonian equations of motion with internal and external forces, the external forces being essentially determined by the flow conditions around and at the object. In the context described above, the Fraunhofer ITWM develops especially tailored solutions for the respective industrial problem, particularly in order to reduce the complexity of the problem to such a degree that realistic application problems can be simulated. The basic fluid dynamical problems of the respective projects are usually simulated by software tools such as FLUENT® and ANSYS CFX®, which are then coupled with individual software for the simulation of the structures' movement.

A special competence has meanwhile been developed for the dynamics of filaments in spinning and depositing processes. The following example shows that our medium-range intention is the integration of the existing algorithmic approaches and simulation components into a simulation tool as comprehensive as possible. The results of the current PhD projects with respect to the interaction of filaments and turbulent flows, the dynamics of yet unhardened filaments, and the spinning process itself will be integrated into this tool as a second step, in order to further extend the range of industrial applications considerably.

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Movement of filaments in air flows

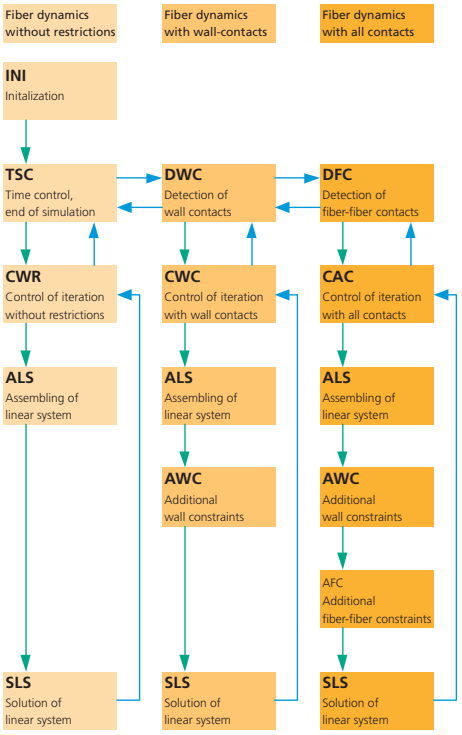
During the production and processing of synthetic fibers, the filaments are subject to forces resulting in significant vibrations, crimping, bundling, and other fiber movements. Fiber dynamics and its specific manipulation are decisively important in many processes. In the last few years, a large number of models and the respective software components for the simulation of fiber dynamics have been developed at the ITWM, which also account for special aspects, such as contact with walls or interaction between individual fibers.

Applications with respect to the production of nonwovens are particularly influenced by fast air flows. These air flows lead to the extension of the fibers through tensile forces, while simultaneously determining the fiber deposition through their steering effects. The effect of the fibers on the flow is of secondary importance in this context, so that the fluid-structure interaction can be formulated by an aerodynamic force term in the Newtonian equation of motion of fiber dynamics:

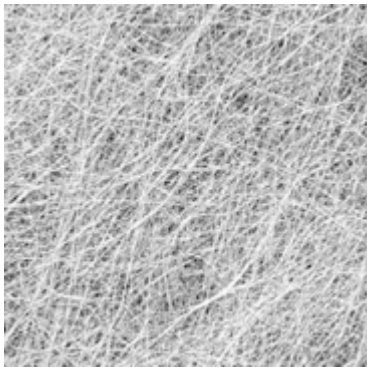
$$\sigma\ddot{x} = \partial_s(T\partial_s x) - S_k\partial_{ssss}x - \sigma g e_\perp + f_L$$

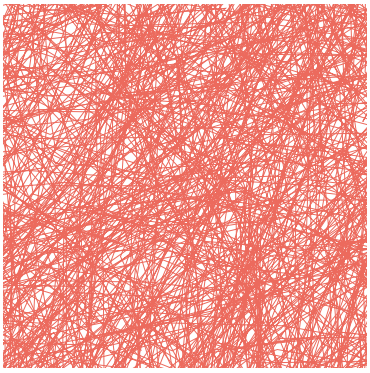
The algorithmic method based on these assumptions can be described in the following way: first, the global flow conditions are simulated by a standard tool, such as FLUENT® or ANSYS CFX®, followed by a simulation of fiber dynamics which is primarily based on an unrestricted movement, iteratively accounting for occurring restrictions like fiber-wall interaction or fiber-fiber interaction.

A comprehensive concept for the realization of a simulation tool for the production of nonwovens has been developed in the framework of an industrial study, a tool based on the mentioned algorithmic ideas and the existing implementation approaches. The realization of this concept represents the foundation for the simulation of a variety of problems concerning the movement of filaments in flows. Thus, even the simulation of applications such as yarn production with all the respective process and processing steps will also become possible. Integrated into systematic optimization, such a tool is a first step into simulation-based reverse engineering for the entire field of production of technical textiles and yarns.



Workflow of the simulation kernel for the production of nonwovens





Real and simulated nonwoven

Grid-free Methods

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Concerning the subject "Grid-free Methods", the department has developed the Finite Pointset Method (FPM), an independent software for continuum mechanical and especially flow dynamical problems (CFD). The development of FPM is supposed to overcome the limits of the existing classical CFD methods (e. g., Finite Element Method FEM, Finite Differences Method FDM, Finite Volume Method FVM) with respect to grid generation and adaptation, thus enabling new applications.

The main weak point of the classical methods mentioned above is the necessity of a mesh for the flow dynamical computations, whose generation requires considerable effort with respect to the entire flow field. This is particularly problematic if the flow field varies during the computation, thus requiring the adaptation of the rigid mesh to the new geometry (remeshing). In the case of complex variations – e. g., the deployment of an airbag – the remeshing requires so much time and effort that the classical methods are no longer able to solve the problem within acceptable computing times, or they may even fail entirely. FPM can do completely without such a mesh for the geometry, because the entire information about the local flow dynamical state is no longer stored on a grid, but on a point set (Finite Pointset) instead. The points of this set are moving at flow velocity, thus flexibly adapting to all geometric variations.

In the past, FPM was developed first for compressible gas flows. During the past years, however, a breakthrough has successfully been achieved also in the field of incompressible flows, so that an efficient software basis is now available for the solution of complex flow dynamical problems – such as the refueling problem described in the following.

Refueling of motor vehicles

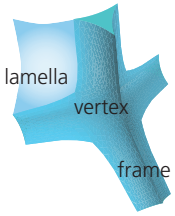
Over a period of three years, we have worked on the development of a simulation tool for the refueling processes of motor vehicles based on the finite pointset method (FPM). The research was supported in the framework of a BMBF (Federal Ministry for Education and Research) program in cooperation with Volkswagen AG. The tool is supposed to offer a possibility for the technical design of fuel systems on the basis of simulations which also account for all the prescribed standards (refueling time etc.). One essential objective is to render the refueling of motor vehicle tanks as environmentally acceptable as possible.

The refueling process is a very complex and polymorphous physical process. A first problem arises from the enormous geometric complexity of a motor vehicle tank, resulting from the more and more compact design of automobile construction. During the last few decades, a simple fuel can has developed into a high-tech unit. Another problem is the physical or dynamical behavior of fuel. Diesel in particular, but also gasoline tend towards the formation of foams, which have an essential influence on the refueling possibilities of the fuel system.

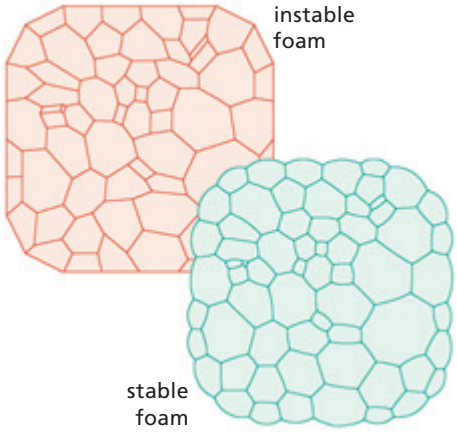
The foam will be considered as a homogeneous phase for the numerical simulations. However, foam has a very complicated structure consisting of bubbles, lamellae, webs, and nodes, so that a mathematical model is required for the consideration of foam as a phase. The following aspects are particularly important:

- the stress-strain behavior of foam (material law), depending on the size of the bubbles and the content of liquid
- the creation of foams at turbulent surfaces of a liquid and due to gases, which are contained or dissolved in the liquid, ascending by gravitation
- drainage, i. e. the fluid transport through the system of foam lamellae
- foam decay (i. e. the question how long a foam lamella exists before disintegrating)

The first point requires a more macroscopic method, by which we try to homogenize the system of foam bubbles and lamellae in order to represent the viscous, elastic, or plastic components of the stress behavior of the foam. The other points require a microscopic method in order to examine the flow behavior within a foam lamella, a web, or a node.

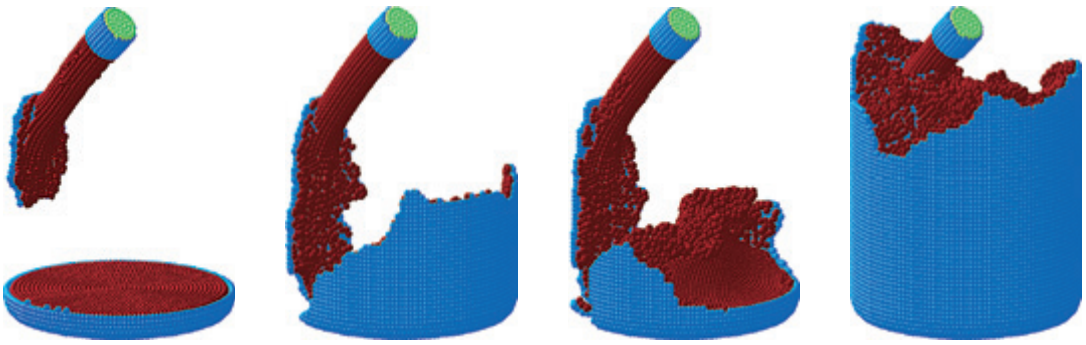


Micro-analysis:
the foam node as a complex flow field



Creation of a real, stable foam on the basis of a Voronoi tessellation (instable foam)

The entire refueling problem is a multiphase problem concerning air, foam, and fuel. Hence, special attention has been paid within the project to the formulation and implementation of consistent conditions at the phase boundaries.



Refueling experiment with gasoline in a glass cylinder

Radiation Transfer and Parameter Identification

In many production processes where materials or components are heated or are cooled down, important factors are not only heat conduction, but also radiation. Semi-transparent materials, such as glass, are especially interesting from a mathematical point of view, because radiation does not only occur at the surface, but is instead emitted and absorbed throughout the entire volume of the material. In the last few years, a wide range of simulation methods for this complex problem has been developed at the ITWM in cooperation with the company Schott Glas in Mainz, now completed by the development of the Discrete Ordinate Method, which will be described in the following. The software which is now available does not only offer the possibility of accounting for absorption and emission, but also for scattering. Besides, last year's research has also concentrated on the modeling of glass as a grey radiator, i. e. on the substitution of the wavelength-dependent coefficient of absorption by an effective value.

Currently, different industrial problems have lead to so-called inverse problems or problems of parameter identification in the field of heat conduction and thermal radiation, apart from the simulation of radiative transfer processes. One example is the reconstruction of the internal temperature gradient of a body without any knowledge about initial conditions based on measurement data from the boundaries. The parameter identification methods which have been developed are supposed to be further extended to related problems in the future. A current example is the modeling and simulation of drug diffusion in the inner ear, where the identification of the different physiological model parameters on the basis of measurement data is extremely important.

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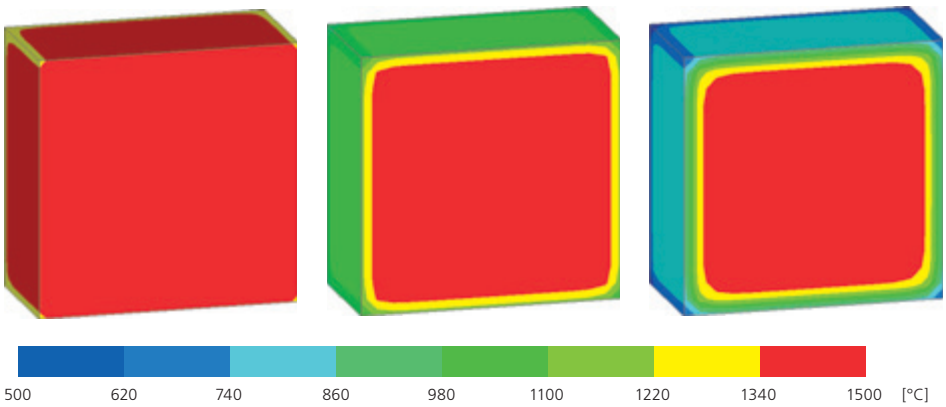
DOM algorithm for radiative transfer

Heat transfer at low temperatures can be handled very easily by commercial software packages as a simple problem of heat conduction. At higher temperatures, however, as they occur, e. g., during glass production, heat transfer by radiation is dominating, so that more complex models are required which couple both heat transfer mechanisms (heat conduction and thermal radiation). In the case of opaque materials, radiative transfer exclusively happens at the surface, whereas semi-transparent materials must be considered as real volume radiators.

The coupled modeling of heat conduction and thermal radiation results in a numerically very complex seven-dimensional system of integro-differential equations, for the solution of which there are different approaches. In the past, an improved diffusion approximation has been derived apart from other methods (e. g., Rosseland and P_1 approximation), which is based on an asymptotic approach, accounting for the radiative transfer by a geometry-dependent correction of the coefficient of heat conduction and of a respective source function in the heat conduction equation. The range of methods has now been extended by a discrete ordinate method known from literature. The direction-dependent radiative transfer equation is transformed into m direction-independent equations by the selection of m discrete directions. These equations are then discretized by a finite volume method, and the resulting algebraic system of equations is solved numerically. This method does not only allow accounting for absorption and emission in the interior and for reflection at the boundaries, scattering effects can also be taken into account very easily.

Scattering is a physical property not to be neglected in different semi-transparent media, for example, in milk glass, ceramics, gases, or also in biological tissue. Scattering and absorption may also represent desirable effects, e. g., by varying the optical properties of glass. Parameter studies can be carried out by the simulation of radiative transfer in the medium, and their effect with respect to the scattering and absorption properties of the material can be examined. The application of asymptotic solution approaches in the case of very strongly scattering media may considerably reduce the computing time required for the simulation.



Simulation of a cooling glass cube; we can see a cross-section of the cube center. Left: only heat conduction, center: heat conduction and surface radiation, right: heat conduction and volume radiation

Dose deposition in radiation therapy

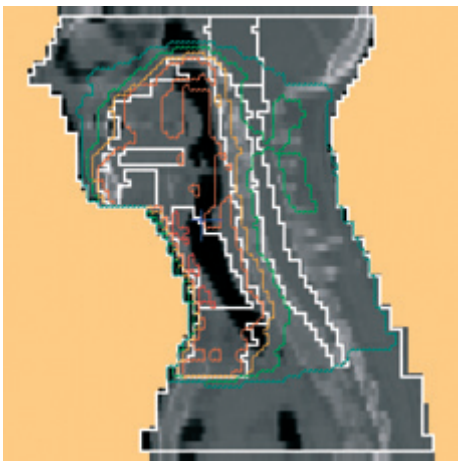
The treatment with ionizing photon beams is one of the most important methods in modern cancer therapy, apart from surgery and chemotherapy. The objective of each radiation therapy is the deposition of energy doses in the tumor tissue which are as high as possible. Simultaneously, the surrounding healthy tissue should only be subject to a radiation dose as low as possible, in order to minimize therapeutical side effects. These competing objectives result in optimization problems whose solution requires, among other aspects, a highly efficient dose computation.

Currently, two models are applied for dose computation. On the one hand, these are the so-called pencil beam models, which allow for a very fast computation on the basis of a heuristic approach, and on the other hand the Monte Carlo models, which, although based on a physically sustained microscopic description of the energy propagation and storage, unfortunately require considerable computing time.

Due to the computing times required, the pencil beam models have currently prevailed in hospital daily routine. However, these models gain their efficiency at the cost of a sometimes relatively inexact dose computation, mainly concerning inhomogeneous parts of the body.

In the framework of the joint research project RADIOPLAN, supported by the BMBF, considerable progress has been achieved concerning the optimization problems mentioned above (see Department of OPTIMIZATION, page 79). Besides, the Department of TRANSPORT PROCESSES has picked up and further developed in close cooperation with the Fraunhofer SCAI another approach to dose computation in the case of photon radiation, which had hardly been followed before. It is based on the radiative transfer equation for photons and on kinetic transport equations for electrons which are set free by the primary photon radiation. These equations account for all the relevant interactions of radiation and tissue in local resolution. The effect of the radiation in inhomogeneous body parts is thus model-inherent and not to be accounted for by additional correction factors, as it is the case for pencil beam models. However, the numerical effort for the solution of these equations can be compared to the Monte Carlo models. The asymptotic development of the transport equations in the project has resulted in the derivation of simplified equations which allow for a faster dose computation, nevertheless comprising the local information of the original equations.

The simple one-dimensional radiation simulations which have been examined up to now appear very promising. The required computing time is shorter than in the case of Monte Carlo, and the results account for local inhomogeneities much more exactly than pencil beam models.



Dose computation in the case of a head-neck tumor (test data: German Center for Cancer Research)

Continuum Mechanical Product and Process Design

This main subject bundles diverse competences of the department with respect to the modeling and simulation of transport processes. We are primarily focusing here on industrial projects concerning the technical design and optimization of products and production processes. The research is based on continuum mechanical models in a very general sense, i. e. fluid dynamics, heat conduction, diffusion, radiative transfer, structure mechanics, acoustics, etc. Commercial software products (such as FLUENT® or ANSYS®) are applied for the simulation, as well as individually developed software and hybrid software solutions. The simulation of the temperature field in a floodlight, which will be described in the following, is a very illustrating example for a project coupling several of the mentioned model equations. Modeling and simulation of the problem require equations for radiative transfer, heat conduction, and convective flow.

Another main competence of the department is the handling of those models which, for reasons of complexity, require an adequate model reduction particularly with respect to optimization problems. Asymptotic and system theoretical methods are applied here. The example concerning networks of gas pipelines, which is also described below, demonstrates how the fluid dynamical description of the gas transport in each part of the pipeline can be simplified by asymptotic analysis in such a way that entire networks can be handled efficiently.

The variety of the modeling, asymptotic, numerical, and simulation problems occurring within this main subject is also continuously generating new subjects of research. Last year, PhD projects with respect to nonlinear acoustics and granular flow have been started on the basis of industrial research projects.

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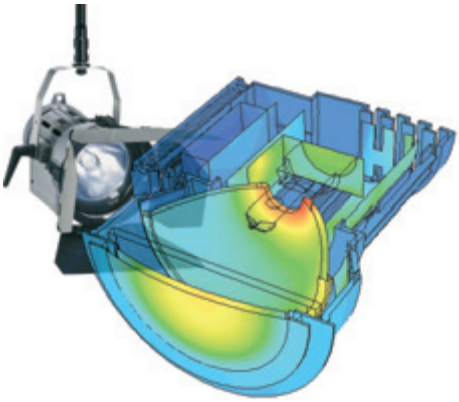
Temperature field in a floodlight

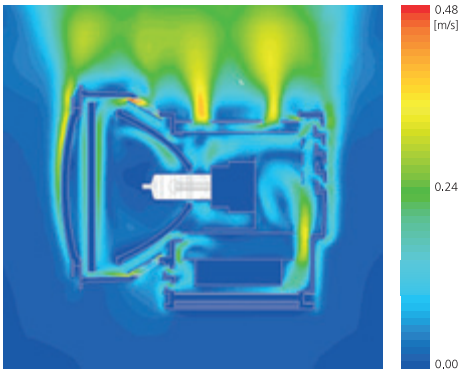
The company ARRI Lichttechnik is a worldwide leading producer of lighting equipment for, e. g., studio technology and motion-picture production. The floodlights produced by the company ARRI provide a significant thermal output due to their strong luminosity. Measurements taken by ARRI have shown that temperatures of several hundred degrees Celsius occur in the interior of the floodlights, which might damage the highly sensitive electronic parts if no countermeasures are taken. In studios or at motion-picture sets, the use of ventilators is impossible due to unacceptable noise. The floodlights are therefore cooled by convection. The floodlight cases are provided with openings, so that cool air streams into the interior, is heated at cooling plates, thus cooling the interior, and leaves the floodlight as hot air. These processes have been made visible in the framework of the project by computer simulation.

The heating of the floodlight is primarily due to surface radiation, which is emitted from the wreath filament depending on its temperature and thermal output, and is subsequently subject to multiple reflections within the floodlight. Other components of the floodlight case are also radiating, depending on their temperature. In the interior of the primarily metallic components of the floodlight, heat is transported by usual heat conduction. The air is now heated at the surfaces of these components, which initiates a convective flow. This convective flow has been modeled by the Navier-Stokes equations and the so-called Boussinesq approximation. The temperature-depending differences of density in the air are only accounted for by a so-called lift term of the impulse equation, they are not accounted for in the continuity equation. Possibly disturbing sound waves are thus avoided from the beginning, which improves numerical stability and reduces computing times. At the contact interfaces, temperature continuity and the reduction to zero of the entire heat balance was required, whereas at the exterior boundaries of the computing domain, requirements were pressure continuity and the reduction to zero of the entire mass flow. Numerical computations were carried out by the commercial software package FLUENT®, where discretized versions of the relevant equations are implemented. FLUENT® is a numerical method using the finite volume method; the computing domain must therefore be divided into smaller cells by a grid. However, the floodlight geometry is very complex, so that several geometry simplifications became necessary for the so-called meshing. These simplifications were to remain without essential influence on the results as far as possible.

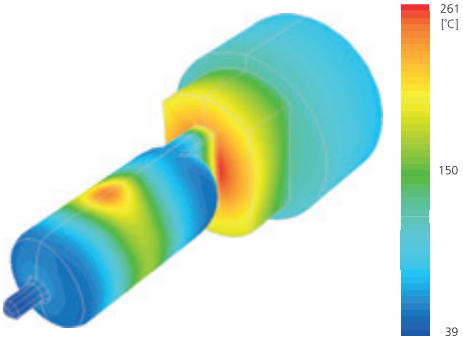
The simulation results show the formation of a convective flow through the floodlight essentially from bottom to top, as expected. The temperatures of the individual components correspond very well to those measured by ARRI. The methods developed within this project are thus able to offer considerable advantages concerning the future design of floodlights.



Simulation of the temperature field



Convection velocities



Temperature at the light bulb and the base

Gas pipeline networks

The research work described here represents a contribution to the EU project e_GASGRID. In cooperation with the department of ADAPTIVE SYSTEMS, software producing companies, business consultants, equipment suppliers, and network operating companies of the European gas industry, we examine the future demand with respect to tools for data exchange and simulation in a liberalized European gas market which is growing together, and we develop respective concepts.

The gas network operating companies are already applying diverse simulation and optimization software. However, tools for an international coordination, e. g., as planning tools for independent gas selling companies operating on an international scale, or for large-scale deviations necessary after heavy accidents, are almost unavailable yet.

A central problem is that the usual description of gas flow by partial differential equations (1D Navier-Stokes) contains far too many unknowns to be applied as a basis for optimization problems on an all-European scale. The objective is therefore the elimination of pressures and flows along one individual pipeline and their exclusive consideration at those points which are important for planning, i. e., at nodes with gas inlets or outlets, or at nodes where pipelines are divided or where there are active elements, such as compressors. For a long time now, an analytical relation has already been known between the mass flow through an individual pipeline and the pressures at the inlet and outlet for the stationary case, on the condition of acceptable simplifications (inertia can be neglected compared to friction, isothermal, constant compressibility). However, especially in the case of balancing problems or for the computation of preparation times in the case of a crisis, a transient description is absolutely necessary. An analytical solution does not exist, and node-based system theoretical models have up to now only been based on relatively naïve approaches with respect to average pressures and flows. Now, a new model has been established based on an asymptotic development of the pressure gradient for slowly varying boundary pressures, which is not only more exact for the same node distribution, but also defines under which conditions the exactness suffers, and how it can be restored by additional internodes.

The pipeline model is the foundation for a transient, Matlab®-based gas network simulator. The department of ADAPTIVE SYSTEMS (see page 59) has additionally integrated the model into the computer algebra software Anlog Insydes® as an option for the symbolic description of gas networks.

Pipeline models

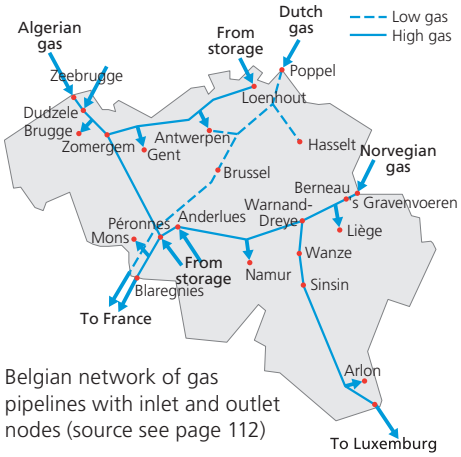
$$0 = \frac{\partial p}{\partial t} + \frac{4zRT}{\pi D^2 M}\frac{\partial Q}{\partial x}$$

$$0 = 2p\frac{\partial p}{\partial x} + \frac{16zRT\lambda}{\pi^2 D^5 M}|Q|Q$$

$$\downarrow$$

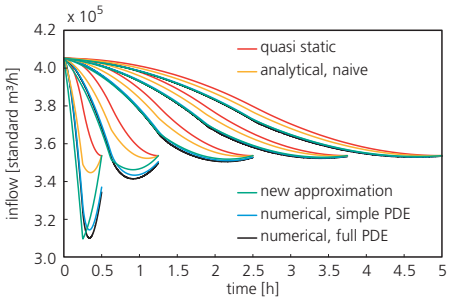
$$Q_A = sign(p_A - p_B)\sqrt{\alpha\left|p_A^2 - p_B^2\right|} + \beta\frac{(6p_A^2 + 18p_A p_B + 16p_B^2)p_A}{15(p^A + p^B)^3}\frac{\partial p_A}{\partial t} + \beta\frac{(4p_A^2 + 12p_A p_B + 4p_B^2)p_B}{15(p^A + p^B)^3}\frac{\partial p_B}{\partial t}$$

Transition from a simplified partial differential equation to an ordinary differential equation based on terminal nodes; Q defines the mass flow and p the pressure. D and λ are diameter and coefficient of friction of the pipeline. The indices A and B mark the pipe's ends. α and β comprise pipeline and gas parameters. The error is proportional to $\varepsilon^2 \sim L^3/t_{tr}^2$ (L: length of pipeline, t_{tr}: transition time for pressure variations, ε: small parameter of asymptotic development).



Belgian network of gas pipelines with inlet and outlet nodes (source see page 112)

Gas flow through a pipeline of a length of 50 km and a diameter of 0.5 m, simulated on the basis of different models; the "bundles" correspond to a differently fast, s-shape decrease of the inlet pressure from 65 to 60 bar.



Flows and Complex Structures

The department of FLOWS AND COMPLEX STRUCTURES deals with the modeling and simulation of fluid dynamical and structure elastic processes for the optimization of materials and components. One of our main competences is the efficient numerical solution of multiscale and multiphysical problems occurring in complex structures.

Current research subjects are the handling of dynamic boundaries and interfaces, complex fluids (polymers, suspensions, granular material) and their solidification, as well as fluid-structure interaction with respect to deformable porous media.

Our clients are producers of technical textiles and composite materials, metal and plastic processing companies, particularly foundries, as well as subsequent processing branches, such as filter producers and system suppliers in the field of automobile technology.

Main subjects are:

- hydrodynamics and complex fluids
- microstructure simulation and virtual material design
- structure and process optimization

"Hydrodynamics" and "Complex Fluids" represent the center of attention concerning the modeling and development of specific algorithms and software for complex fluid dynamical processes. Current applications are the coupled simulation of floodwater at the surface, in the sewer, and in the soil, the complete modeling of filter systems, and the infiltration simulation of porous layers.

The main subject "Microstructure Simulation and Virtual Material Design" has a large developing potential particularly due to the software GEODICT which was presented for the first time in autumn. GEODICT can produce virtual fiber and composite materials intuitively and fast, and is able to compute their fluid and structure dynamical properties. Software for the design of filter media will soon be available.

The main subjects "Filling and Casting Processes" and "Structure Optimization" represent a common domain of development with the primary intention of a comprehensive approach to component design by simultaneously accounting for material selection, production method, and sizing of the components. Current applications are the continuous simulation chain for the structure optimization of molded parts and the design of textile sound absorbers for automobiles.

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Hydrodynamics and Complex Fluids

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The subject "Hydrodynamics and Complex Fluids" deals with flows which are relevant for industrial as well as for ecological applications. Usually, we have to solve multiphysical problems, partly with free surfaces, and simultaneously accounting for complex rheological fluid properties. Our main focus currently is on

- Transitions from free flow to flow through porous media, e. g., filtration problems
- The two-phase flow in micro-geometries where capillary forces are also accounted for
- The flow through heterogeneous materials (composites)
- Suspensions and granular flow
- The flow of industrially relevant fluids whose flow behavior is strongly non-Newtonian.

The last point comprises, e. g., fluids with a locally varying viscosity, depending on the occurring flow patterns, or flows which can show viscous as well as elastic behavior. Especially interesting for application are liquid polymers, suspension colors, ink, pastes, glass melts, but also gels or blood. In the case of flow through porous media, deformations of the medium caused by the flow are also very interesting for industrial practice.

In the field of floodwater simulation, simplifications of the Navier-Stokes equations are applied for the simulation of floodwater development depending on the topography, the amount of rain, the capacity of the available sewer system, and the coverage of the surface.

A wide range of mathematical methods is used in order to cover adequately the variety of phenomena occurring in complex fluids. We are, for example, not only extending the applicability of the classical numerical methods of fluid mechanics (finite volumes, finite elements, and finite differences) to complex fluids, but also that of the Lattice-Boltzmann method.

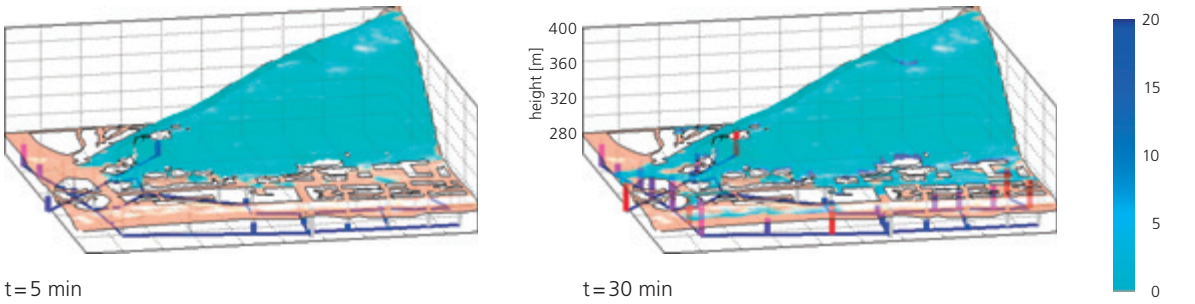
RisUrSim – floodwater simulation in (peri-)urban areas

Each year, heavy rainfall causes large damage in urban areas because the drainage systems are unable to cope with the amounts of water. However, not every floodwater event can be avoided because the long-term costs to be minimized also comprise the costs for the system installation, so that drainage systems designed for extreme events become uneconomic. Standards for a sufficient protection of the infrastructure against flooding risks are legally defined by numerous regulations, whose observance during the planning of drainage systems requires the simulation of the water run-off behavior at the surface and in the sewer system for different degrees of system loading.

Within the BMBF/Eureka project RisUrSim (Risk Management in Urban Areas – Simulation and Optimization) and in cooperation with, among others, the Technical University of Kaiserslautern, the Fraunhofer ITWM has successfully developed a computer-based method which allows the substantiation of overflow proofs according to EN 752 – in contrast to conventional methods which are only restricted to the substantiation of a surcharge proof. The decisive innovation here is the computation of the surface water run-off behavior on the basis of the shallow water equations and the bidirectional coupling of surface water and sewer network, which has thus become possible. Data processing comprises the decomposition of the computational domain into domains where the run-off behavior is to be simulated hydrodynamically, and into domains where the run-off is to be computed in a conventional hydrologic way. The second group includes domains which show homogeneous surface properties or for which no sufficient topographic data are available and which are feeding water into neighboring subdomains without backcoupling. These are in general built-up areas and the buildings themselves (roofs). A sensible description of the surface for hydrodynamic modeling requires a sufficiently dense grid of spot elevations in the urban area, whose meshing is restricted by polygons representing boundaries of houses, walls, etc. Data processing is supported by geographic information systems (GIS).

The figure below shows a sequence of water levels on the street and in the sewer system (fictitious here) for a 500 × 500 m section of a German city. Neighboring domains feed water into the streets and into the sewer system. Submerged manholes are marked in red. Sheet-like water levels on the street or in the vicinity of critical objects can be interpreted by GIS and examined with respect to their damage potential in correlation with additional data available within the system. Laser scanning and photogrammetric data can be used for an efficient development of urban surface models for large domains. Software is available in the form of the packages RisoSim (entire process) and RisoSurf (hydrodynamic surface run-off).

Simulation of water levels on the street and in the sewer system of a German city



t = 5 min

t = 30 min

SuFiS –software for flow simulation in oil filters

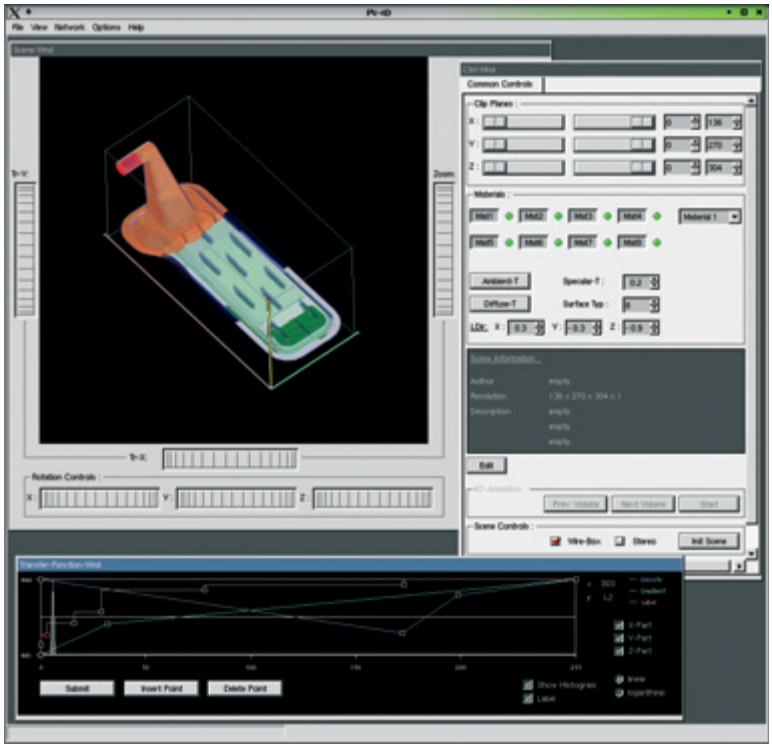
The development of special software for the numerical simulation of flow through oil filters was the subject of a project with IBS Filtran. The filtration of liquids and gases is important for many processes in automotive industry. Our project's objective is the consideration of the filtration of rigid dirt particles out of oil. Schematically, an oil filter consists of a box with an inlet and an outlet, which are completely separated by the filtering medium. The application of computer simulations has several reasons:

- possible evaluation of the pressure drop - flow rate ratio before manufacturing a prototype
- optimum design of the ribs (supporting the filtering medium) on the basis of flow computations
- evaluation of the designed box shape
- evaluation of the uniform loading of the filtering medium.

Available commercial CFD software packages do not provide the possibility of an adequate modeling or efficient simulation of the respective problems, therefore the development of specialized algorithms and software is necessary.

The special software SuFiS, which has been developed within this project, performs the numerical simulation of coupled incompressible flows in arbitrary filter housings. It is equipped with GUI, an interface for CAD data, and a powerful visualization tool (see figure below; for more information, please see p. 95 following). The development of the CAD interface is based on the level set method. The mathematical model and the developed algorithm are specialized for the requirements of filtration simulation, thus showing excellent efficiency with respect to the analysis of the investigated filtration process. The software is especially useful for small and medium-sized enterprises because its application does not require detailed knowledge in the field of computational fluid dynamics. Many of the parameters of the numerical algorithm (e. g., adaptive grids) are automatically controlled by the software, which has been achieved by the software developers' many years of experience. The developed solver provides detailed information about velocity and pressure distribution in the filter (in particular, in the filtering medium), thus assisting engineers in the design of more efficient filters.

The software can also be used for filter simulation with respect to other liquids (e.g., water).



Visualization of filter simulations by PV-4D

Liquid Polymer Moulding – moulding process simulation of liquid composite materials

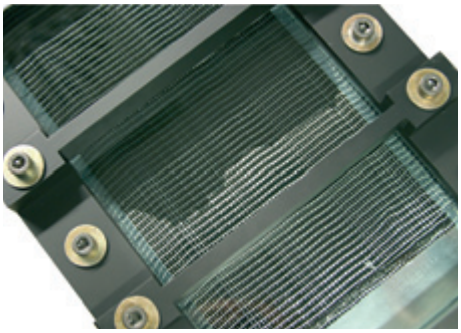
The objective of this project, which is funded by the German Research Foundation (DFG), is the development of a molding process simulation of liquid composite materials. During this process, polymerizing monomers are in situ injected into carbon fiber layings.

The project is worked upon in cooperation with the Institute for Composite Materials (IVW) in Kaiserslautern. The IVW develops the measuring technology and a pilot plant for infiltration experiments; the resulting material and process parameters represent the foundation of the modeling which is done by the Fraunhofer ITWM, and they are also used for the validation of the simulation software developed on the basis of the models.

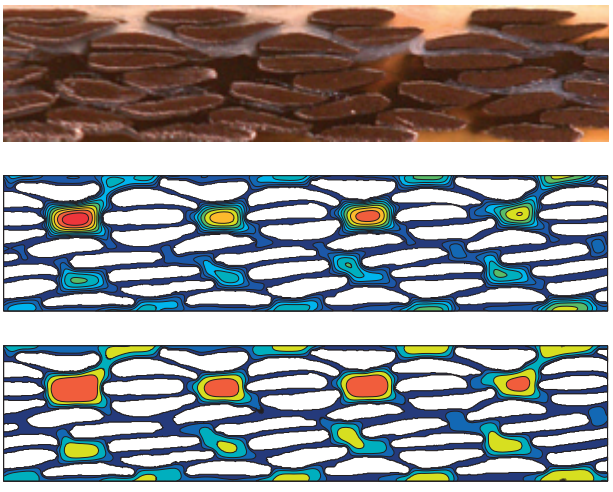
The viscosity of the original material is very important for the modeling: at the beginning of the injection, it corresponds to the low level of water, increasing towards the end of the process up to two hundred times its original value. Additionally, the initially Newtonian character of the monomer adopts a structural viscous behavior during polymerization. The low viscosity at the beginning causes high flow velocities which cannot be described by Darcy's law any longer. The structural viscous case is neither covered by this law, which means that modifications of Darcy's equations are required for both cases.

The modified Darcy equations, which are described on a centimeter scale (macro scale), include parameters such as permeability, which is determined on a micrometer scale due to the microstructure of the carbon fiber laying. The microstructure simulation developed at the Fraunhofer ITWM allows for, e. g., the computation of permeabilities. The existing rheology models of the Lattice-Boltzmann code ParPac, which has been developed at the institute, are therefore extended by non-Newtonian models, such as the Cross model.

The developments at the ITWM concerning the structural viscous case have proceeded so far that the first validation of model and software can currently be carried out by measurements.



Infiltration experiment with a clearly visible soaking front at the pilot plant for infiltration experiments of the Institute for Composite Materials



Micrograph and flow simulations of a carbon fiber laying:

the shear-thinning effects in the case of a non-Newtonian fluid (lower part) can clearly be recognized by the resulting increase of velocity. The permeability can be computed on the basis of the velocity field by averaging, and then be inserted into the macro model.

Microstructure Simulation and Virtual Material Design

A specific choice of production processes can lead to certain material properties or properties of composite materials with respect to firmness, acoustics, and filtration behavior. The approach of the ITWM is to influence, e. g., geometric properties of the microscopic material structure through the production process. The microstructure of composite or porous materials is primarily responsible for the functional properties of the composite or porous material, apart from the properties of the original material. The improvement of a material by simulation therefore requires the computational modeling of different geometric structures. In the ideal case, the modeling depends on a small number of parameters, whose optimum adaptation is computed on the basis of the simulation of the material properties.

For more than five years ITWM has been cooperating in projects particularly concerning fiber-based porous materials (nonwovens). Here, a random generation of fiber structures with a given porosity, fiber mixture, and fiber orientation distribution is coupled with algorithms for grid generation and movement, and with methods for the computation of properties. Applications include 2d micrographs generated for 3d structures with given properties, the simulation of flow resistances for the prediction of acoustic absorption properties, the flow computation of highly viscous fluids in carbon fiber layings, and the determination of effective elastic properties of fiber structures depending on fiber properties and binding material.

Since September 2003, the fiber structure generator, including modules for computational solid and computational fluid mechanics, has been available under the product name GeoDict. A workshop on the subject "Microstructure Simulation and Virtual Material Design", which took place in September, met large resonance in science and industry and will be repeated in September 2004 on the subject "Simulation and Design of Filter Materials". The project is currently focused on the virtual design of filter materials and the development of models for sintered materials.

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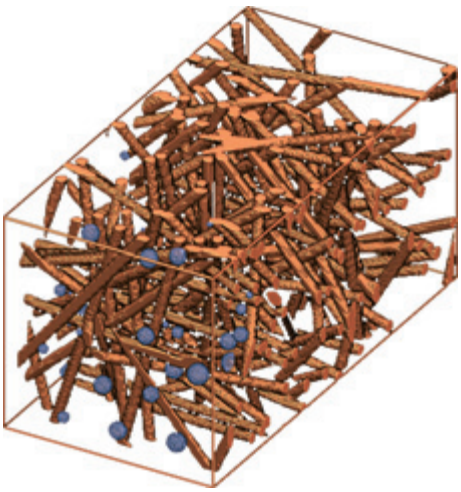
GeoDict/FilterDict – virtual design of filter materials

A project funded by the "Stiftung Rheinland-Pfalz für Innovation" has dealt with the development of software for the simulation of particle filtration in microstructures. The requirements which filters have to meet with respect to efficiency, selectivity, and absorption capacity in order to prolong life cycles (service life) are increasing continuously. Depending on the application, identical objectives may only be reached by the use of partly very different filter media, because the physical-chemical behavior of different liquids or gases and of the particles suspended therein can turn out to be very different.

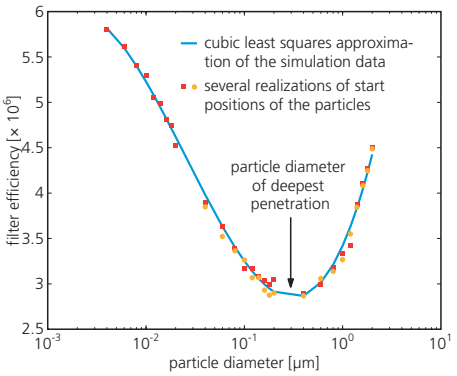
Thus, each filtration problem has one specific solution, whose determination, however, is very time-consuming and expensive by conventional methods, i. e. by the construction and testing of prototypes. The software developed within this project now allows for the accounting of many different influence factors on filtration, and for the virtual determination of the particle filtration properties of a microstructure. The integration of this software into the microstructure generator GeoDict results in a software tool which is currently unique. It allows the virtual design of filter media by extending the feature of GeoDict concerning the parameter-dependent generation of microstructures and the simulation of the flow conditions therein to the simulation of proper particle filtration (FilterDict).



The figure demonstrates how particles are moving in a microstructure and how they have partly already been deposited.

User interface of the interactive microstructure generator and simulator GeoDict

Simulated filtration efficiency depending on the size of the particles; the simulation quality corresponds to reality. There is a high probability that small particles are filtered due to their Brownian movement, big particles get stuck between the fibers. The percentage of medium-sized filtered particles is lowest.



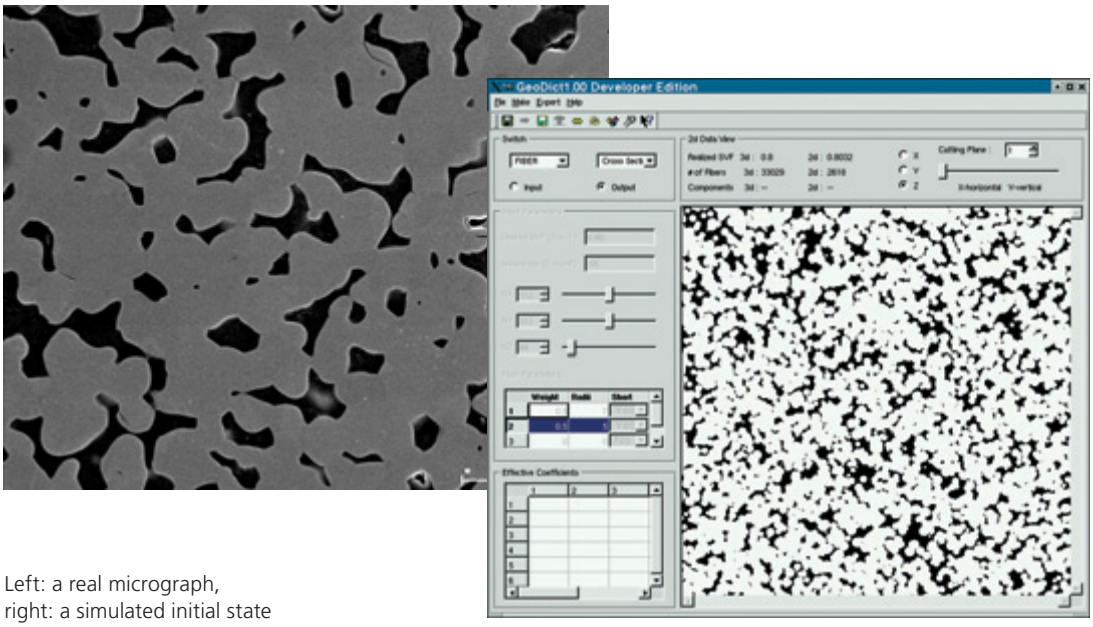
SINTERDICT – virtual material design of granular structures

Within the subproject "Structure generator" of the Fraunhofer-internal MAVO (market-oriented strategic advance research) project "Development of Comprehensive Multiscale Material Modeling (MMM tools)" in cooperation with the Fraunhofer institutes ISC, EMI, and IWM, the ITWM has taken over the task of generating granular structures occurring during the sintering process of ceramic or metallic materials. SINTERDICT serves for the generation and modification of three-dimensional granular structures occurring at different states of the sintering process, which show desired or even guaranteed properties. On the basis of these simulated structures and the resulting definition of grain properties, the partner institutes of the ITWM within the project MMM tools simulate material properties, e. g., firmness. Available commercial tools do not meet all the requirements for the generation of these structures.

The ITWM is therefore developing a specific solution corresponding to the requirements of those Fraunhofer institutes dealing with material problems. These requirements are partly of geometric-mathematical nature: by the evaluation of microscopic or tomographic images, geometric material properties – or at least two-dimensional section views of materials – can be determined by "averaging". These stochastic parameters of the generated structures must correspond to those of the real structures (see Department of MODELS AND ALGORITHMUS IN IMAGE PROCESSING, page 53).

The second important requirement is the availability of the structures in an appropriate form for the computation of properties. The department's long years of experience with structure generation and computation of properties represent the basis of this research. The main problem is the geometric quality of the generated surface and volume grids. The grids must meet adequate restrictions of the institutes where they are applied. The next step of data processing by commercial tools (e. g., ANSYS®) or tools of the Fraunhofer institutes (e. g., ParPac, DDFEM, SOPHIA) is supported by the process of grid generation.

The geometric structures specified by users as initial, intermediate, or final states of the sintering process can either be characterized on the basis of the material (one-phase or multiphase), or by the pore space geometry (open or closed pore grain packing, dense packing). If such parameters are given, realistic sintered structures can be simulated, as can be seen in the figures below.



Left: a real micrograph,
right: a simulated initial state

Structure and Process Optimization

In order to shorten product development times, simulation techniques and automatic optimization methods are applied for the optimization of component shapes, of their manufacturing process, or of the selection of materials which have been used. Process optimization is focused on filling and solidification simulations for classical metal casting processes with a subsequent computation of the residual stress by the commercial software package MAGMASOFT®. Particularly in the field of magnesium pressure casting, the first steps towards the development of an extended simulation of casting processes have been taken in cooperation with the Fraunhofer IWM, in the framework of the Fraunhofer WISA (economically oriented strategic alliance) "Magnesium Lightweight Construction" (see page 65). The simulation is based on already established simulation methods and is finally supposed to provide a prediction of the local mechanical properties of a molded part. The new aspect is the application of mathematical methods from the field of data mining (see Department of ADAPTIVE SYSTEMS, page 62) for the correlation of characteristic material parameters on the basis of appropriate results of the casting process simulation. Furthermore, we are working on the modeling and simulation of new processes in the field of plastic injection molding.

In the project *OptCast*, the simulation of the production process is coupled with automatic topology and shape optimization methods, in order to provide optimal mechanical properties during the phase of usage, and at the same time to guarantee feasibility of production. Thus, several objectives, which are partly even competing, are worked on simultaneously: we are dealing with the solution of multi-criteria optimization problems.

Apart from mechanical properties, acoustic properties of materials and components are becoming increasingly important. The design of acoustically effective nonwovens within the IPP project (see page 43) is also representing a multi-criteria optimization problem, because acoustic properties, properties concerning the production process, haptic properties, and optical properties must be considered simultaneously. Within the mentioned projects, software tools are developed and coupled, and they are tested directly by application with respect to practical examples in close cooperation with our industrial partners. This results in adequate, practical, and highly efficient solutions.

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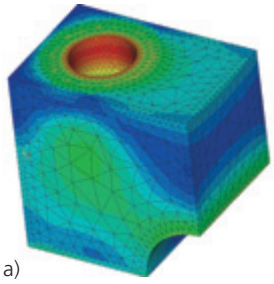
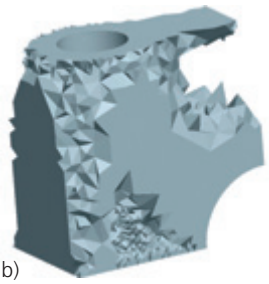
OptCast – adequate structure optimization methods for foundries



a)



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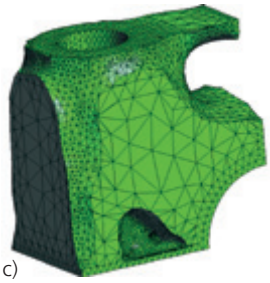

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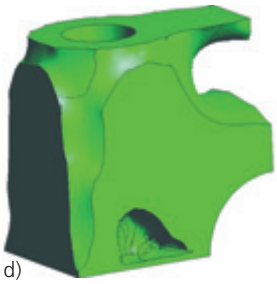


d)

Structural optimization process of a crankshaft bearing cap (for symmetry reasons, only one half of the bearing cap is shown):

a) design space with equivalent stresses in the case of complete usage of the available space

b) result of topology optimization

c) result after surface smoothing

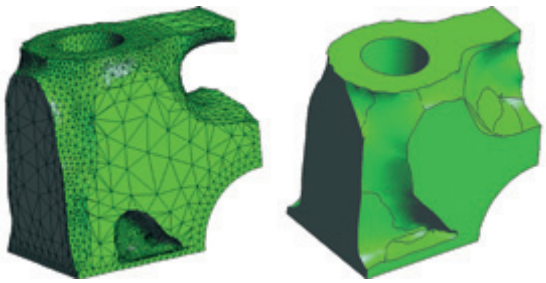
d) CAD description of the optimized structure

Within a project funded by the Ministry of Economy of Rhineland-Palatinate and the EU, the ITWM proceeds in the development of automatic methods for topology and shape optimization in cooperation with regional foundries (HegerGuss, Gienanth, Römheld & Moelle) and engineers (Müllers Büro, hg.zwo). These methods additionally account for restrictions due to casting technology and include the simulation of casting processes. Optimization criteria are mass reduction, maximum stiffness, and minimum residual stresses with respect to the molded parts, while at the same time the technical feasibility of manufacturing must also be accounted for.

In cooperation with the foundries, so-called benchmark problems were selected (here: particular types of castings), which could be used for studying the requirements of structural optimization tools for castings. The actual state of the components is analyzed by finite elements (FE), in order to be able to estimate the potential of the topology or shape optimization. A chain of CAE tools was assembled for the development of a FE model appropriate for the automatic topology and shape optimization. The model was intended to be developed on the basis of the CAD model by as few manual steps as possible. For these reasons, in cooperation with the company FE-Design, an interface was developed between the commercial software packages TOSCA (structure optimization) and PERMAS (FEM), which will be integrated in the upcoming version of TOSCA. PERMAS considerably shortens computing times regarding the structure analysis within the optimization method. At the end of the CAE chain, the improved FE model is transformed back into a CAD model.

During the work on the benchmark problems and the development of the CAE chain, it became clear that not only mathematical-physical problems were to be solved, but also technical ones. An experiment distinctly proved that the optimum shape of a molded part strongly depends on the material which has been used and its solidification properties. Hence, data from solidification simulation must also be included in the optimization, in order to be able to account for the material properties adequately.

A range of software tools for the development of improved castings are available. The computations are very complex and can only be carried out in an acceptable time span on modern parallel computers, which is why the ITWM will offer the use of its Linux cluster for the structural optimization of molded parts in the future – as it has already been doing for some time now with respect to the simulation of casting processes by the software package MAGMASOFT®.



Optimized crankshaft bearing cap:

left: without given restrictions due to casting technology;
right: with a given demolding direction with respect to a middle plane; holes in the middle plane are explicitly not allowed.

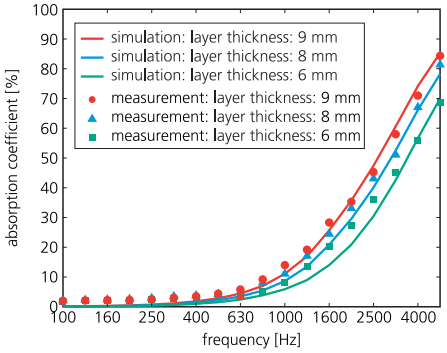
AdOpt – integrated product policy (IPP) for acoustic trims in automobile construction

The result of this project, which is funded by the Bavarian Ministry for Environment, Health, and Consumer Protection, is a simulation tool for the modeling and optimization of acoustic trims on the computer.

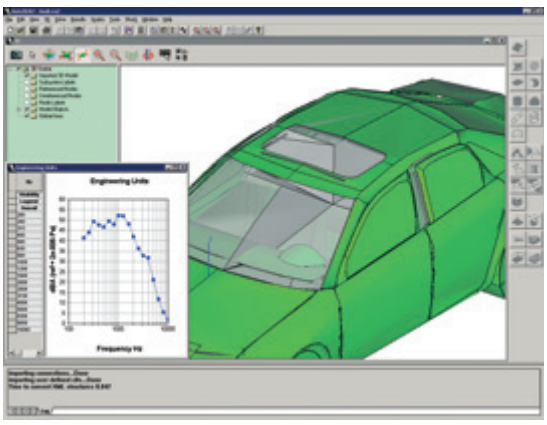
Most of the acoustic trims which are currently used in the interior of an automobile consist of a mixture of different synthetic and natural materials. Consequently, recycling these parts according to the new EU Directive on End-of-life Vehicles (2000/53/EC) is very complex. Therefore, cooperation was initiated with the companies Audi, Faurecia, and Sandler, resulting in the necessary know-how for a substitution of these composite materials by pure materials. We have selected PET press nonwovens as an example for application, because they offer enormous possibilities for variation during the production process, e. g., with respect to fiber diameters, layering of the nonwovens, and molding degree. The simulation software AdOpt, which has been developed within this project, allows an extensive automated examination of variants, simultaneously reducing the necessity for the construction of prototypes, which is time-consuming and expensive. First steps are the development of an adequate computer model for the microstructure of the PET nonwovens and the direct computation of the material properties. Knowledge about the acoustic efficiency of the examined materials allows their correct integration into the acoustic model of the entire automobile. The acoustics of the automobile interior in the medium and high frequency range is simulated at the ITWM by the software package AutoSEA®.

The development, production, and assembly of system components during automobile construction are usually divided between several partners. Therefore, the new simulation tool has been implemented as a Web solution, which guarantees common access of all participating partners across company boundaries.

One result is that the company Sandler AG has been able to produce an optimized PET headliner – on the basis of the computer simulations –whose acoustic absorption properties exceed those of standard headliners. It is a main objective of the project to guarantee the possibility of transferring the method also to the production of other components. The new approach of predicting the acoustic properties of components and their interaction with other components on the basis of the microstructure can also be applied to numerous other materials, e. g., natural fibers, papers, foams, or ceramic materials. In practice, the acoustic properties of a component are only one aspect of design among numerous others. Depending on the application, other aspects, such as thermal insulation, filter efficiency, stability, or weight of the component are of decisive importance. Based on the microstructure of the material, these parameters can also be simulated on the computer and can thus be simultaneously accounted for during the optimization of the component. This field of multi-criteria optimization will be one focus of the future research work of the department.



Measured and simulated acoustic absorption curves



Acoustic simulation of the entire automobile by AutoSEA®

Models and Algorithms in Image Processing

The department MODELS AND ALGORITHMS IN IMAGE PROCESSING is primarily working on the following subjects:

- surface inspection
- signal analysis for railway systems
- analysis of 3d microstructures
- analysis of image and video sequences
- cryptology

Our main focus is the development of complex algorithms for image and signal processing, and their implementation into efficient software within complete systems.

The successful year of 2003 was characterized by balance in every domain. We have a wide range of experience in the field of surface inspection – especially with respect to the development of algorithms and systems for the monitoring, examination, and evaluation of textured surfaces (e. g., paper, textiles, nonwovens, wood, fiber plates, and coatings). Also in 2003, especially tailored inspection systems for industrial application were integrated into the production processes of several customers.

The development of autonomous railway monitoring systems, which has been the subject of our research for many years now, also was continued in 2003 without interruption.

The field of 3d image analysis is increasingly gaining importance because the technical possibilities for a three-dimensional high-resolution representation of different materials are developing very fast. Our research is focused on the determination of geometric features of material microstructures. On this basis, 3d models of these materials are developed which reflect the geometric structures very well. These new possibilities of material analysis are also increasingly realized by industry, which can be documented by a growing number of customer inquiries. Besides, the commercial software a4i 3d for the analysis of three-dimensional images has been successfully developed and introduced on the market in cooperation with the company aquinto. A library with a similar range of functions for Linux systems is also available.

In the main subject Analysis of Image and Video Sequences, the development of a complex search system for data bases or video sequences, based on image similarities respectively image features, was continued in cooperation with our partners.

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Surface Inspection

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One of the main competences of the department MODELS AND ALGORITHMS IN IMAGE PROCESSING is the surface inspection for industrial quality control.

In contrast to manual quality control, which is still applied very often but either only allows for the examination of random samples or cannot be carried out during the production process, the methods of the Fraunhofer ITWM allow for an online defect detection and classification, so that early intervention in the production process become possible, e. g., in the case of serial defects. Automatic optical surface inspection does not impair the production. Besides, the resulting objectivity guarantees a constant quality of the inspected parts.

The manual control mentioned above is carried out by especially trained personnel. These have enormous visual auditors skills and are specialized on their current task. The automatic surface inspection systems developed at the Fraunhofer ITWM are working in a similar way, i. e. they are adapted to the particular requirements of the customer and the local conditions.

Applications range from paper and textile industry and metal and leather processing industry to the suppliers of automobile industry. In order to meet the requirements of such a large number of possible applications, we have developed a modular system (MASC - Modular Algorithms for Surface Control) comprising a large number of tools and system components ready for use. The components are organized according to a modular structure, thus offering an appropriate basis for fast and flexible solutions for almost every individual task concerning surface inspection.

In the following, several of the applied methods and solutions based thereupon will be presented in detail by means of two current projects.

OPAQ: inspection of unpainted free formed surface parts

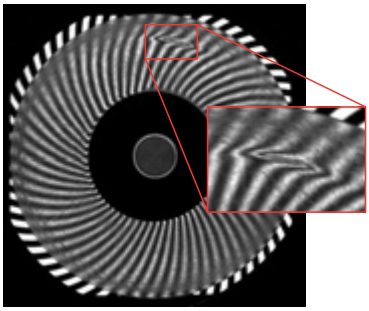
During the processing of free-surface parts, surface defects are unavoidable, many of them already resulting from the reshaping process of the parts. In order to reduce post-processing after the painting or anodic oxidation processes and to guarantee a constant quality level, it is necessary to detect and eliminate surface defects as soon as possible. The objective of the joint research project OPAQ, which is funded by the BMBF, is the detection of such defects during the first processing step of the raw material (e. g., during the molding or deep-drawing process).

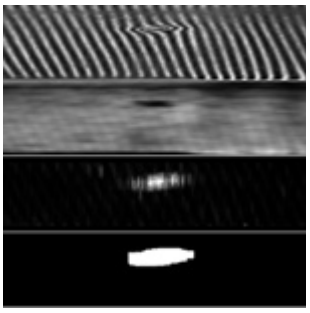
One of the practical applications, in cooperation with our partner Seidel GmbH in Marburg, is the detection of surface defects in the case of strongly reflective caps for perfume bottles and lipsticks. Very small defects of the surface geometry (bumps, scratches) and surface structure (polishing defects, rough zones) must be detected online during the production process. For example, microscopically small scratches in the raw parts with a depth of only 0.02 mm, due to the high degree of reflection, result in surface defects after the anodic oxidation treatment which can be recognized very clearly, thus leading to customer complaints.

The company Steinbichler Optotechnik GmbH in Neubeuern and the Fraunhofer ITWM have cooperated in the development of new image acquisition and processing methods for the detection of such small defects on reflective surfaces. In order to render the complete lateral surface by one image, a projection system via a conic mirror has been developed. The variety of defect types and their appearance has lead to the development of two measuring systems: in the case of surface deformations, a method of image acquisition by a stripe pattern (stripe image), whereas variations of the surface structure are detected by dark-field illumination (dark-field image) has been selected.

There are two methods for the evaluation of the stripe patterns: the first one is a more or less classical variant, where the variations in the stripe pattern are determined by the formation of gradients. The second variant refers to a 2.5d image computed on the basis of the stripe image. First, on the basis of the image information, the deviation with respect to a defect-free surface is estimated by a linear filter. Defect areas, such as dents or bumps – in contrast to noise -, correspond to relatively large values of this deviation image. In a second step, so-called defect candidates are determined by smoothing and adaptive threshold values. The focus of the dark-field image is the determination of local variances by covariance computation. The relevant defects are computed by an adaptive threshold value.

At the moment, the demonstration system is evaluated by practical tests. The objective of the research project is the development of a (semi-)automatic system with manual feeding which meets practical requirements.



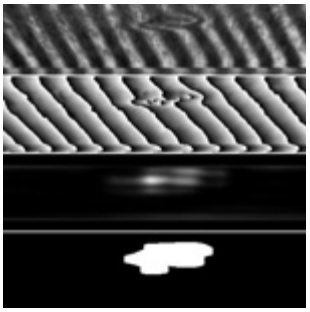


Method 1:
Unwrapped lateral surface

Contrast image

Variance image

Resulting image



Method 2:
Unwrapped lateral surface

Phase image

Variance image

Resulting image

Evaluation of stripe images by different methods

Surface inspection of gaskets

At the company MSC/GAC in Eisenach, up to now the surface quality control of compressor gaskets took place in the following way: a first, very rough control was carried out directly after the punching process. The punched parts were stapled and stored, in order to pass through an individual manual hundred-per-cent-control afterwards. This last step took place considerably later.

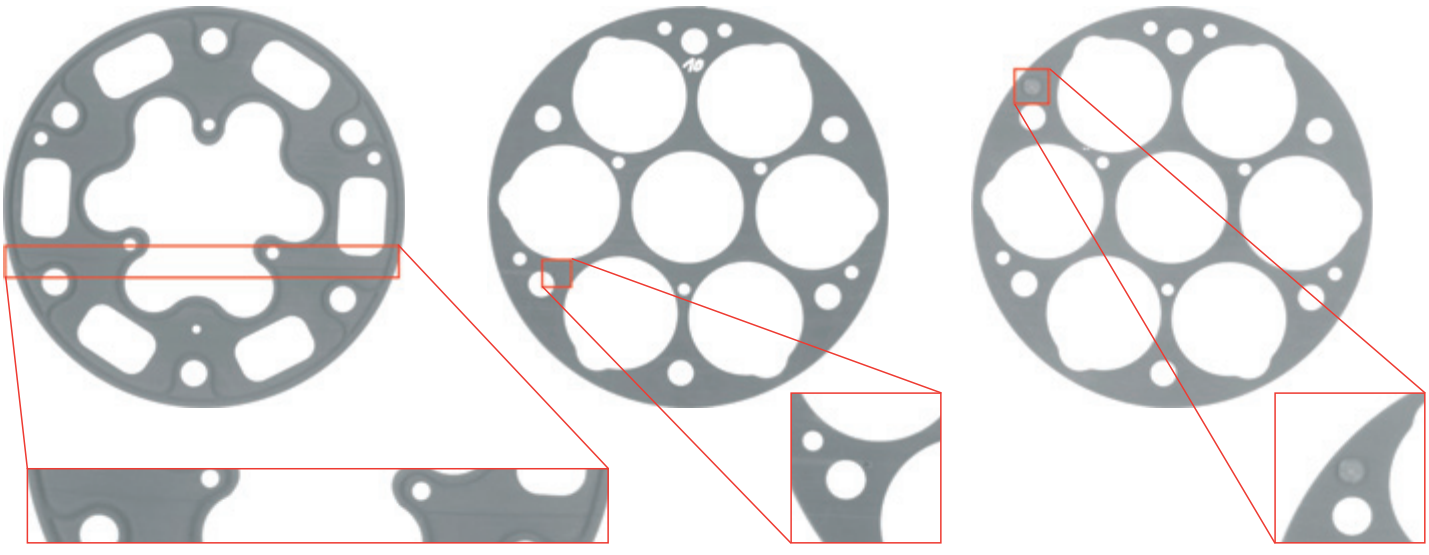
The considered gaskets are rubber-laminated metal parts of different geometries which can show different surface defects, such as bubbles, contaminants, or dents and scratches resulting from the punching process. Traces of paint or adhesive may also occur.

The task of the Fraunhofer ITWM consists in developing an inspection system which is integrated into the production process, thus reducing the inspection time considerably. The automatic defect detection reaches a degree of objectivity which is almost impossible in the case of manual control. Besides, the fast detection of serial defects becomes possible, which otherwise can lead to a large number of rejections during production.

The method consists of several steps, always observing the top and bottom side of each gasket. Due to the partly very complex shape of the gaskets, which also show holes and bulges, the method works with samples of the same shape serving as reference for a go-workpiece. After the image acquisition of the inspected part, the relevant image section must be found. In the next step, the image of the gasket to be examined is adjusted to the reference image with respect to displacement as well as rotation, in order to allow for a comparison with the reference parts. In such a way, boundaries and structures are to be recognized as far as possible, so that they are not accounted for during defect detection. Different methods are required for different types of defects (mainly with respect to their size) in order to bring them out in the best possible way and to allow for comparisons with the reference part. When the comparison is completed, the relevant positions are marked; a graphic representation is also possible here. The examined gaskets are sorted with respect to go- and no-go-workpieces, and detected defects are classified. Finally, type and frequency of the occurring defects are documented statistically.

If the respective reference parts are available, a fast and automatic teaching of new types of gaskets with similar surfaces is also possible.

Scratch, bubble, and dent as defect examples (The gaskets are represented at a scale of approximately 1:2.)



Monitoring for Railway Systems

The ITWM develops and maintains the software for the chassis monitoring sleeper (FÜS) for the company GE Transportation Systems in Bad Dürkheim. The software is running in more than 400 systems throughout Europe.

The monitoring of overheated axle bearings and stationary brakes on passenger and freight trains requires a remote measurement method. In the solution selected here, the temperatures are measured by registering the infrared profile of the passing chassis, and the resulting data are transferred to a PC. It may also happen that not only the data for a wheel are registered, but also foreign radiation data, e. g., caused by the sun or the brake blocks. These cases are dealt with by special methods, in order to determine wheel or bearing temperatures correctly. The system works without human control, which is why an appropriate self diagnosis system for the hardware and software is also integrated, as well as an exception and error handling system. The results of evaluation and self diagnosis are transferred to a central system which, e. g., arranges for a stop of the train at the next station.

The measurement data also provide information about the type of chassis and brakes, in order to allow for a correct detection of the different type-dependent temperature profiles, thus avoiding false alarms.

The registration hardware and data transfer from the sleeper to the evaluating computer have been modernized thoroughly for the new generation of the chassis monitoring sleeper. The evaluating computer consists of an industrial PC with special additional components and is running under Linux. Apart from the evaluation software, additional software packages have been developed, such as self diagnosis software, drivers, user interfaces, and server software. Measurement data and protocols are saved centrally on an archive server, representing the basis for the refinement of evaluation algorithms.

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3d Image Analysis and Modeling of Microstructures

Concerning the examination of materials, three-dimensional images of their microstructures are acquired more and more frequently. Usual methods are micro-computer tomography on the basis of X-rays or synchrotron radiation, confocal laser-scanning microscopy, or AFM (atomic force microscopy). In contrast to classical microscopic methods, these methods yield the entire information about the 3d microstructure, which cannot be reconstructed on the basis of 2d images, or only with considerable effort. Moreover, these methods are also able to capture the microstructure of very soft, fragile, or highly porous materials, for which conventional microscopic methods fail because the preparation of planar sections or microsections is impossible.

There are fully developed tools for the visualization of 3d image data sets which usually also include image processing components. In comparison, the methods for the analysis of 3d images of complex microstructures have not yet been developed very far up to now. At the Fraunhofer ITWM, we have provided the mathematical foundations of the 3d image analysis and implemented the respective algorithms. This year, a complete software system (a4i 3d for Windows) and a software library (a4iL for Linux) for 3d image analysis have been made available. Both are based on the analysis methods developed at the ITWM.

The combination of stochastic geometry, three-dimensional statistics, and image analysis not only allows for the application-specific analysis of very different 3d structures, but also for the ereation and fitting of geometric models for the numerical simulation of macroscopic material properties.

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System a4i 3d and library a4iL for the analysis and processing of three-dimensional image data

a4i 3d, which has been developed in cooperation with the company aquinto AG, Berlin, is a system for 3d image processing and analysis, driven by a user-friendly menu and including a visualization tool supporting the analysis. Its modules allow for the analysis of, e. g., open foams by simply pressing a button. A high modularity guarantees the solution of various industrial and research problems. a4i 3d is sold as a complete system for Windows by aquinto.

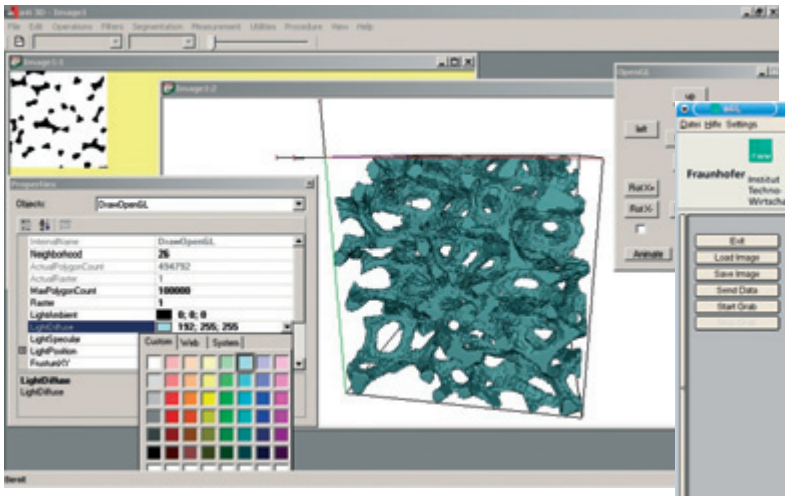
a4iL is a pure C-library with the same functionality for image processing and analysis under Linux. Besides, a4iL also offers the processing and analysis of two-dimensional images, as well as the modeling of selected structures. a4iL has been created on the basis of the development environment used at the ITWM and is structured in the form of a tool box. Therefore, the adaptation to customer requirements (e. g., loading of a desired image format), the combination with individual software, and the solution of customer-specific problems are possible very quickly. a4i 3d and a4iL are based on analysis algorithms, which are completed by algorithms for image (pre-)processing and segmentation: filter and morphological transforms, distance and watershed transform, skeletonization, Fourier transform.

Geometric parameters of components and particles

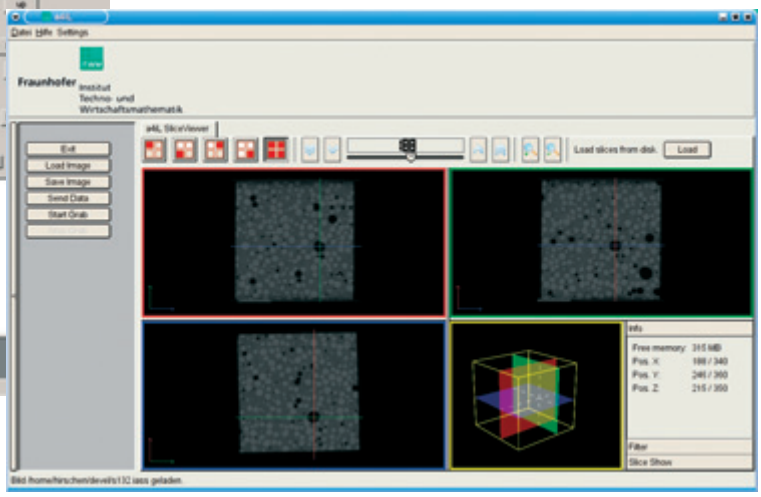
a4i 3d and a4iL are specialized on the characterization of the complex geometry of microstructures. The core of the analysis is the determination of basic geometric parameters – of entire components of the structure, if we have to deal with a section of a macroscopically homogeneous material, or individual particles or cells, if these can be identified. Characteristic properties, such as porosity, specific surface, density of the Euler number, mean chord length, fractal dimension, mean fiber length per volume unit (for fiber materials), number of particles (in the case of isolated particles), or information about preferred directions and strength of occurring anisotropies, can be determined fast and robustly. The algorithms combine methods of integral and stochastic geometry with digital image processing methods. They are primarily based on discrete versions of classical results of integral geometry, such as the Crofton formulas. The addition of simple model assumptions also yields the mean cell size (for open or closed foams).

Three-dimensional objects (particles) can be isolated exactly and quickly with an algorithm developed at the ITWM. Object features (volume, surface, curvature, diameter, shape, orientation …) are also determined by methods of integral geometry.

a4i 3d and a4iL also offer spectral analysis as a further analysis tool. Research at the Fraunhofer ITWM with respect to the spectral analysis of random sets has provided the mathematical foundation for the applied methods.



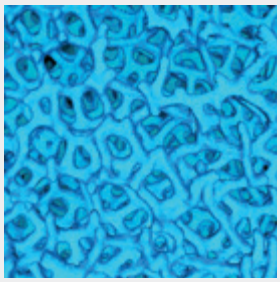
a4i 3d: application example – analysis and 3d visualization of an open foam



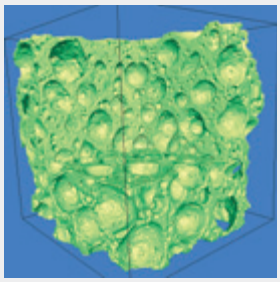
a4iL: graphic user interface (currently being developed) – visualization of refractory concrete by 2d cross-sections in three directions of space

Service: analysis of three-dimensional image data

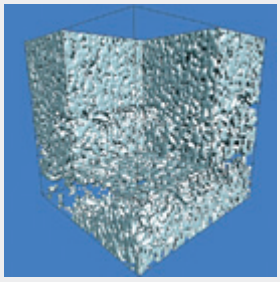
Apart from the development of algorithms and their mathematical basis, the ITWM also offers the service of the analysis of microstructures. Depending on the material, the ITWM is cooperating with different partners with respect to image acquisition (Fraunhofer IZFP, RJL Micro & Analytic GmbH, Alfred Wegener Institute for Polar and Marine Research). Examined materials include metal and polymer foams, ceramic materials, concrete, fiber nonwovens for vacuum-cleaner bags, and snow.



Nickel foam



Porous concrete



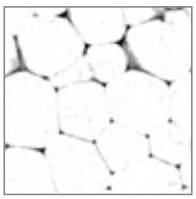
Snow

Analysis of open foams

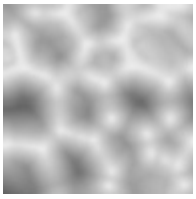
If individual objects are to be measured, they must first be separated by object isolation or watershed transform. However, a more complex method is required for the determination of pore size distributions, because the pores or cells must be reconstructed by image analysis. Smoothing, a subsequent distance transform, reduction of the distance transform, a further smoothing step, and finally the watershed transform yield a system of pores whose borders represent the edges of the original image. Size and shape, for example, can then be measured on the basis of these pores.

Cross-section of the 3d data set:

Reconstruction of a µCT image of a closed polyurethane foam

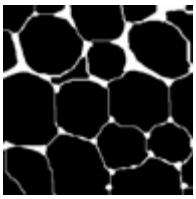


Distance image



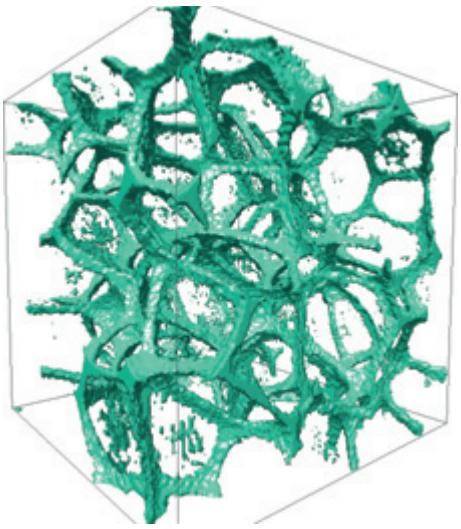
Result of the watershed algorithm, applied to the smoothed distance image

Reconstructed cells (black) and cell walls (white)



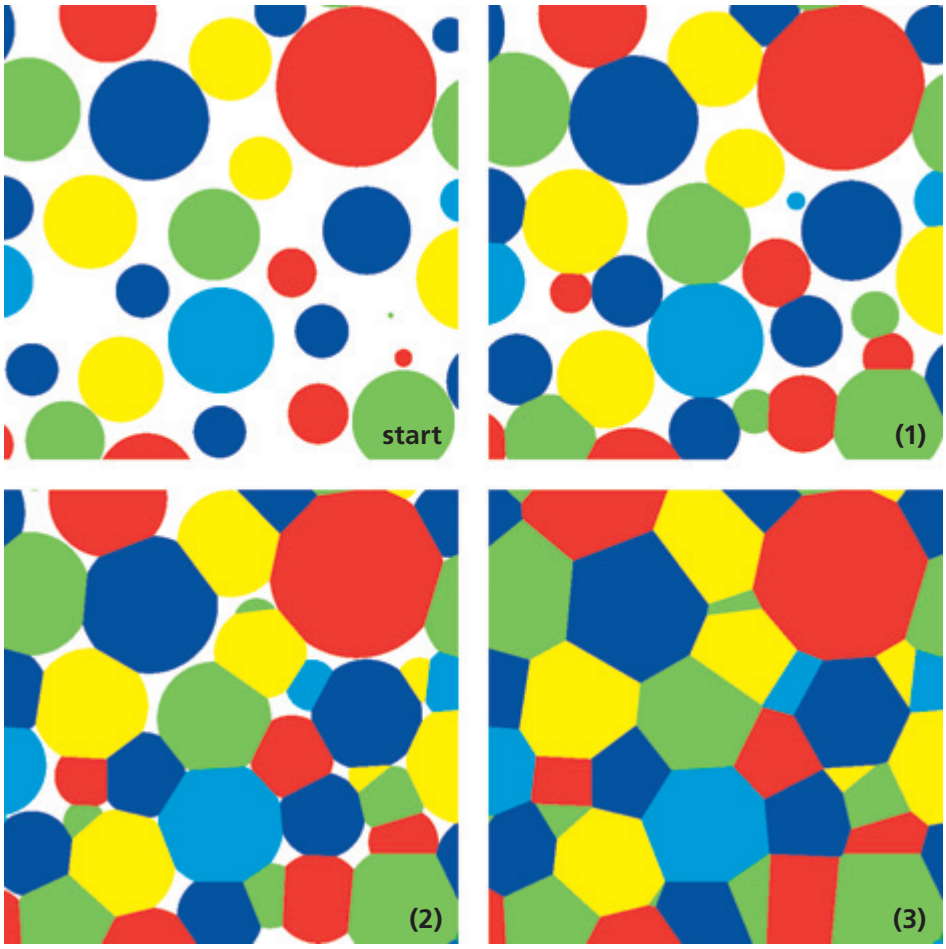
Reconstructed cells (each color corresponds to a cell) and cell walls (white); on the basis of this image, the geometric characteristics of the pores can be measured.

3d visualization of the polyurethane foam



Modeling of sintered structures

In the framework of the SINTERDICT part of the Fraunhofer-internal MAVO project "Development of Comprehensive Multiscale Material Modeling (MMM tools)" (see also page 40), the department MODELS AND ALGORITHMS IN IMAGE PROCESSING develops models for the microstructure geometry of diverse sintered materials at different states of the sintering process. The selected models must be very flexible, because even identical materials show completely different geometric structures under different conditions. Dense packing is a good model for the initial state of the sintering process. In the final state, the sintered particles fill the space completely, i. e. they form tessellations, which is why Voronoi tessellations and generalized Voronoi tessellations (Laguerre and Johnson-Mehl) are suitable for the description of the final state. In order to give the user also access to arbitrary intermediate states, it is desirable that intermediate states should be developed continuously on the basis of the initial state by a kind of growth process. Models are fitted using the information about the sintered particles which have been used and by simple geometric parameters, such as porosity. Other characteristics, such as the pair correlation function of the centers or the chord length distribution, serve for the model validation.



As initial state, we use a packing of 200 spheres with a discrete radius distribution in a cube of a side length of 600 pixels. During the growth process, the spheres are expanding (1), touching each other (2), and finally forming a Laguerre tessellation which fills up the entire cube (3).

Analysis of Image and Video Sequences

I-Search: development of a contents-based image search engine on distributed systems

The aim of this project supported by the BMBF is the development of algorithms and of a parallel software architecture as a basis for a high-performance contents-based video and image search engine.

The subject of security, which is strongly in discussion at the moment, for example involves the task of searching for a lost piece of luggage at an airport monitored by intelligent web cameras, or of detecting and identifying a person of conspicuous behavior. The solution requires robust and event-controlled video analysis and face recognition methods on distributed systems which are able to provide online results for the security personnel. In the fields of broadcasting and internet, the main problems are the fast finding of scenes in media archives or the contents-based search for images.

In cooperation with partners from industry and research, methods of fast online image processing on distributed systems are combined with high-performance algorithms and, depending on the requirements, connected to the respective database and internet technologies. The ITWM develops a component-oriented parallel software architecture which can be operated on a failure-proof system of SMP(PC) clusters and computing grids, as well as on highly distributed systems of small high-performance computers, as they are occasionally offered in the web cameras.

The application of the I-Search cluster requires the system to meet high standards of performance and reliability, which is why load distribution and fault tolerance mechanisms are necessary within the architecture. These have partly been designed and implemented during the framework of a master's thesis. The integration of these strategies enables cluster nodes to detect failures of their own components and also of other nodes, and to initiate the respective fault recovery mechanisms.

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Cryptology

In order to guarantee the protection of information from unauthorized access in a time relying on electronic data transfer, a continuous development and refinement of cryptologic methods is necessary. The application of asymmetric methods is essentially important for achieving the objective of secure communication.

The most well-known asymmetric cryptosystem is RSA. Its security is based on the fact that the factorization of a large integer number is generally considered to be difficult. The current factorization record is held at 158 decimal digits for the composite number. Today, even 512-bit RSA keys cannot guarantee security any longer. It is therefore important that alternatives are available, which, however, mostly have not yet been able to compete with RSA with respect to run time and security.

Elliptic curves have proved to be a good basis for cryptosystems which can seriously compete with RSA. Their security is based on the problem of computing discrete logarithms in the group of rational points on an elliptic curve. Generally, this is already difficult for relatively small parameters, which is why these systems guarantee high security also for small keys. Therefore, they are used particularly in the case of Smart Cards and comparable environments. Hyperelliptic curves are generalizations of elliptic curves. Their advantage is a larger selection of appropriate parameters and the resulting higher security.

Within a project in cooperation with the company BGS Systemplanung AG, the Fraunhofer ITWM has developed algorithms for the determination of subfields and the explicit computation in the ring of endomorphisms of hyperelliptic function fields. These algorithms allow for a test with respect to possible weaknesses of the selected parameters and provide information about the structure of the Jacobian. Essential parts of the research results were presented during the conference "Efficient Methods in Algebraic Geometry" (MEGA) 2003.

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Adaptive Systems

Research of the department of ADAPTIVE SYSTEMS is mainly focused on the data- and knowledge-based modeling of technical and biological systems and processes. The models resulting from the application of adequate methods provide new knowledge about processes and allow for the prognosis of process behavior. Besides, control algorithms are developed on the basis of the identified models.

During the last few years, the research of the department has been concentrating on the following subjects:

- CAD for analog circuits
- monitoring and control
- biosignal processing and diagnosis support
- prognosis of material and product properties
- multiscale structure mechanics

The practical problems connected to these subjects are solved on the basis of the mathematical main competences of the department from the fields of system and control theory, stochastics and statistics, data mining, and asymptotic homogenization.

Apart from the work on publicly funded and industrial research and development projects, the continuous development and refinement of individual software products is very important in the department. During the year covered by this report, Analog Insydes®, our CAD tool for the support of analog circuit design, was further developed with respect to the integration into the industrially established Cadence Framework, and with respect to improved user friendliness. The series of monitoring tools for rotating machinery was complemented by a module for the detection of subsynchronous resonances.

Although general conditions, particularly in the field of public funding, have worsened, the year covered by this report did end quite positively for the department. Industrial customers have remained true to the department, and new promising contacts could be established.

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Jan Hauth, Dr. Alex Sarishvili
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Not on the picture: Harriet Bach, Frank Kneip, Tim Wichmann

CAD for Analog Circuits

We are working on methods and tools for the modeling, analysis, and sizing of linear and nonlinear analog circuits with the help of symbolic methods. In this context the EDA tool Analog Insydes® (www.analog-insydes.de), has been developed by the department. Our objective is the integration of symbolic methods into the industrial design flow, thus supporting the circuit designer in their daily work. The software is based on mixed symbolic / numerical algorithms for linear and nonlinear differential algebraic systems of equations (DAE systems).

There is a large number of various industrial applications for symbolic methods, ranging from classical circuit understanding to error analysis, and from circuit sizing and optimization to behavioral modeling on the mixed signal or system level. Especially the automatic behavioral modeling is a very promising approach with respect to the simulation of heterogeneous systems (system simulation). This aspect is gaining particular importance for industrial hardware development, because the complex development of hardware prototypes can thus be avoided, including the development costs.

A special challenge is heterogeneity, i. e. the coupling of various hardware components from different physical areas. For example, the department has simulated an electrochemical measuring device by system simulation. Main components were the control and analyze electronics of the device, as well as a three-dimensional model of an electrolytic cell on the basis of electrokinetic, enzyme kinetic, and diffusive processes. System simulation can thus be helpful for the examination of the component behavior and their interaction among each other already before the realization of a prototype.

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ANASTASIA 2

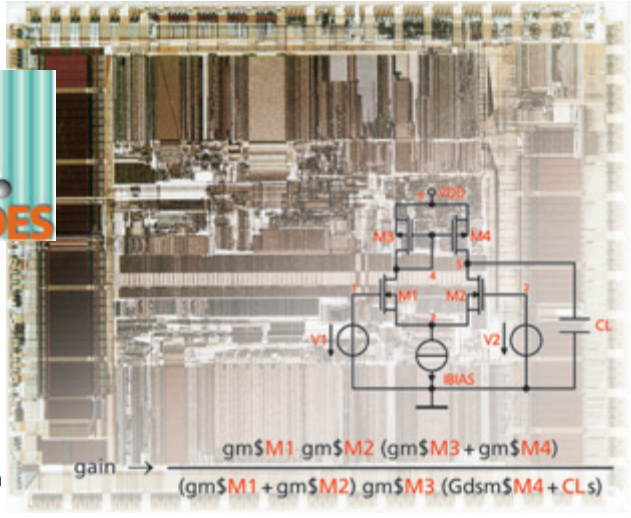
The first phase of the European joint research project ANASTASIA+ has been concluded successfully. In the second phase, the ITWM is now working on the subjects "Methods for the Application of Symbolic Analysis" and "Methods for the Generation of Behavioral Models for Nonlinear Circuits". One objective is the development of specific solution procedures for particular circuit classes, in order to provide the industrial designer with a more intuitive access to the symbolic methods, thus enabling him to solve analysis and modeling problems efficiently on his own. Besides, the nonlinear simplification methods have been expanded with respect to the transient circuit behavior, which is also accounted for. Essential aspects are the development of a reliable and efficient evaluation function, as well as the index control of the simplified DAE system.

e_GASGRID

This European FP5 project, on which we are working in cooperation with the department of TRANSPORT PROCESSES (see page 31), deals with the examination of gas pipeline networks. The symbolic methods, which originally stem from the field of microelectronics, were successfully transferred to this new application field. The adaptation was restricted simply to the development of adequate models for the typical components of gas pipeline networks (pipelines, compressors, reservoirs, deliveries, etc.). The simplification methods could be transferred directly due to their general mathematical approach. Thus, an actual national pipeline network could be successfully reduced to a few dominant components. Compared to a description of the complete system, this method offers decisive advantages for simulation or for the solution of optimization problems.

User seminars

For professional users, the Fraunhofer ITWM organizes a seminar of several days offering theoretical and practical knowledge with respect to the application of Analog Insydes® for circuit design.



Symbolic methods for chip design with Analog Insydes®

Monitoring and Control

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The research work of this group is focused on the development and implementation of mathematical methods for system modeling and for observer and controller design. Main applications are technical systems, such as turbine generator shaft lines or test rigs for automobiles.

Mostly, an adequate substitutional model is required for the description of a certain behavior of a technical system. The model should represent the interesting system aspect as exactly as possible. Depending on the available system information and the desired model properties, black box models, white box models, or a mixture of both, so-called grey box models, are used. Apart from linear approaches, more complex nonlinear methods are also applied here, for example a network consisting of several linear models of local validity – a so-called local model network (LMN). The linear sub-models may be black box as well as white box models. The different modeling approaches can, e. g., describe the behavior of turbine generator shaft lines or of test rigs for automobiles.

Observer and controller design is based on the identified models. Although the design is also based on classical methods, methods of H_∞ control theory are principally applied here, which guarantee more robustness of the resulting observer or controller with respect to model uncertainties and other system disturbances. Additionally, methods from the fields of adaptive control, iterative learning control, and model predictive control are also used.

The control methods based on linear models may often turn out to be insufficient, e. g., in the case of a strongly nonlinear system behavior. A main subject of our group's research therefore is the development of expansions of the linear control strategies on the basis of the LMN models. We are especially concentrating on the development of efficient and robust methods.

Systems for monitoring and analysis of torsional behavior

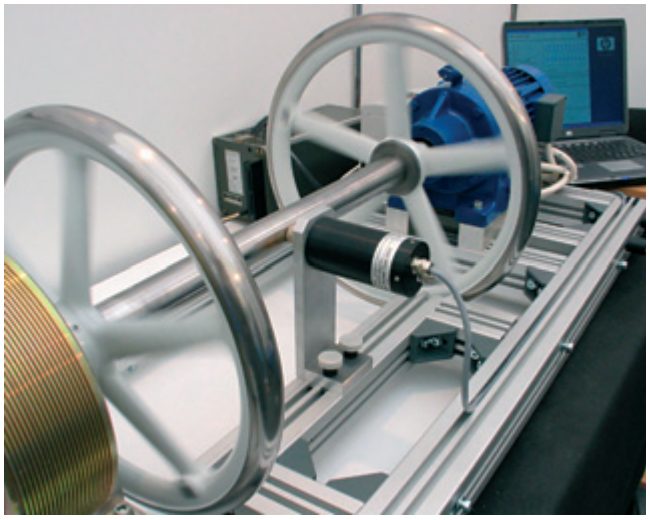
In the last few years, the software packages TorStor, TorFat, and TorAn have been developed within this research area. In combination with a contactless torque sensor which is exclusively marketed by the Fraunhofer ITWM, they represent differently focused individual systems for the monitoring and analysis of torsional oscillations. The online monitoring systems are applied in the case of rotating shafts. Particularly in the case of long-term monitoring of turbine generator shaft lines in power plants, they have proved to be very effective in practice. Further applications are, e. g., wind electric power stations, where they can be used as analysis systems for torsional behavior in addition to the conditional monitoring systems which are prescribed by insurance companies, thus providing further information about the state of the generator shaft. Sensor and software were presented to measurement engineers during the fair Sensor 2003 in Nürnberg, and especially to the producers and operators of wind electric power stations during the fair HUSUMwind 2003 in Husum.

Monitoring of subsynchronous resonances

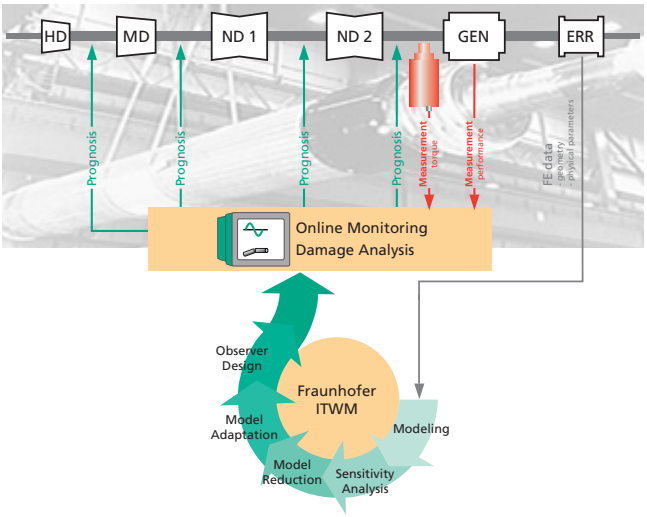
In cooperation with our project partner, the Institute for Electrical Machines, Drives, and Power Electronics of the University of Dortmund (Prof. Stefan Kulig), the software tool TorFat was expanded for the application in power plants by a new algorithm for the detection of subsynchronous resonances (SSR), which can be especially critical for a turbine generator.

This phenomenon particularly occurs with turbine generators supplying electrical networks where serial capacitor are supposed to compensate the negative effects of an energy transfer via very long cables. Due to feedback effects, the operation of the capacitor may create an additional rotating field in the generator, which is then transferred to the generator shaft line. If the frequency of the rotating field corresponds to a mechanical natural frequency of the shaft, an electro-mechanical resonance is generated. The excited natural frequency is smaller than the frequency by which the generator is synchronized with the electrical network, which is why the phenomenon is called a subsynchronous resonance. Depending on the mechanical and electrical damping of the shaft line and the electrical network, the turbine generator starts to oscillate with more or less increasing amplitudes if a SSR occurs. Strong torsional oscillations represent a critical load for a shaft line. They must therefore be avoided as early as possible. Based on an especially developed algorithm, TorFat monitors torsional oscillations online, detects increasing amplitudes, and gives warning signals according to the danger level if amplitudes are increasing critically. Simultaneously, the occurring torsional oscillations are saved, and a fatigue analysis is carried out for the disturbance which has occurred.

Mobile sensor test rig during HUSUMwind 2003



Torsional analysis of rotating machinery



Diagnosis Support in Life Sciences

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The examination of processes and systems from the field of life sciences is often dominated by extreme complexity and by a lack of available information about the system state. Therefore, a description by explicit models is often only partly possible. Nevertheless, diagnostic as well as prognostic statements about these systems can be made using the basis of data- and knowledge-based methods. An examination of the systems must therefore rely on systematic data mining, as well as on any expert knowledge which might be available. Here, methods such as cluster analysis, decision trees, neural networks, support vector machines, and time series analysis are applied. Expert knowledge must first be formalized appropriately in order to be used for a computer-based evaluation. This can principally be done on the basis of an object-oriented approach known from the theory of programming languages, or by a so-called rule-based approach.

The main research area of the group lies in computer-based diagnostics in medicine: a typical example is the software CENA for nutrition consulting, which evaluates the nutrient supply on the basis of the user's nutrition plan acquired over a period of several days. This plan is improved step by step afterwards. The software is based on the mathematical modeling of the evaluation scheme that is used by nutrition scientists. Two further projects – one of them dealing with the analysis of electrocardiograms, and the second with regulation thermography - are based on data- and knowledge-based methods too.

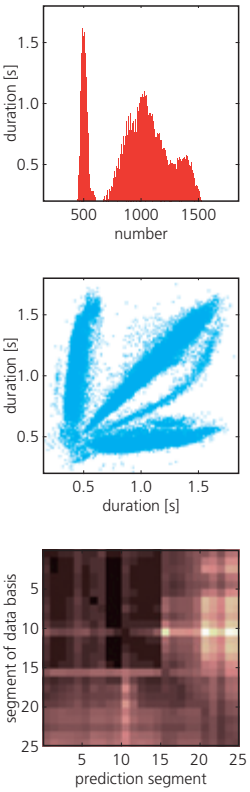
The moderation of the MACSI-net working group "Cardiac and Cardiovascular Models" belongs to the scientific activities of the research group. Within this framework, the work shop "CardioPoint" was held in Graz in June 2003: scientists from industrial and academic institutes presented mathematical applications in medicine and medical engineering in the field of cardiovascular systems. The efficiency of currently available software for the numerical simulation of blood flows, as well as problems concerning the development of medical software at universities, were subjects of discussion.

Analysis of electrocardiograms

In the medical science the activity of the heart is recorded using the electrocardiogram (ECG). One part of ECG analysis is the examination of numerical parameters extracted from the signal, e. g., the time between successive heartbeats (RR intervals). Medical studies have revealed that the distribution of the RR intervals and their chronology contain relevant medical information. The research group develops methods for the mathematical analysis of the RR interval time series. Among the methods applied are, for example, the so-called Lorenz plots, which represent the short-term dynamics of the RR intervals geometrically. The long-term signal structure of an ECG can be determined, e. g., by a comparison of structural similarities of small ECG segments. The figure on the right hand side shows the result of such a comparison by a (not symmetric) mathematical measure; higher similarity is represented by darker color.

In the year 2003, a software developed for the automatic detection of atrial fibrillations (AF) on the basis of an approximately one-hour recording of RR intervals was completed. The software was ordered by Geratherm Medical AG, and implemented into a handset. A medical study carried out by Geratherm proved high detection quality of the device. A beta version of the device was presented during the fair MEDICA-2003.

Heartbeat distribution, Lorenz plot, and cross prediction plot as different representations of a 24-hour ECG



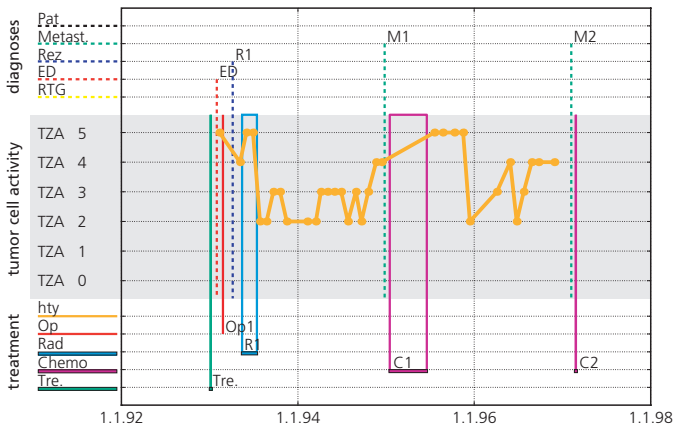
AFD monitor of the company Geratherm

Regulation thermography

Regulation thermography is a complex diagnosis method of complementary medicine which is based on a double measurement of the skin temperature at 110 specific points. Between the measurements, the test person is subject to a defined cold stimulus. The resulting thermogram is interpreted by experts on the basis of partly heuristic rules in order to detect diseases such as breast cancer.

In cooperation with the company gbo AG and the Institute for the Scientific Evaluation of Naturopathic Methods, the research group is working on a project for the diagnosis support in regulation thermography with respect to breast cancer, which is supported by the BMBF. In the current third year of the project, the work on an evaluation program based on fuzzy logic and neural networks has been concluded.
A software provides a risk classification of thermograms with respect to the occurrence of breast cancer on a six-level scale. The evaluation of the variation of these risk classes with respect to time during a therapy (figure below) is the subject of current research.

Graphic scheme of a treatment with respect to time by MATLAB®



Prognosis of Material and Product Properties

Due to a lack of adequate physical models, it is first completely unclear for many complex systems and processes on which ones of the potential influence factors a selected performance parameter depends. In particular, the existing dependences are often nonlinear, varying with the state of the considered dynamical system.

If, however, sufficient representative data are available, e. g., from systematic series of experiments with respect to the input-output behavior, a system description in the form of a black or grey box model can be formulated by adequate methods of system identification, data mining, and mathematical statistics. These models can then be used for a prognosis, especially allowing for the derivation of system sensitivities with respect to selected influence parameters.

The activities concerning the "Prognosis of Material and Product Properties" can basically be divided into the following two subjects:

Statistical system identification

Examples are sensitivity analysis and prediction of the crash performance of composite materials, depending on significant production parameters, such as geometric properties, layer structure, test rigs, materials, etc.

Dynamic system identification

Multivariate dynamic systems were identified by delayed feed forward and recurrent neural networks and long-term predictions were successfully carried out for different time-dependent industrial production processes.

Within both subjects, efficient MATLAB®-based tools were developed during a series of industrial cooperation projects, which have successfully been applied for the solution of subproblems of system identification, such as variable selection, model selection, and parameter identification.

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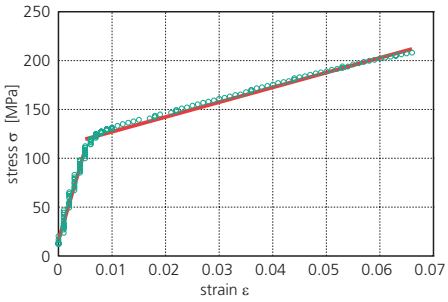
Magnesium lightweight construction

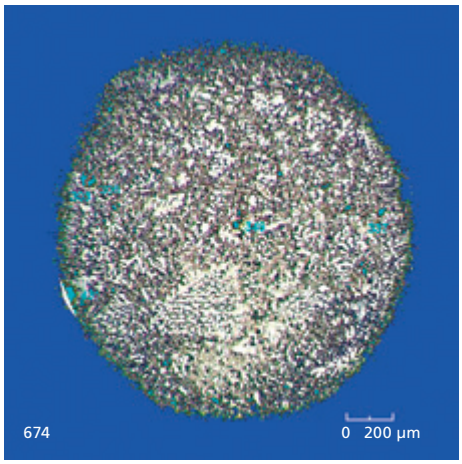
In the framework of the Fraunhofer-internal economy-based strategic alliance (WISA) "Material- and Function-Adequate Magnesium Lightweight Construction", which is a cooperation with the Fraunhofer Institutes IWM, IFAM, IWS, IWU, LBF, and the department of FLOW AND COMPLEX STRUCTURES of the ITWM (see page 41), the tensile properties of magnesium dashboard supports in automobiles are determined.

So-called sigma-epsilon curves are given, which are determined by systematic experiments. These stress-strain curves each represent the material behavior within one section of the dashboard support while the tensile force increases until material failure occurs. The fracture was examined thoroughly after each experiment and the significant variables were determined by special image processing software. For example, the following parameters were registered: fracture surface, pores, cracks, micro-pores, pre-solidified material, fine grain structure, eutectic, and general imperfections. These variables were used as input parameters for the modeling of the molded part's properties. Four parameters which uniquely identify the stress-strain curves were selected as output task variables: "slope of the Hook line", "mean slope in the elastic area", "fracture stress", and "fracture strain".

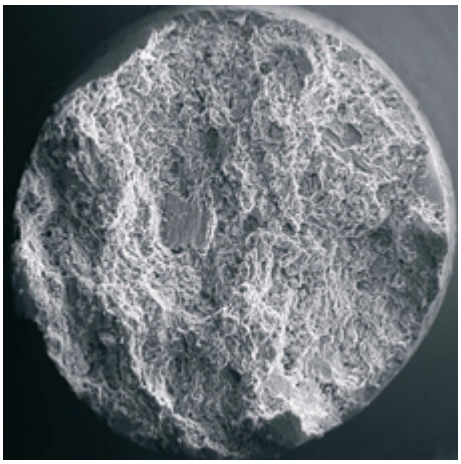
After an approximation of the function between input and output variables by a neural network especially adapted to the problem, the so-called sensitivity curves were estimated and visualized. These curves describe the nonlinear variation of the dependence between a certain input variable and the task variable with respect to the variations of the input variable's value. These plots are an effective tool in the hands of engineers whenever they have to decide which input variables must be changed by which order of magnitude in order to yield a high probability of the task variable to behave in the desired way under the considered loading scenarios. If we consider in particular the scarcity of available data, the resulting performance of the neural network – measured by the "mean squared error" of the cross validation and the interpretive capacity of the sensitivity curves - has supported the strength of our approach and has convinced the project partners that the method is worth a further development in the year 2004 and that the number of available experimental data should be increased by further experiments with respect to tensile properties.

Stress-strain-curves





Grounded surface (parallel etching with respect to the fracture surface)



Fracture image

Multiscale Structure Mechanics

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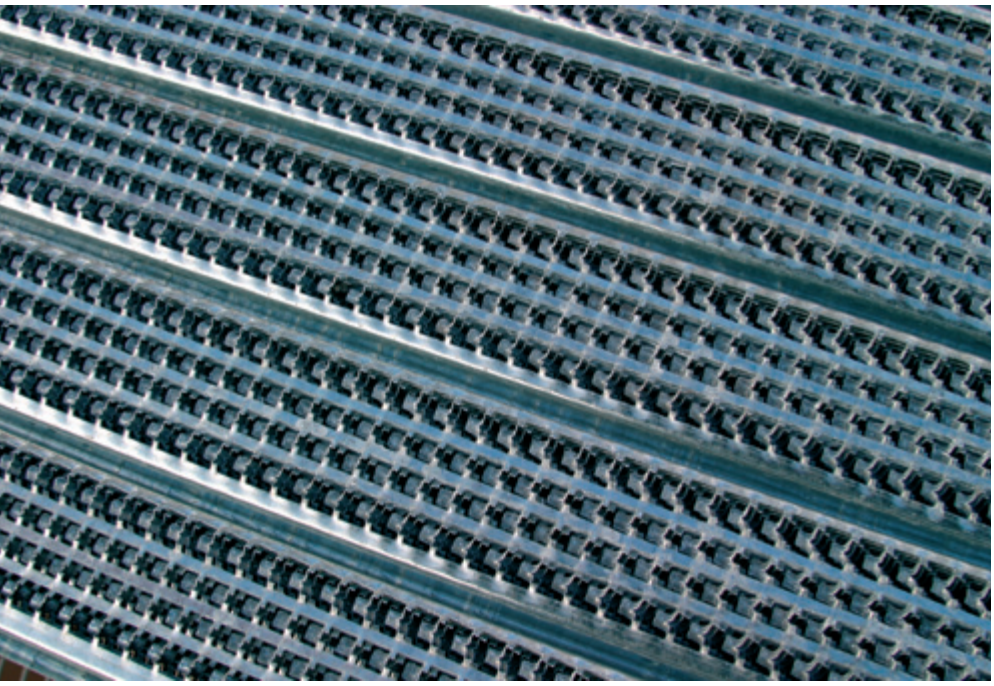
We are mainly working on three subjects here. The first one refers to the numerical computation of the microscopic stress-strain behavior and effective material properties of composite or porous materials. We apply homogenization methods which allow for the computation of average (effective) elastic, viscoelastic, and plastic material properties, accounting for the microstructure and the different material laws. The computation of effective free temperature deformation, swelling, and shrinkage is also possible. The second subject deals with contact problems with micro-rough surfaces, which can also be solved by homogenization methods. Finally, within the third problem complex we consider time-dependent processes for composite bodies, whose macro-strength and durability are examined with respect to fatigue, creep, impact load, and wear.



Homogenization methods are applied if the composite material shows strongly differing size scales. In this case, a direct computation of properties and effects on the macro scale is mostly impossible due to the enormous efforts which are necessary if the microstructure is to be accounted for. The homogenization method which is applied here works with an asymptotic expansion of the entire problem with respect to the length ratio of the micro and macro scales. In the limit, the result is an equivalent homogeneous problem which includes only mean effective properties. The solution of this homogenized problem finally represents an approximation of the exact solution.

Compared to other, simpler averaging methods, such as self-consistent methods according to Hashin and Eshelby which can only be applied to special geometric types, asymptotic homogenization methods have the essential advantage that they can be applied to arbitrary microstructures and many different material laws.

Homogenization with respect to elastoplasticity

The asymptotic homogenization method is examined very well and can easily be applied to linear problems. Within this project, however, large deformations as well as nonlinear material behavior must also be accounted for, which requires additional efforts.

The basic idea is to divide up the stress into two components. The first component only depends on the elastic strain, whereas the other component accounts for elastic as well as plastic deformations.

The macroscopic boundary value problem is handled by a homogeneous nonlinear material model whose effective properties are derived from the microscopic structure. On the micro scale, the problem consists of the solution of one nonlinear and nine linear auxiliary problems on the unit cell, which reflects the material microstructure. However, a complete separation between micro and macro scale of the problem is impossible, because the nonlinear problem on the micro scale is coupled with the problem on the macro scale by a volume force resulting from the macroscopic stress component. Therefore, the application of iterative solution methods is required.

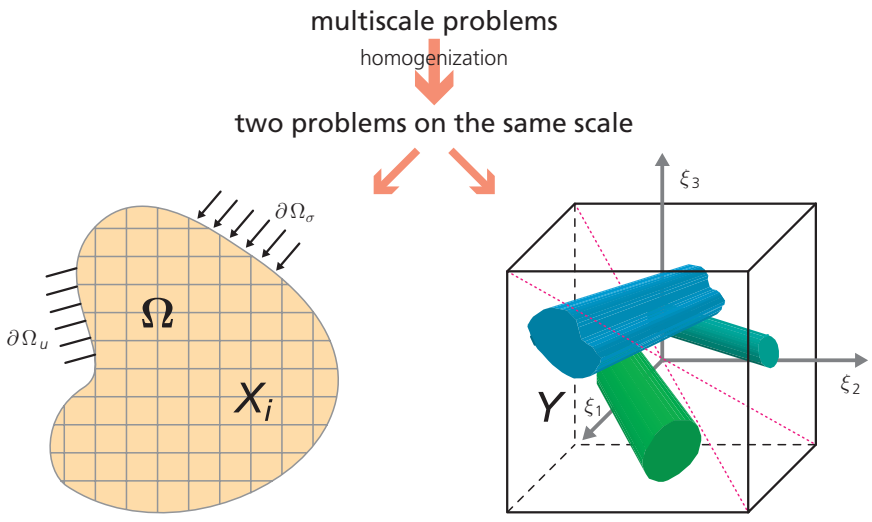
The algorithm developed at the ITWM is to be simulated numerically at the Fraunhofer IWM. Every occurring computation can be carried out by the usual FE software packages, such as ANSYS® or ABAQUS®. Plans for a subsequent project are the expansion of the algorithm in such a way that the computation of backstress and of the complete non-elastic stress components will additionally become possible. Finally, the objective will be the availability of curves or tables for future industrial applications which allow for the simple reading of effective macro values depending on the microstructure and the load scenario.

Hip prostheses (EU-CRAFT)

After two years of research work, this project was successfully finished in the year 2003. Based on a microscopic description, the effective contact properties of a hip prosthesis with the hip bone have been computed. On this foundation, a reliable determination of the elastic stress field in the bone has become possible.

Thermosetting resin

The DFG project, which has been started in 2002 and has recently been prolonged, deals with methods which are based on the microstructure properties of integro-viscoelastic composite materials and allow for statements about their effective strength and durability. The numerical modeling results in a series of 3d finite element computations which are coupled with a collocation method with respect to time.



FEM: $\nabla_x \cdot \int_Y P\big(\xi, F^{(0)}(X) + F^{(1)}(X,\xi)\big)\,d\xi = f(X)$

$F^{(0)}(X)$: macro-deformation gradient

P : Piola-Kirchhoff stress tensor

FEM: $\nabla_\xi \cdot P\big(\xi, F^{(0)}(X) + F^{(1)}(X,\xi)\big) = 0$

$x^{(1)}(\xi) = \xi + u^{(1)}(\xi)$ is periodic

Optimization

Objectives of the department are research and development with respect to models and methods of mathematical optimization for industry and the service sector. The development of software solutions in cooperation with the customer is especially important here. The year 2003 has introduced much new potential to the department of OPTIMIZATION. Already existing contacts to customers were intensified, and many new customers acquired. Results of the research projects were presented during two important fairs – MEDICA in Düsseldorf and transport logistik in Munich - and at the Siemens Focus Meeting "Radiotherapy" in San Francisco. Additionally, interesting industrial workshops with respect to hospital logistics, location planning, and school organization software were organized.

Research of the department is divided into the following subjects:

- internal logistics
- global logistics and traffic planning
- continuous optimization
- knowledge management and e-commerce

Within the main subject "Internal Logistics", contacts to local small and medium-sized enterprises were intensified by the research lab for production which is financed by the Land Rhineland-Palatinate. Besides, a project for the evacuation simulation of buildings was initiated in cooperation with the company SAP AG. Concerning the subject "Global Logistics and Traffic Planning", we started to cooperate with the company proALPHA Software AG in Weilerbach, a provider of ERP solutions for medium-sized enterprises. The software tool AnSiM for the planning of secure connections in public transport was met by large public interest. With respect to the subject "Continuous Optimization", contracts with SIEMENS Medical solutions for the marketing of a software for intensity-modulated radiotherapy planning were concluded. In cooperation with the company partu lapidaries in Idar-Oberstein, a project for the optimal design of an automatic production process of gemstones was initiated. The main subject "Knowledge Management and E-Commerce" included the development of an internet product catalogue for the company MiniTec in Waldmohr, which is now available, and the initiation of a project in cooperation with Tehalit GmbH in Heltersberg with respect to process management, which will be continued in 2004.

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Dr. Michael Schröder, Michael Monz, Hans Trinkaus, Ahmed Saher Sultan Azizi
PD Dr. Karl-Heinz Küfer, Dr.-Ing. habil. Alexander Lavrov, Carsten Goesmann, Julia Kallrath
Dr. Teresa Melo, Juliette Armbrecht, Alexander Scherrer, Fernando Alonso

Not on the picture: Dr. Thomas Hanne

Internal Logistics

The activities within the main subject "Internal Logistics" are primarily focused on the development and improvement of planning, control, and organizational processes in already existing plants, as well as in plants which are yet to be realized.

In addition to the extensive use of standard optimization methods, we apply methods such as evolutionary algorithms or fuzzy techniques for particular multi-criteria problems. The basic solution approach consists of a systematic application of both simulation and optimization.

The problems on which we are working within the different projects range from technical questions, such as:

- When and how do I commission incoming orders to the stations of a ring sorter? According to which algorithm do I control rack serving units? Which routing strategies do I apply for the control of material flow? How do I distribute articles across order-picking lines? Which box sizes fit best to my range of products? How do I synchronize logistic and engineering simulation tools?

to organizational problems, such as:

- How do I plan a complex software development project if the required efforts cannot be estimated exactly? How long does the evacuation of a planned building take? According to which order do I alarm the personnel in case of dangerous situations?

and questions like

- How do optimal feed rations for cows look like?

Scientists of our research group do not only work on the concrete problems concerning their projects, they also deal with technology and knowledge transfer by the organization of training programs and workshops. The exploitation of optimization and simulation potentials in industry can thus be improved.

Among our most important industrial partners in 2003 were psb GmbH Materialfluss+Logistik in Pirmasens, SAP AG in Walldorf, Pierau Planung in Hamburg. Scientific and research activities are carried out in intensive cooperation with other Fraunhofer institutes, e. g., IML, SCAI, UMSICHT, IESE, and FIT.

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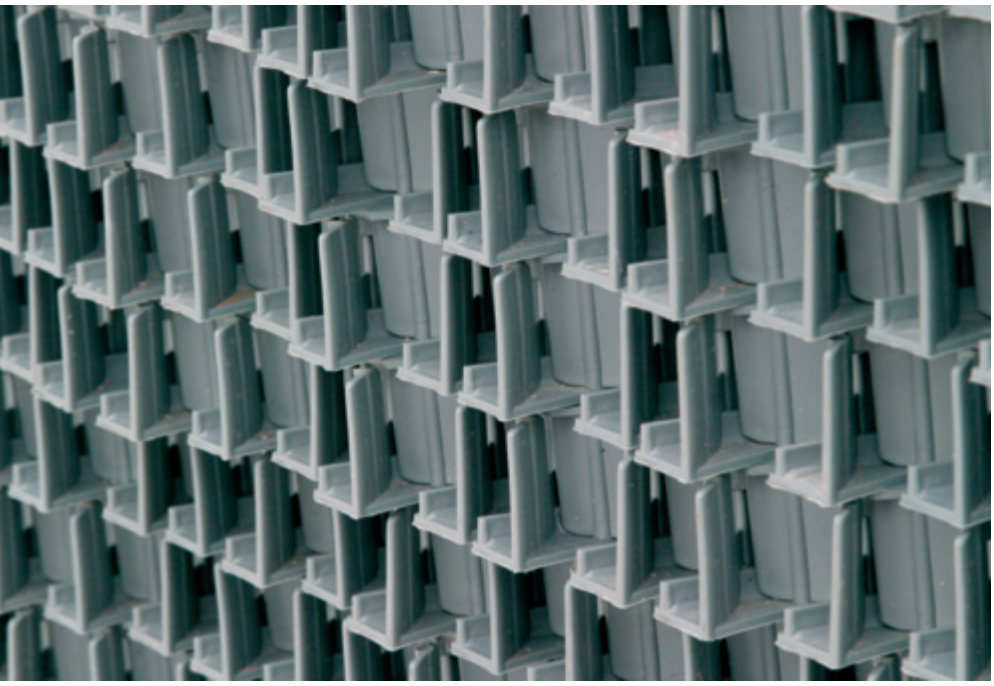


Evacuation simulation

Human life, health, and security enjoy highest priority in society. Nevertheless, fires, industrial accidents, or terrorist attacks repeatedly cause immense damage and claim victims. Sometimes, an examination of causes reveals that sufficient training and the correct planning and design of escape routes could have helped to avoid the damages.

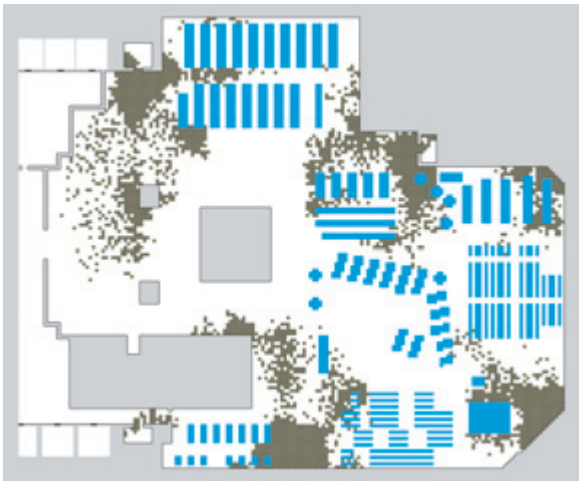
The problem is that field research, evacuation training, and human escape analysis are very time-consuming and expensive, and that qualitative studies or analytical descriptions cannot be derived exclusively on the basis of layout data. A solution is the active application of evacuation simulations, which are appropriate for extensive examinations of different scenarios, as well as for training programs. The ITWM has developed an approach for the evacuation simulation of buildings on the basis of eM-Plant. Special performance features of the system are:

- individual tracking/registration of all movements of each single person
- representation of different types of persons (including the effects on velocity, reaction time, etc.)
- flexible, dialogue-based input of type distributions per floor
- persons with restricted mobility (persons in wheelchairs) and their effects on escape routes (especially staircases) are accounted for
- use of existing information about the placing of persons across the rooms and of artificially generated assignments
- alternative assignments of escape routes to the rooms
- separate alarms for different parts of buildings
- different alarming strategies
- dialogue-based activation of fire-resistant walls

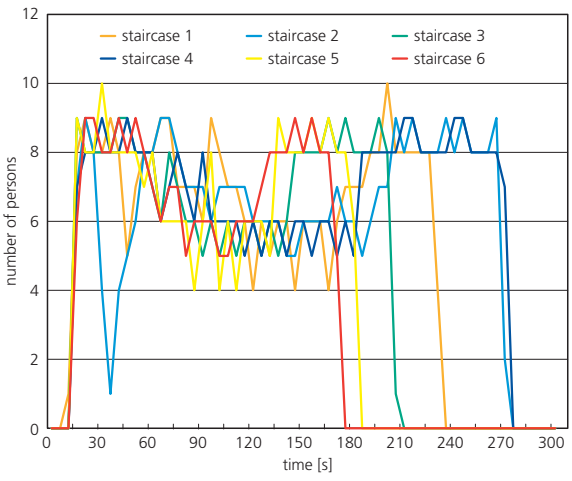
Extensive statistics are recorded: with respect to each person, aggregated for the individual floors, for the entire building, with respect to the dynamic utilization of staircases, etc. All the information is visualized.

The system can be used for several applications: for the planning of buildings (determination and validation of escape routes), for the operating of already existing buildings (examination of capacity and location of emergency exits, determination of the most effective escape routes), for the preparation of real evacuation training, for visualization during training programs. A further integration into traffic simulation is planned for the examination of fire lanes and the analysis of terrains.

Simulation of the flow of human beings during an evacuation



Number of movements per time interval from the 1st floor to the ground floor

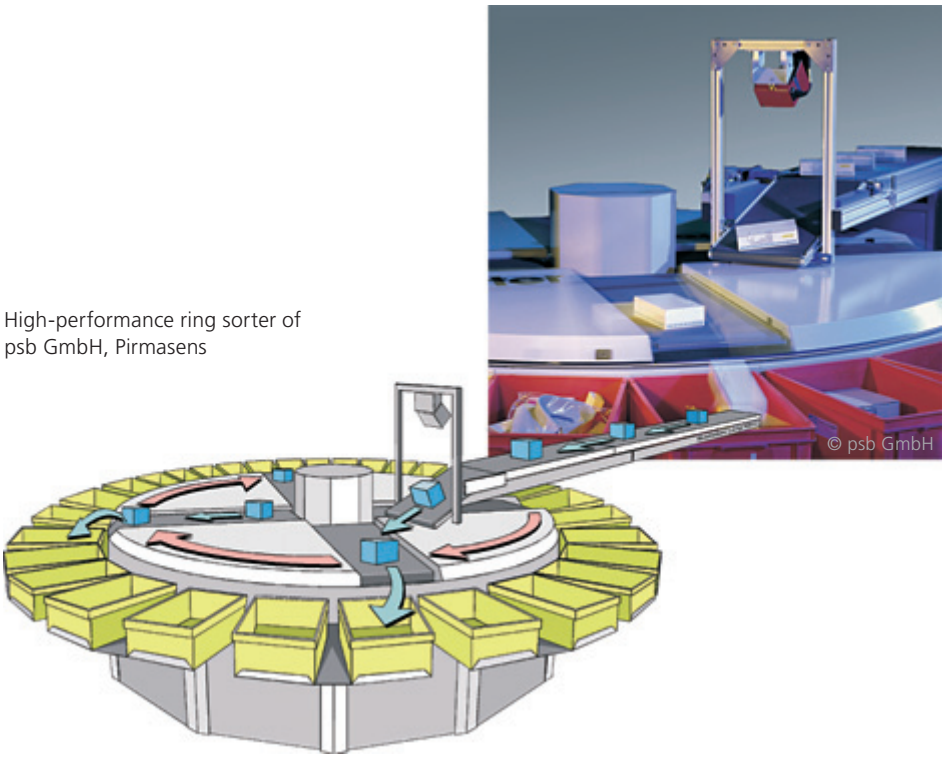


Research lab "Production Planning for regional SME"

In large enterprises, material flow simulations represent a standard instrument for the planning and optimization of production processes and the substantiation of investment decisions. However, their application is less common in small and medium-sized enterprises (SME). Based on the Research Platform (see page 6), a research lab has been initiated in cooperation with regional enterprises. Its objective is the establishment of simulation systems as attractive tools also for SME.

It has turned out that many logistic problems also exist for SME and can be solved with the tools of simulation and optimization. The complexity of problems is not necessarily lower than in the case of larger enterprises, and efficiency requirements of the applied tools are often even higher.

In cooperation with our industrial partner psb GmbH in Pirmasens, ITWM is developing a prototype standard library of SME-relevant modules for common simulation systems. The research is focused on the modeling of conventional components (continuous flow conveyors, distributing elements, sorter systems) if the functionality of existing components proves to be insufficient. Additionally, strategies for the control of material flow are developed. It is particularly important here that the resulting components have a modular structure and can be used for different purposes, so that they can also be applied by other SME.



High-performance ring sorter of psb GmbH, Pirmasens

Simulation and optimization of software development processes

Central problems of project management with respect to software development refer to quality assurance, delivery deadlines, and cost saving.

In the framework of two projects, one of them supported by the BMBF, methods of modeling, simulation, and optimization were used in order to improve decision support with respect to the planning of projects. Special attention was paid to the modeling of software inspections, which are considered as a key technology in order to guarantee the quality of software products. Typical questions concerning the planning of inspections are: Which modules are to be inspected? Which methods are to be applied? How many persons are to cooperate?

In cooperation with the Fraunhofer IESE and the Fraunhofer FIT, event-discrete simulation models have been developed which represent the essential phases of software development in detail. A special challenge is the adequate accounting for human-influenced factors. In this context, a process optimization regards the determination of decision variables, such as the assignment of persons to tasks and the scheduling, so that results become as good as possible with respect to the objectives of quality, project duration, and costs. This multi-criteria optimization problem is solved by evolutionary algorithms, which yield a considerable improvement compared to first-come, first-serve solutions.

Global Logistics and Traffic Planning

In order to be able to react quickly to customer requirements and market changes, enterprises are continually endeavoring to improve their logistics processes. Within the area "Global Logistics and Traffic Planning", these objectives are supported by the development and application of efficient computer-based optimization methods and algorithms. Apart from strategic planning problems, the improvement of daily operational procedures is also considered.

Mathematical optimization methods in logistics are very useful throughout different industrial branches. They support the planning and coordination of all the processes concerning global supply chain networks, ranging from material supply and manufacturing into intermediate and final products to the distribution to customers. Especially tailored quantitative methods can also improve logistic processes in hospitals. They support the hospital personnel during their daily work, e. g., with respect to the planning of schedules or of patient transports.

Public transport companies also offer potentials for optimization through the application of mathematical planning models. At each stage of the planning chain, from the scheduling of stations and lines, the development of time tables and connections to the planning of rosters and staff deployment schedules, complex decisions must be taken on the basis of large amounts of data. Computer-based models help to improve decisions, to save costs, and to render public transport in general more attractive.

The applied mathematical methods include exact as well as heuristic methods in discrete and combinatorial optimization. The implementation of the resulting solution algorithms focuses methods is focused on a modular structure, which allows to support several planning areas and to carry out adaptations to similar problems easily.

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Strategic design of supply chain networks

Supply chain management comprises methods and tools necessary for the organization and coordination of logistics networks. At the Fraunhofer ITWM, mathematical methods are developed which support decisions with respect to the design of supply chains. For this purpose, the software tool LibStrat-SCM has been created. Usually, planning starts with the modeling and evaluation of the existing supply chain's structure. During this step, LibStrat-SCM helps to identify weak points and to detect optimization potentials. Subsequently, the logistics network can be restructured completely. LibStrat-SCM simultaneously deals with problems from the following areas: material supply (selection of suppliers and determination of required raw materials), production (determination of product ranges and amounts of products), location planning (number, geographic location, and capacity of new facilities), distribution (use of transport channels between facilities), and catchment areas (assignment of customers to facilities). LibStrat-SCM is supplied with interfaces for MS-Access© and MS-Excel©. The supply chain is visualized with the geographic information system ArcView©.

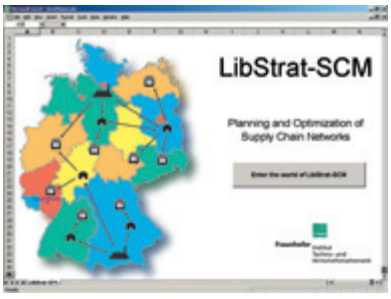
Analysis and optimization of patient transports in hospitals

The continuously growing pressure of saving costs in the health care system also forces hospitals to rethink about possibilities for the optimization of available resources on all decision levels. In-house patient transports are especially important here, because a poor planning of transports and the resulting lateness of patients have a strong impact on many other areas of hospital logistics. For example, the best kind of surgery planning is of no use if the patient to be operated does not appear on schedule.

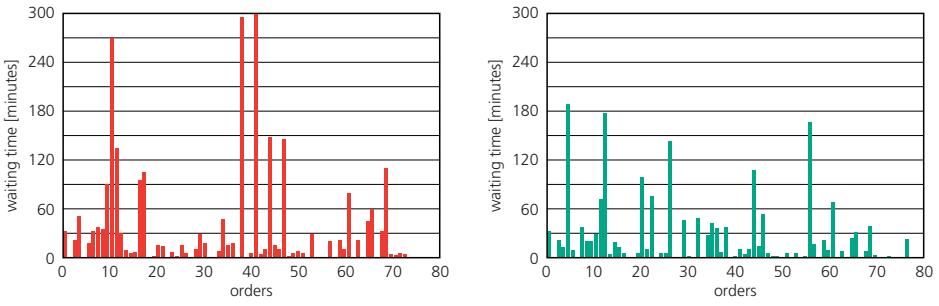
The entire transport service (dispatcher and transport teams) has the task of transporting patients between wards and service areas (e.g. X-ray, operation rooms, laboratory) as punctually as possible. However, individual requests are usually registered manually on a list of requests and handed over to the next free transport team. This system of order scheduling often results in delayed transports and undesired waiting times for patients.

For the University Hospital of the Johannes-Gutenberg University of Mainz, the current strategy of order scheduling first was analysed by a simulation model on the basis of various available data. The observed transport schedules were evaluated by different parameters, e. g., workload of the individual transport teams, waiting times and lateness of patients. In the second phase, different order scheduling strategies were tested with the help of the simulation model. Thus, a validation of optimization strategies became possible before the introduction of new dispatching strategies into daily hospital routine. Heuristic online optimization methods have been developed which account for different general conditions, such as personnel qualification, vehicle equipment, and order priorities, resulting in a considerable reduction of lateness and waiting times of patients. A further advantage is a uniform distribution of workload to the capacities of the transport teams. Thus, the system represents a contribution to increasing economic efficiency of the hospital, as well as to an improvement of service quality.

The resulting methods are integrated into the software tool OptiTrans, which is developed for the automation of order scheduling in cooperation with the companies SIEDA GmbH and COMEXAR AG.



User interface
of LibStrat-SCM



Comparison of patient waiting times in the University Hospital of the Johannes-Gutenberg University of Mainz before (red) and after (green) the optimization: the waiting time has been reduced by 26%.

Management of connections in public transport

Secure connections are a central quality factor of public transport. If there are problems here, these are realized very clearly by the customers, thus diminishing the attractiveness of public transport. Transport companies and communities are therefore undertaking measures in order to improve the network of connections. Particularly important is the inter-company exchange of data concerning current delays.

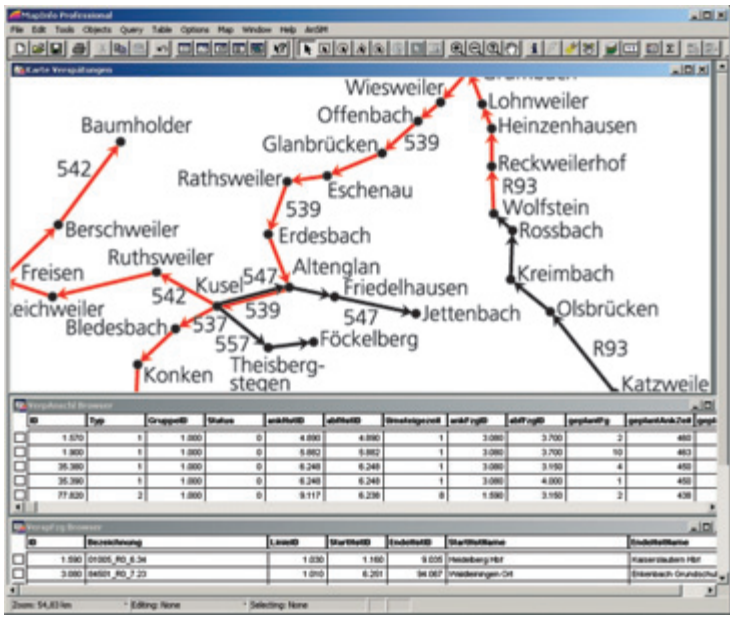
However, more information also means more decisions to be taken.

- Should the bus wait for the delayed train?
- If so – how long? What are optimal waiting rules?
- How important are the connections for the customers?
- How should dispatchers decide in the case of delays?

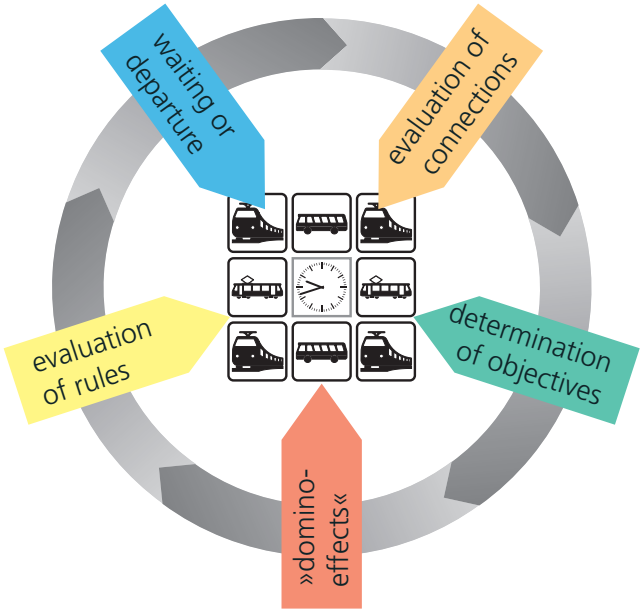
In the project "AnSiM" (Management of Secure Connections) of the Fraunhofer ITWM, the decision problems with respect to connections in public transport were modeled mathematically and a software tool for decision support was developed. This approach has numerous advantages. Decision proposals can be computed on the basis of data and objective criteria. The best compromises can be computed for incompatible objectives of secure connections (as few subsequent delays as possible vs. as few missed connections as possible). The domino effects of subsequent delays can be accounted for – which is a feature that greatly helps the dispatcher.

AnSiM is currently available as a software prototype and has been integrated into the geographic information system MapInfo®. The objective of the ITWM is a further development resulting in an individual software product. Studies of connection quality are already today carried out with AnSiM for various public transport companies.

AnSiM integrated into MapInfo® offers a GIS-based management of secure connections; optimal decisions for secure connections become possible.



Elements of the management of secure connections



Knowledge Management and E-Commerce

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Almost all problems in practice are characterized by numerous criteria and mostly competing objectives. Nevertheless, methods of multi-criteria decision making (MCDM) are not very wide-spread yet in company operational processes. The main reason may be that a colleague doing practical work is afraid of using these methods because he/she considers them as too difficult or complex. It is probably the man-machine interaction which is regarded as too complicated and is therefore responsible for this situation. Obviously, there is a strong need of user-friendly software which renders the application of MCDM methods attractive for a large circle of very different users.

These practical requirements are met by knowCube®, an innovative method for decision support. It is focused on the transparent visualization of knowledge contexts and the generation of ergonomic possibilities of interaction. Thus, persons who are not experts are also able to evaluate alternatives effectively and efficiently in complex decision situations.

Different types of criteria – quantitative or qualitative, objective or subjective, active or passive, dependent or independent, deterministic or statistical - can be considered simultaneously, and each user can navigate in the decision space according to his/her special strategy and accounting for current restrictions.

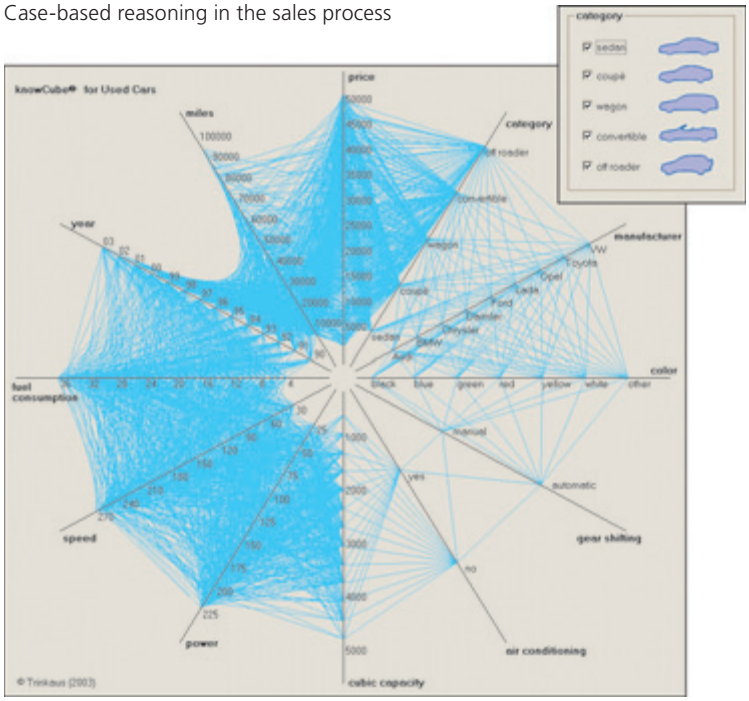
Both domains of this main subject include aspects of knowCube®. Special fields of application are virtual product design, but also logistics, marketing, and the sales sector.

Knowledge management in business processes

The management of the resource "knowledge" is of increasing importance for enterprises of all sizes. It includes the "new" knowledge resulting from innovation processes, as well as the whole range of diverse capacities and experiences which have once been acquired and collected during the history of a company. Central tasks of knowledge management are on the one hand the protection of knowledge, with the objective of explicating valuable knowledge and saving it according to a certain structure, and on the other hand the finding of knowledge, in order to make use of the stored company knowledge for value creation.

Contrarily to the trends on the market, a large industrial cooperation project with respect to the sales sector could be initiated in the year 2003, which will be continued in 2004.

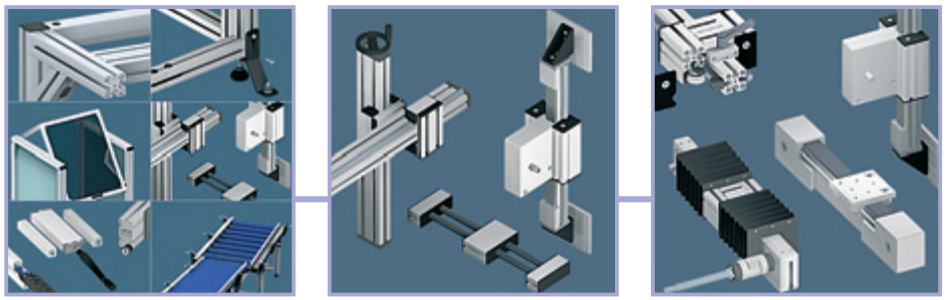
Case-based reasoning in the sales process



Electronic Product Consultant

An interactive product catalogue consisting of graphical objects has been developed for e-commerce. The customer can navigate on the internet through complex product systems requiring explanations, and he/she can arrange his/her orders via mouse click. In the year 2004, a multi-language variant of this "virtual consultant" will be realized for the company MiniTec.

Virtual product consulting on the internet



Continuous Optimization

The efficient design of products and production processes or the decision about the optimal accomplishment of clinical therapy can be formulated mathematically as a constrained, parametric optimization problem: a structure – product, process or therapy – is determined by given and selectable parameters. The usually very complex structure is evaluated by decision makers according to one or several numerical quality indicators. In general, these indicators can not take account of all aspects of the entire structure to be optimized, which are partly even considered very subjectively, but they allow for the search of good parameter selections which are optimal with respect to the determined indicators. The task of mathematical modeling and optimization now is the specification of sensible quality indicators by substitution functions in cooperation with the user, and the formulation of the problem as an optimization problem. Depending on the selected modeling, these are single-criterion or multi-criteria problems. The latter case uses the concept of Pareto-optimal sulutions. For these solutions, an improvement of one quality indicator would worsen at least one other.

Optimization problems concerning the optimal design of processes and products are usually large-scale problems requiring special numerical methods for their solution.

Currently, the research group "Continuous Optimization" is working on projects in the field of multi-criteria intensity-modulated radiotherapy planning, which are funded by the BMBF and by Deutsche Krebshilfe e. V. (German Cancer Aid), as well as on an industrial project for the computation of optimal usable volumes for the automatic production process of colored raw gemstones.

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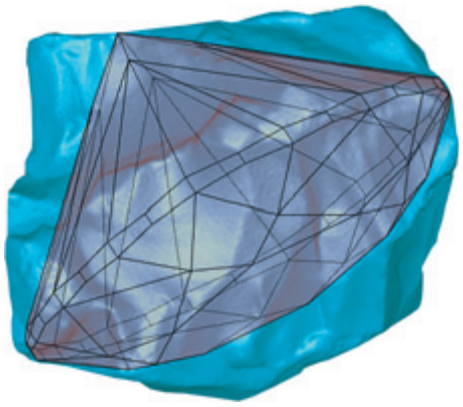
Production of gemstones

The search for usable volumes which are as large as possible in the case of colored raw gemstones is a classical design centering problem and can be formulated as a single-criterion, semi-infinite, high-dimensional optimization problem. Within a feasibility study by order of the company partu lapidaries in Idar-Oberstein, test computations were carried out on the basis of test data sets. They are to embed a round form of brilliant optimally into a raw gemstone with respect to the quality indicator "volume". The structure to be optimized among the given proportions of the stone is the position of the design to be cut in the raw gemstone. A preliminary study was carried out on the basis of competences with respect to internal logistics, i. e. the simulation and optimization by genetic algorithms. The study has shown that the high dimension of the problem, which is due to the discretization of the raw gemstone, can be handled by hierarchical approximation methods, as they are used for the numerical computation of radiotherapy planning. Additionally, optimal parameter configurations can be computed within the time limits required by the production cycle.

Optimal embedding of a usable volume in a raw gemstone



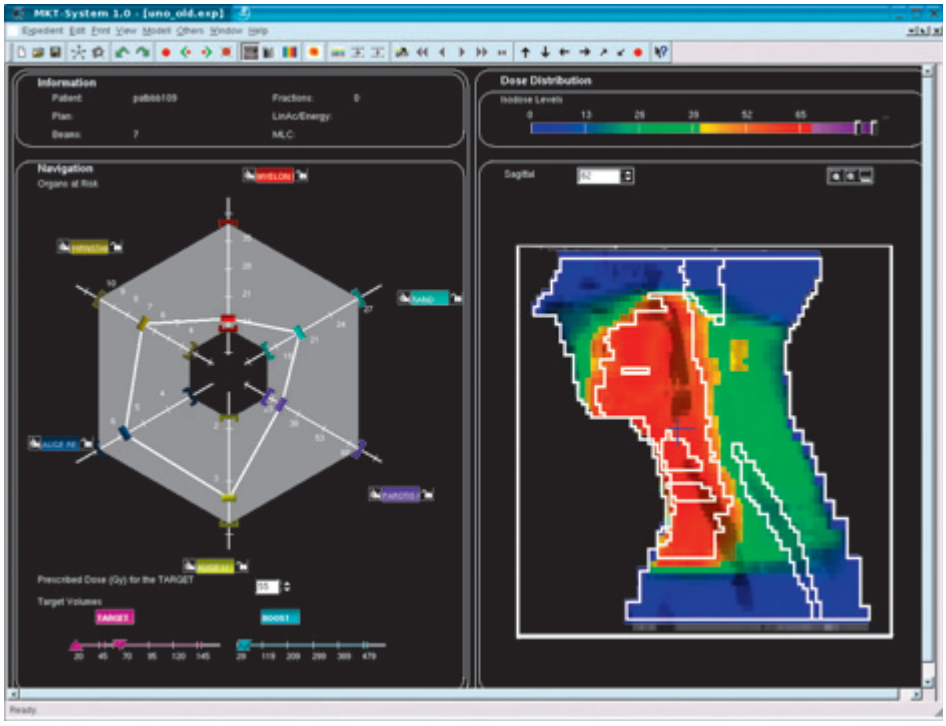
Radiotherapy planning

The task of clinical radiotherapy planning is the realization of a high therapeutical dose within a target volume in order to guarantee a high probability of tumor control. Simultaneously, high doses in healthy tissue are to be avoided in order to guarantee a low probability of complications concerning risk organs.

The structure to be optimized in this application is the dose distribution within the body of the patient. Given therapeutical doses for the tumor tissue and tolerance doses for the healthy tissue are based on statistical sources and medical experience. The parameters of the optimization are the irradiation geometry and the fluence distributions.

In the last three years, a product for the generic multi-criteria optimization of intensity-modulated radiotherapy planning has been developed in cooperation with the German Center for Cancer Research in Heidelberg and the Massachusetts General Hospital in Boston. The clinically relevant part of the Pareto solutions is approximated in short computing time by a special numerical platform based on individual adaptations of data and volume structures. The resulting variety of solutions is presented to the decision maker with a decision support instrument patented in 2003, which helps to select plans in real time according to subjective experience with respect to optimal therapy. License agreements have been concluded for the commercial application of the tool.

User interface for radiotherapy planning:
navigation frame (left) and dose distribution (right) in the case of a head-neck tumor



Financial Mathematics

In the year 2003, the department of FINANCIAL MATHEMATICS mainly concentrated on the reinforcement of its position acquired by a strong growth during the previous two years. In the economic sector, this objective has successfully been achieved by an impressive number of industrial projects, which were primarily worked on in cooperation with already known partners of the previous years. Nevertheless, new partners with respect to Basle II and the SME sector could also be acquired. Increased efforts with respect to customers from SME, however, have not yet resulted in large-volume orders.

We are pleased to announce the initiation of our cooperation with the Centre for European Economic Research in Mannheim, which is showing first results in the acquisition of a common order by the Federal Ministry of Finances. Further cooperation is intended especially in the field of public projects. Although industrial projects represented a high percentage of our work, the year 2003 was by far our most successful year on the scientific sector. Several papers have been published in excellent journals.

The main subjects of research and project work which had been determined in the last few years, i. e.

- option pricing
- credit derivatives
- interest rate models
- credit risk
- portfolio optimization,

were confirmed in 2003. The subjects of option pricing and credit risk are leading with respect to funds which have been acquired, whereas most of the research results were achieved in the subjects of portfolio optimization and option pricing.

Last year, our range of products and services has increased considerably with respect to industrial projects as well as to the research area. One example to be mentioned here is the field of credit derivatives. Our research is particularly innovative concerning inflation bonds.

Scientific highlights of 2004 are expected by the planned cooperation with Nizar Touzi (Paris) concerning the Malliavin calculus and its applications with respect to Monte-Carlo methods, and with the visiting professor Chris Rogers (Cambridge). Both projects will expand our competence regarding financial mathematics at the highest level.

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Option Pricing

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The main subject of option pricing is focused on the derivation of pricing formulas and the development of numerical algorithms for the computation of the price of exotic derivatives. Derivatives are, as the name already tells us, derived securities whose actual payment depends on the price development of their basic good, e. g., an equity or an interest rate. In the trading sector of large banks, option trading is also an important item especially in times of unfavorable market conditions. In order to offer their investors attractive products with a limited risk of loss, odds notwithstanding, also during weak periods of the market, banks frequently offer derivatives with a very complex payment structure. These products guarantee that the investor will not suffer a loss (capital guaranteed products), simultaneously limiting the maximum payment of profits on the part of the bank.

The pricing of such derivatives requires realistic market models which are able to represent the market prices of the standard products very well, and to model the price trend of the basic securities in a sufficiently realistic way. Besides, efficient numerical methods are necessary if derivatives with a complex payment structure are to be priced by these models.

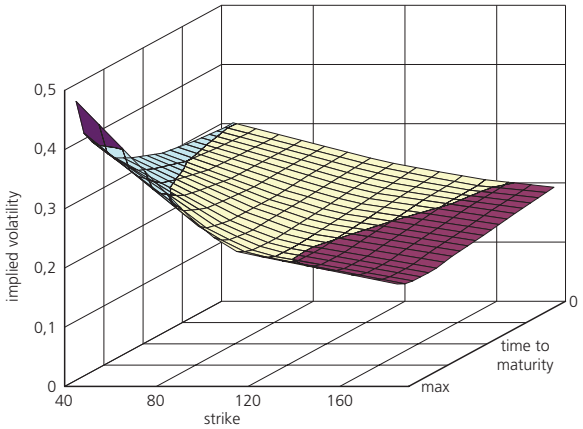
The demand for such models is reflected by the fact that we have been able to continue our industrial projects initiated in 2002 with respect to equities by focusing on stochastic volatility (e. g., Heston model) and the pricing of exotic options. We have thus been further increasing our know-how in this area. A second application concerning equities is the successful implementation of a model for the pricing of convertible bonds which is based on jump diffusion processes.

Option pricing by stochastic volatility models

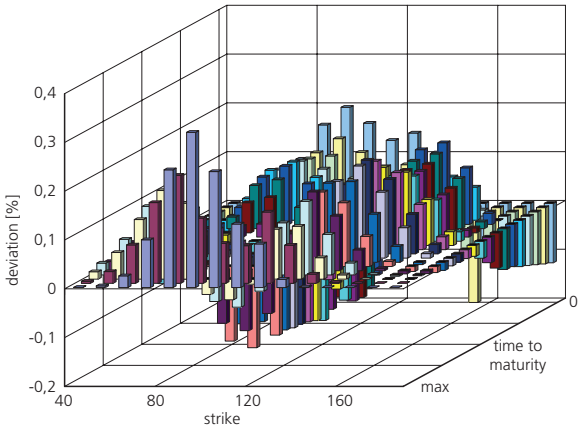
The pricing and risk management of exotic options are decisive problems of modern financial mathematics. Especially in the case of structured products, such as Cliquet or forward starting options, whose percentage of traded options is continuously increasing, a more realistic modeling of the basic equity price than in the simple Black-Scholes model is necessary.

The stochastic volatility model of Heston is a model which is successfully applied in practice. Due to the closed solutions for standard calls, the model provides the possibility of adapting the model parameters in practice to the current market situation (calibration). In contrast to the Black-Scholes model, the Heston model is able to reproduce the volatility smile observed on the stock market. Resulting maximum deviations for ATM call options were less than 0.15 per cent. Several continuous industrial projects were successfully concluded in 2002, so that in 2003, research was concentrating on numerous expansions of the Heston model. Efforts were mainly focused on a further improvement of the calibration results, of the pricing of new, exotic options, and of structured products, as well as on the expansion of the Heston model to so-called cross asset products.

All the new routines and the improved model calibration are available as C++ functions in MS-Excel® and can thus be integrated comfortably into existing Office systems.



Volatility surface for S&P-500 index of July 12, 2001



Deviation of the computed volatility surface from the market data after successful calibration

Credit Derivatives

In the last few years, the pricing and hedging of credit risks has strongly changed. In the past, mainly intuitive methods were used in practice, whereas recent developments have lead to considerably more mathematical approaches. This is principally due to the development of credit derivatives, which now allow for an active trading of such risks on the financial markets. Classically, the trading of credit risk was characterized by a buy-and-hold strategy. However, particularly the efficient and simple transfer of standardized products opens up numerous new possibilities with respect to risk management, portfolio optimization, investment, and speculation, which is confirmed by extreme growth rates on the market for credit derivatives and the continuously growing number of new products. This growth will again be reinforced when the new Basle Capital Accord ("Basle II") will come into effect.

Mathematical modeling is focused on the pricing of credit products with respect to their risk of default. From the point of view of a credit risk trader, an essential difference with respect to classical derivatives (e. g., options on equities) is the disequilibrium between a relatively small chance of profit (upside chance) and a considerably higher loss and probability of loss (downside risk). Therefore, mathematical models of credit risks must meet very complex requirements. In contrast to market risk, which has already been traded actively for a long time now, no standard model has yet been established on the market of credit derivatives, so that the modeling of credit risks still is the main subject of intensive research.

Credit derivatives have always been a part of the main issue "credit risk". However, in the year 2003 several long-term projects were initiated, so that additional extensive competence has been developed in this area, resulting in the creation of an individual main issue "credit derivatives".

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Pricing of basket default swaps

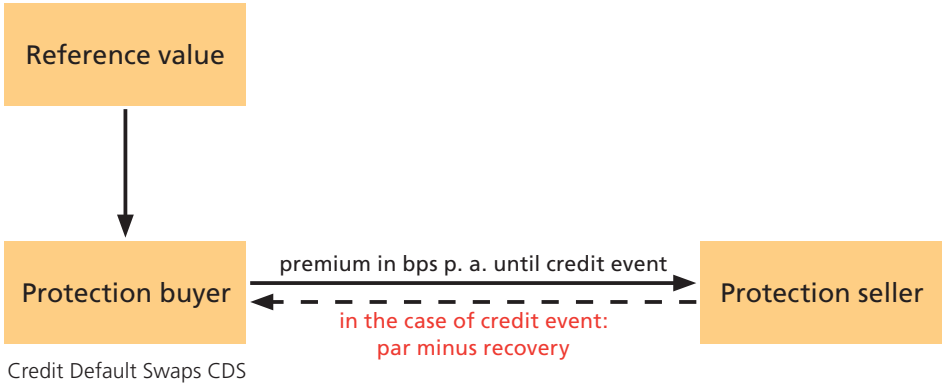
Since the introduction of credit derivatives in the middle of the Nineties, the trading of these comparably young derivatives has also been one of the most strongly expanding markets of financial products. This is not only reflected by an exponentially growing trading volume and an increasing interest of numerous hedge funds, but also by an increasing standardization of simple derivatives and a simultaneously strongly growing demand for exotic and structured products.

However, the problem of trading with credit derivatives is that there is no standard model for the default probability of a credit yet. Within an industrial project started in 2003, the ITWM deals with the selection, implementation, and further development of appropriate models.

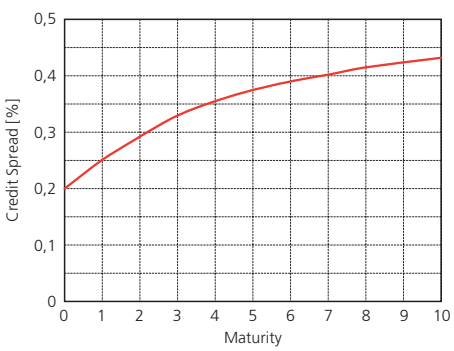
An example for a strongly standardized product based on only one individual financial instrument subject to default risk is the so-called credit default swap (CDS). A CDS is a bilateral financial contract where the seller effects an equalization payment if credit default occurs previously to the stabilized event of the credit. In return, the buyer effects a periodic payment to the seller until either default occurs or maturity of the contract is reached.

Meanwhile, the traded CDS have formed a sufficiently liquid market, so that their market prices can be used for the calibration of a credit's default probability. The credit spread curve resulting from this calibration is the foundation for the pricing of further products. The institute tests and develops different methods for the determination of this spread curve (e. g., bootstrap, parameterization, etc.).

In contrast to these simple CDS, so-called basket default swaps (BDS) are based on several (usually more than five) underlyings. Typical products are first-to-default swaps (FtD), second-to-default swaps (StD), or collateralized debts obligations (CDO). The difficulty in pricing such BDS is the modeling and calibration of the correlated default probabilities of the basket portfolio. It turns out that the usual linear correlation in many cases is not sufficient for an adequate description of observed effects on the financial market (e. g., economic crises). The ITWM implements and develops more general models, e. g., with the help of Copula methods, and offers tools for the pricing of BDS.



Credit Default Swaps CDS



Parameterized credit spread curve

Interest Rate Models

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Interest rates are not constant with respect to time. Each consumer is subject to this experience regarding the credit as well as the debit side. Although interest rates usually do not fluctuate as strongly as equity prices, the future development of interest rates can only be predicted with difficulty, because it is subject to different economic and macro-economic influences. Especially market interest rates, such as the EURIBOR interest rates (the interest rates at which the banks on the Euro market borrow money from one another) with their different terms, react to changing market conditions, so that stochastic modeling appears appropriate. Because of the large volumes of transactions carried out on the interest rate market, it is very important that the development of interest rates is modeled as realistically as possible.

In contrast to the modeling of equity prices, however, no benchmark model, such as the Black-Scholes model for equity prices, has yet been developed for interest rates. There are numerous interest rate models which must be examined with respect to a possible application and selected, depending on the product and the basic interest rate. A further special feature of the interest rate market is the very large variety of complex interest rate derivatives. Their contract structure is often difficult to understand, so that pricing is a strong challenge to financial mathematics.

Markets are currently focused on, e. g., inflation-linked bonds and derivatives, whose payments hedge the investor against changes of purchasing power because they are linked to inflation development. The modeling of inflation and the pricing of the above mentioned products belong to the current research and project work of the Fraunhofer ITWM. We can attest that there is large development potential here.

Credit Risk

The department of FINANCIAL MATHEMATICS is supporting banks with respect to the application of the new Basle Capital Accord ("Basle II"), which will substitute the current eight per cent flat rate of bank securities ("Basle I") by the end of 2006. The new regulations require equity funds which are adapted to the credit risk of the bank portfolio.

In order to develop a credit rating, individual analyses of the variables with respect to their discriminatory power to separate between default and non-default are carried out first. The next steps are the estimation of scores and default probabilities with the objective of determining an optimal weighting of the factors in the credit score. A simultaneous estimation of scores and default probabilities on the basis of cross-sectional data can be carried out by statistical-econometric approaches (Logit model, logistic discriminant analysis). There is a large number of extensions for these methods, which make different aspects of the model more flexible. Panel and survival models are used if observations covering several years are available. Neural networks, classification trees, estimation under monotony restrictions, and semi-parametric models serve for the examination of models and help to find appropriate variable transformations.

The most important optimality criteria for the evaluation of scores or ratings are the discriminatory power to separate good from bad credits and the calibration (exactness) of the estimated default probabilities. Classical power measures quantify the distance between the score distributions of defaults and non-defaults, for example, Lorenz and ROC plots and their derived parameters (Gini coefficient, accuracy ratio). The rating system of a bank should undergo regular evaluation by back and stress testing. From a statistical point of view, these evaluation objectives can be reached by resampling methods (Monte-Carlo methods, bootstrap).

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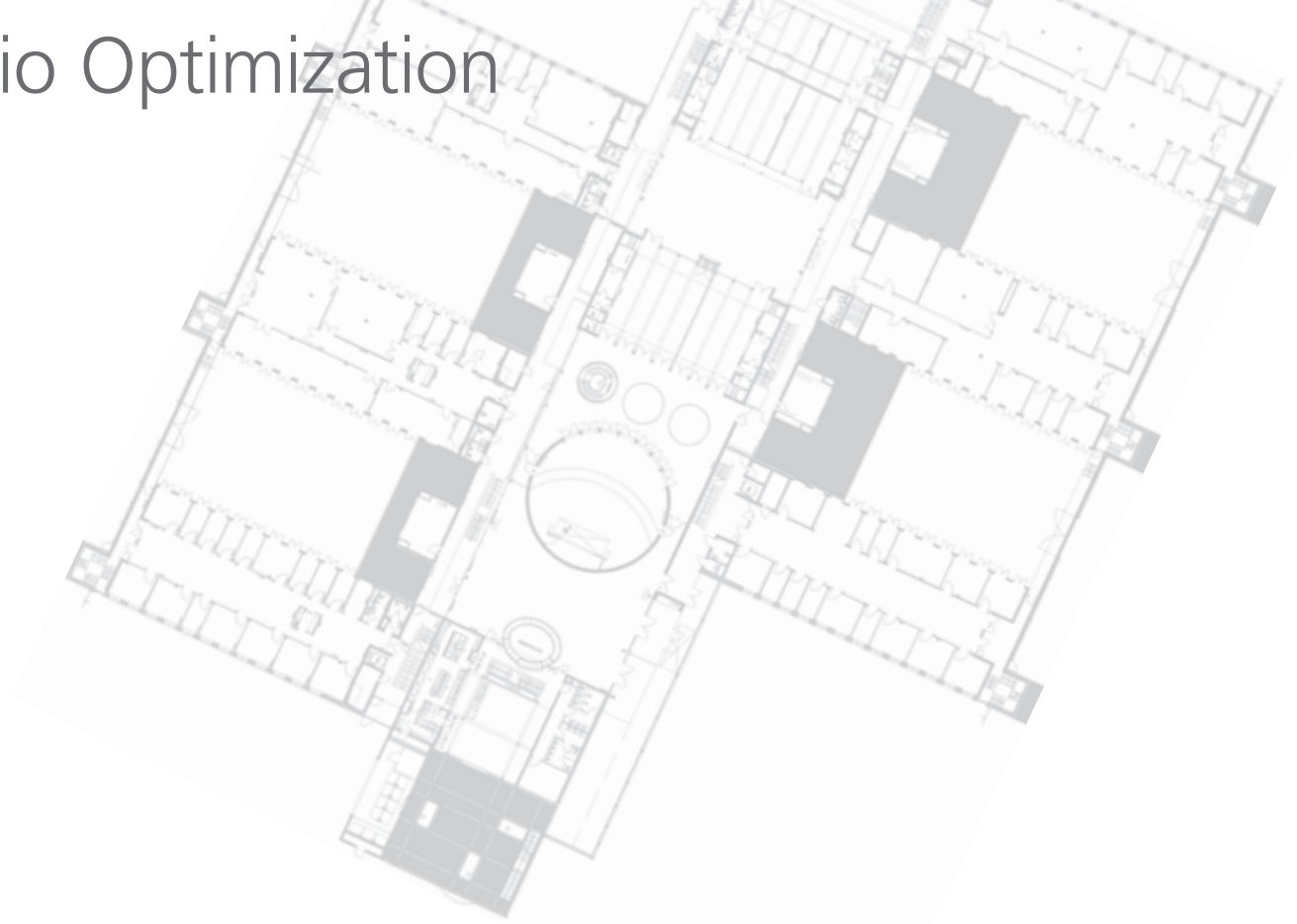
Portfolio Optimization



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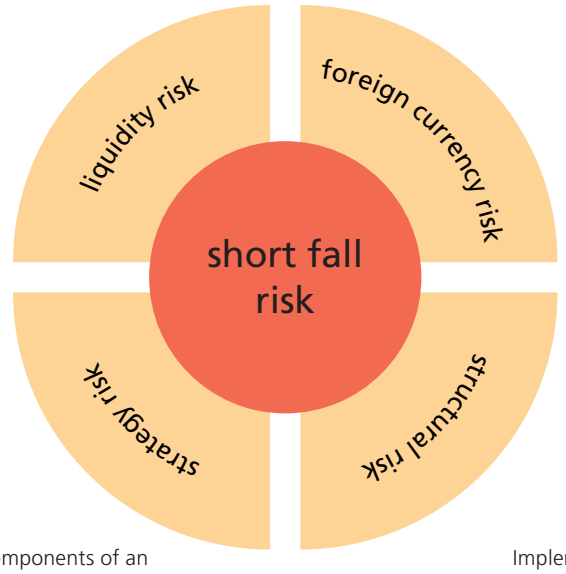
Portfolio optimization is mainly focused on the determination of an optimal investment strategy on a financial market. More precisely: the investor must decide how many shares of which securities to hold when, in order to maximize his/her utility of wealth at the end of the planning period. In contrast to option pricing, where time-continuous models of financial mathematics have been applied in practice for decades now, the more than 40-year-old single period model of Markowitz, including several variations, still represents the foundation of fund managers' investment decisions. In the meantime, the development of modern, time-continuous portfolio optimization has advanced so far that many algorithms are available for practical application and implementation, which have also been carried out now at the ITWM. A possible project in this framework would be the development of an online consultation tool.

First orders from the SME sector (application of alternative investments) could be acquired in 2003. In the research sector of the main subject, the optimal determination of bond portfolios (also of bonds with a credit default risk), the portfolio problem in the case of stochastic volatility, optimal investment in the case of a threatening crash, and the practical application of portfolio optimization methods with respect to transaction costs have been examined. New results of portfolio optimization can also be found in the PhD thesis by Martin Krekel "Some New Aspects of Optimal Portfolios and Option Pricing".

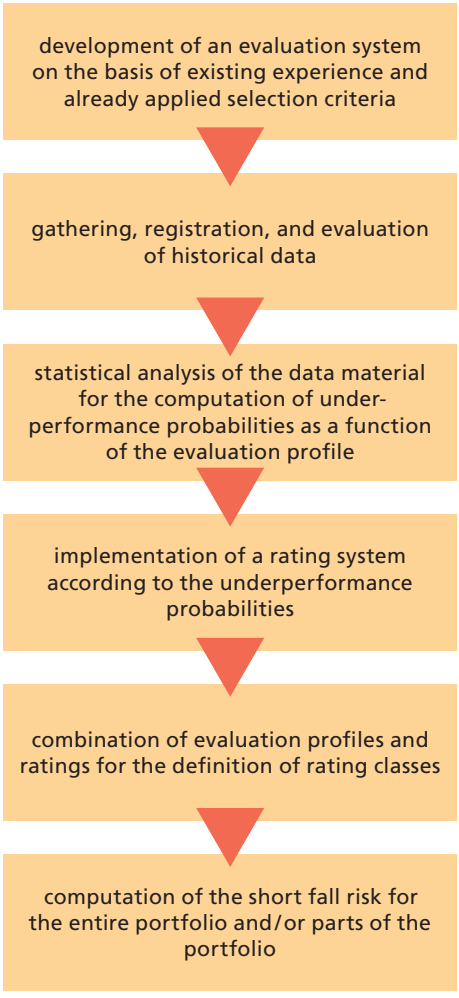
Risk management of alternative investments

Traditional investments are, as the name already tells us, standard investments for every investor. However, those investors who restrict themselves to these investments find themselves subject to the trends of the respective financial markets and to economic changes even if they possess a well diversified portfolio. The range of investment possibilities has been increasing within the last few decades, so that alternative investments such as hedge funds, managed futures funds, and private equity funds have become increasingly interesting apart from international capital markets. This is not only due to above average profits compared to traditional investments, but also to low correlations with respect to other investments. Alternative investments – if selected diligently - are not only able to contribute to a performance improvement because of these properties, but also to the diversification effect of a portfolio by offering securities in support of a potential loss in the case of strong market fluctuations or – like real estate funds – in support of impending inflation or deflation. However, the selection of appropriate alternative financial products is frequently impeded by a lack of publicly available information and the respective quotation. Similar to the evaluation of credit risk for banks, the decision about an investment is taken on the basis of quantitative and qualitative features of the individual funds. Therefore, the implementation of a rating model for alternative investment possibilities suggests itself for the determination of a short fall risk (i. e. the probability that a minimum profit might not be achieved). The development of such a model is based on our experience in the field of credit risk.

The basic idea of such a valuation model is to separate "good" from "bad" investments by focusing on selected criteria, in other words to identify investments offering a minimal return with a pre-specified probability. Therefore the rating model not only supports the identification of portfolio risk but also the choice on investment.



Risk components of an alternative investment



Implementation steps for a rating system as a basis for risk determination

Competence Center High Performance Computing

A few years ago, parallel computing almost exclusively took place in public research, meteorology, and at a small number of large enterprises. Due to the increasing importance of simulation and the availability of the respective software in industry, the commercial use of parallel systems has also become possible today. The increasing performance of PCs and their connection in the form of PC clusters have essentially contributed to this process.

The ITWM is one of the pioneers with respect to the application of PC clusters in the case of industrial simulation problems. First systems with applications developed at the Fraunhofer ITWM were already delivered to our customers in 1995. Today, the ITWM maintains a coupled system of three PC clusters with an overall number of 240 CPUs for the development of parallel software and the computation of industrial application problems.

A strategic cooperation with Linux Networx (Linux Networx Research Lab at the Fraunhofer ITWM), a leading supplier of cluster solutions, joins the know-how of the ITWM with respect to application and parallel computing with the cluster know-how of Linux Networx, resulting in a competent partner for industry. The Linux Networx Research Lab is integrated into the Distributed Computing Research Lab, where the companies techmath AG and Mobotix are additionally cooperating.

The research work of the Competence Center High Performance Computing is mainly focused on

- parallel algorithms
- development of parallelization frameworks
- performance analysis, benchmarking, code optimization
- HPC architectures, grid computing
- parallel volume rendering
- molecular dynamics

The visualization software PV-4D, which is the first one world-wide to realize interactive handling of very large amounts of data without special hardware, as well as the Fraunhofer Resource Grid (www.fhrg.fraunhofer.de) were presented very successfully during several international fairs.

The development of new, strongly parallel computation codes in the fields of molecular dynamics, structure mechanics, and financial mathematics represents three subjects for the Competence Center High Performance Computing which will be very important for the future and can be further expanded also in 2004 on the basis of a solid financing.

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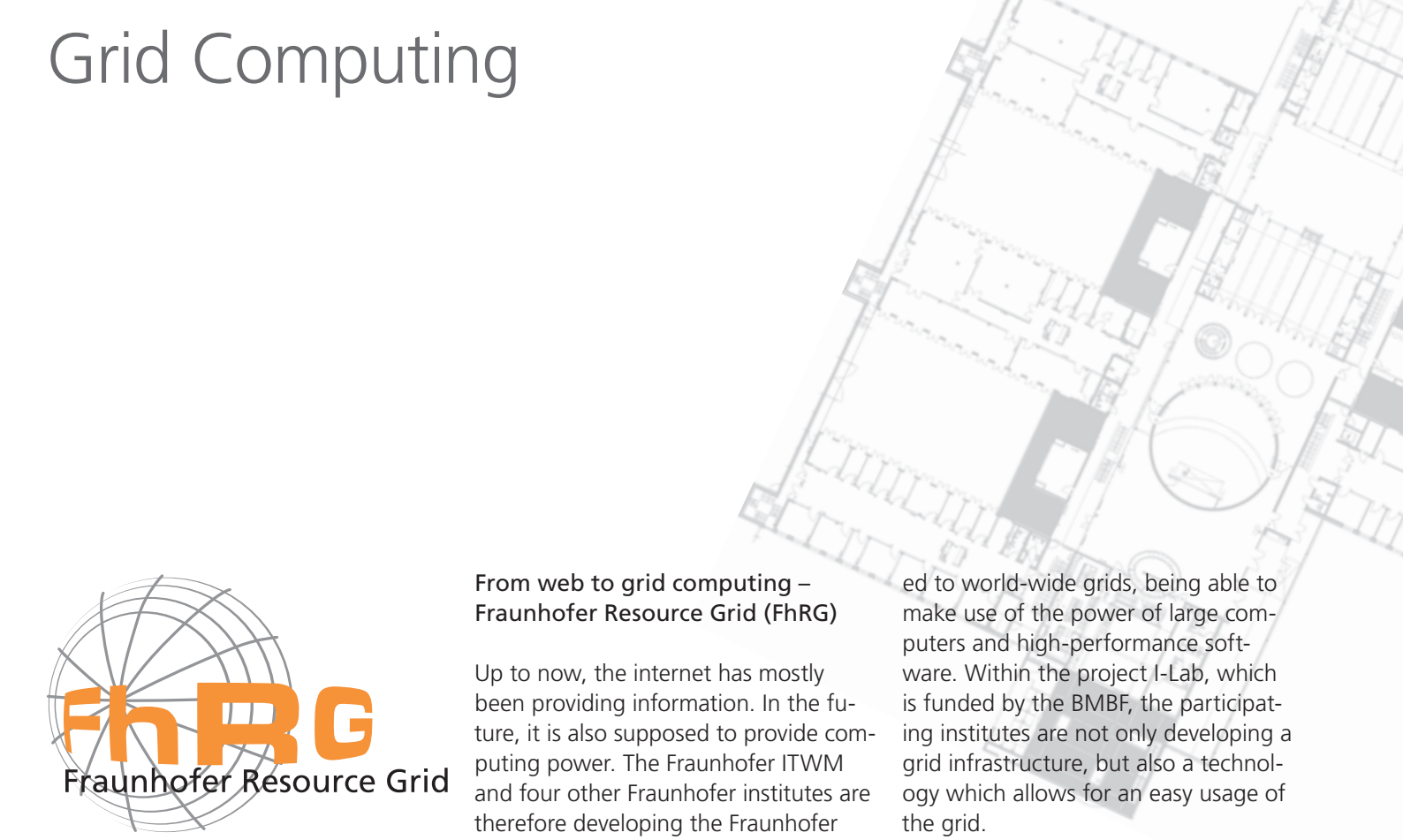
Not on the picture: Dr. Carsten Lojewski

Grid Computing



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From web to grid computing – Fraunhofer Resource Grid (FhRG)

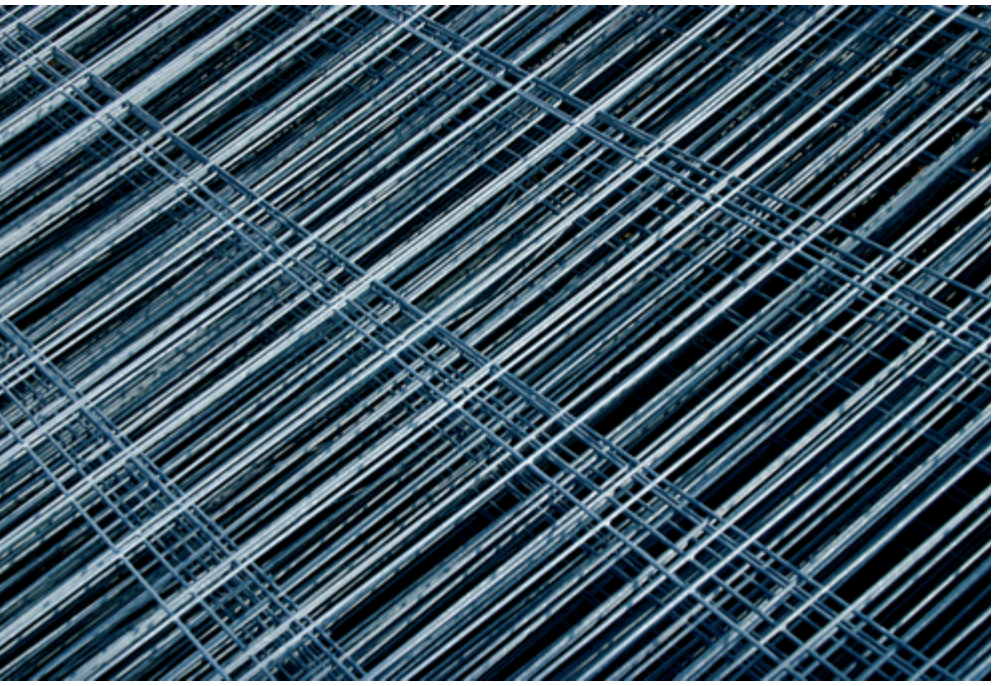
Up to now, the internet has mostly been providing information. In the future, it is also supposed to provide computing power. The Fraunhofer ITWM and four other Fraunhofer institutes are therefore developing the Fraunhofer Resource Grid especially for application in industry. An example for such applications is the system ERAMAS for the simulation of environmental risks (e. g., after a tanker accident), which was presented during Cebit 2003.

In the same way as today a laptop is connected to the power supply network, we will in the future be connected to world-wide grids, being able to make use of the power of large computers and high-performance software. Within the project I-Lab, which is funded by the BMBF, the participating institutes are not only developing a grid infrastructure, but also a technology which allows for an easy usage of the grid.

A portal developed by the Fraunhofer IAO will lead the grid user to the applications, and support him/her in order to carry them out. A very detailed resource repository provides information about software, hardware, and their dependences. The workflow system of the Fraunhofer FIRST, which is based on Petri networks, allows for the modeling of very complex simulation processes. When a job is to be carried out, the resource broker developed at the ITWM will select an appropriate free computer or, if necessary, the cheapest one.

The Fraunhofer Resource Grid is supposed to offer extensive services to engineers and scientists within and outside of the Fraunhofer-Gesellschaft. The word “resource” in the title already suggests that the subject is not only computing – machines, sensors, and measuring instruments will also be included in the future.

The objective of these activities is to turn the grid into a productive factor and to standardize it. Therefore, the ITWM is also represented in the Global Grid Forum with a special focus on the Production Grid Research Group.



Parallelization and Performance Analysis

Modern high performance computers allow for the computation of very complex problems by processing enormous amounts of data. However, the increasing complexity of processors, memory hierarchies, and computer connections in the form of clusters and grids also results in an increasing complexity of the optimal usage of the available computing power. For example, the distribution of computing jobs to the individual processors, the communication between the nodes, and the access to the different memories of the system must especially be accounted for.

The main subject of parallelization and performance analysis deals with the efficient parallelization and detailed code optimization of customer software. Within several projects, already existing MPI codes were made considerably faster, applications were parallelized, and also non-parallel codes became considerably faster due to optimization. Among our customers are the Deutscher Wetterdienst (German Weather Service) and enterprises from the financial sector.

The development and application of benchmarks for the performance determination of hardware and software is a further competence of the main subject. Only if the properties of all the system components and the resulting computing power of the entire system are known precisely, we are able to develop software optimally tailored to the respective computer, thus making full use of the available performance. Within a project supported by the BMBF, the ITWM is developing an extensive benchmarking environment for parallel computers in cooperation with its partners.

The efforts of the ITWM concerning software parallelization and performance analysis are also based on extensive competence and experience due to the operation of the institute's own PC clusters. In the year 2003, the ITWM ranged as number 296 among the 500 fastest computers in the world (TOP500) with a measured LinPack performance of approximately 400 Gflop of its system of 128 Pentium 4 Processors.

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Benchmarking and performance analysis

In the framework of the joint research project IPACS (Integrated Performance Analysis of Computer Systems), which is funded by the BMBF, we are developing a comprehensive benchmarking environment with the objective of an application-oriented analysis and evaluation of the performance of modern parallel computers. An application benchmark based on the CFD code ParPac, which has been developed at the ITWM, was applied to different architectures with up to several thousand processors. The resulting portability of the software as well as the scalability of the benchmarks will guarantee wide applicability. Additionally, the performance with respect to typical industrial applications can be measured and compared on the basis of appropriate problems for commercial software. Besides, an exact analysis of the run-time behavior with respect to memory and network accesses yields a system-independent characterization of these applications. In combination with (application-independent) information stemming from adequate low level benchmarks, the run-time for arbitrary hardware environments can be predicted, as we have been able to show exemplarily for the CFD software FLUENT®.

DDFEM – parallel code for three-dimensional structure mechanics

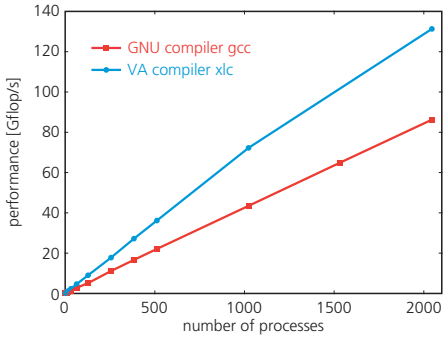
DDFEM is a newly developed code for the computation of internal stresses and deformations of an elastic body which is subject to (external) forces. The objective of the development is a high-performance, high-scalability code (1,000 CPUs) for the solution of really large problems. The parallelization of the network generation and of the finite element discretization (FEM) is based on the concept of domain decomposition: the computing domain is divided into subsections which are treated independently. The resulting linear system of equations is solved in parallel using the PETs library. In the case of simple geometries which can be described analytically, the integrated network generator can be used. However, the network for more complex geometries is read from a file and is decomposed subsequently.

DDFEM is used at the ITWM for the modeling of elastic properties of fiber structures. If the integrated network generator is used, the code shows a very good scaling behavior and can therefore be applied very well as a benchmark to estimate the performance of parallel architectures.

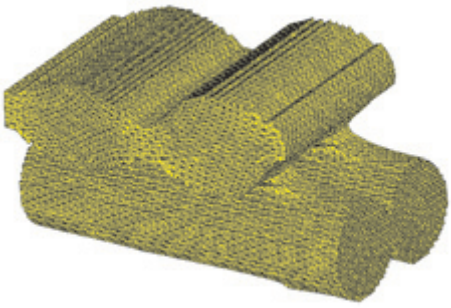
Parallelization framework ParMC

For a customer from the financial sector, we are developing within this project a parallelization framework in the form of a manager-worker system, which allows for a parallel computation of Monte-Carlo simulations for portfolio evaluation on a PC cluster. The individual computations, which partly are very time-consuming, are accelerated considerably, while a large number of computations can be carried out simultaneously. This project is focused on the development of a high-availability application which is able to tolerate faults or entire failures of individual cluster nodes and, interacting with hardware components of redundant design, leads to a fault tolerance of the entire system which is as high as possible. Besides, a performance prediction accounting for the computing time and the effort required for communication between manager and workers results in an optimal usage of the available computing power of the entire system, so that the application shows a very good scalability also on very large PC cluster systems.

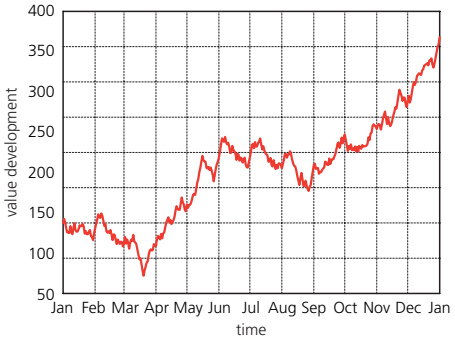
Performance of the ParPac benchmark on up to 2048 processors of an IBM SP Power3 cluster



Deformation of a three-dimensional fiber



Example of a Monte-Carlo computation for portfolio evaluation



Visualization

Many applications from the fields of simulation technology, medicine, fluid dynamics (CFD), material science, or geology produce volume data which no visualization system is able to render interactively today due to their size. This restriction of the interactive analysis of multi-dimensional data records has occasioned the ITWM to develop an individual visualization system. Today, PV-4D is the most powerful software in the field of volumetric rendering of complex, multi-dimensional data. The high performance of PV-4D enables the user to move through four dimensions (x, y, z, t) in stereo. The performance of this pure software solution with respect to space and time surpasses all other hardware and software systems by far.

The direct volume rendering method "directly" computes the resulting 2d image on the basis of the volume data. In contrast to a pure surface rendering of the 3d data (iso-valued rendering), this method is able to render considerably more information. Moreover, the lacking approximation of the iso-value towards a geometric primitive further increases the exactness of this method.

Performance

The PV-4D kernel is based on the vector shift algorithm developed at the ITWM, which allows for the mapping of 3d data structures onto the vector units (SSE-I, SSE-II) of the processors. Several units of the rendering kernel thus reach the peak performance of the current Intel/AMD processors. PV-4D is designed as continuous parallel software and uses all the available parallelization levels (on chip, SMP, distributed memory) optimally. Lacking performance during visualization always means that more time and thus more money are required on the part of the user. PV-4D therefore applies parallel I/O wherever this is possible. PV-4D is a complex parallel visualization tool supporting Ethernet, Myrinet, and Infiniband as connecting networks. It is however presented to the user as an easy-to-use Windows or Linux viewer. Today, PV-4D is available as a generic visualization tool and in the form of special adaptations for MAGMASOFT® users, for the seismic industry, and for the visualization of CT data in medicine.

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Examples for the Application of PV-4D

PV-4D SEISMICPRO

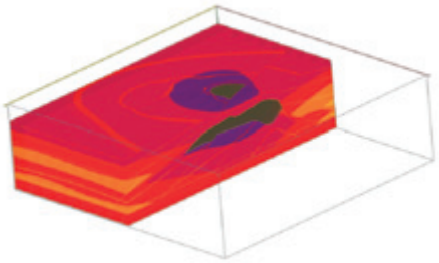
The visualization of seismic data, which generally occur in very large amounts, still is a very complex and expensive process in industry which definitely is of decisive importance for the interpretation of reservoirs and thus for the detection and the improved use of oil and gas resources. The specially adapted version of PV-4D supports widely used data formats, and can also visualize extremely large depth-migration data records (velocity fields). The viewer-server structure enables the enterprise to apply the tool globally in joint cooperation without any considerable loss of performance. As a PC-based tool, PV-4D is leading on the market with respect to price and performance.

PV-4D MAGMAVR

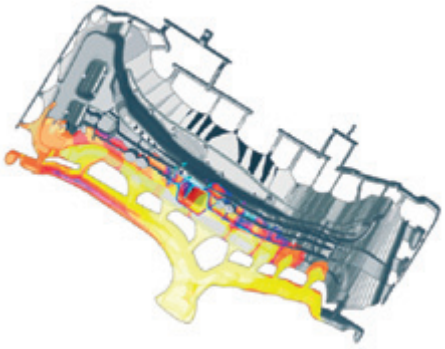
As first applications, the software package ParPac, which has been developed at the ITWM, and the parallel version of MAGMASOFT®, the leading casting simulation package, were supported by PV-4D. The large amounts of data resulting from parallel simulation can thus be visualized really interactively for the first time in the form of moving films. The representation in the Virtual Reality Lab of our institute, which is now available for the first time, allows for completely new insights and overwhelming images. The generation and effect of vortices in a flow can now be experienced in three dimensions by high-resolution images. A solidification process is precisely analyzed in detail as a time-dependent process for the first time.

PV-4D MEDICAL

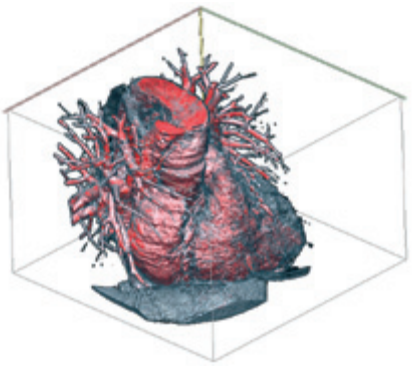
In cooperation with the Medical University Hannover, a beating heart of a living person was rendered for the first time as a high-resolution moving object in three dimensions in such a way that the user can immerse himself/herself interactively into the object without any temporal delay (50 images per second). This is a considerable advantage for the physician who has been working mainly with static or low-resolution images up to now. In practice, a double processor computer without special requirements with respect to the graphics hardware (Dual P4, FireGL) is sufficient. With the upcoming new 64-bit systems of AMD, which will be available in 2004, PV-4D moves volumetric rendering into a new performance class.



Seismic data record



AUDI: B-shaft (200 million control volumes)



The human heart

Availability and performance

PV-4D (release 1) is available for the platforms Windows/Linux, as well as for Linux PC clusters (4-256 SMP nodes). In cooperation with our partner Linux Networx, we also offer complete visualization solutions. The integration of PV-4D into already existing production environments is also available on demand.

Molecular Material Design

The prediction of material properties by computer simulation is of the biggest interdisciplinary problems of material science. The progess in miniaturization of electronic components has reached the atomic scale, where quantum mechanical effects become significant. On the engineering side of the problem, the manufacturing process of these components can greatly benefit from simulations

Our research is based on the molecular dynamics (MD) methodology which directly simulates atoms and their interactions. Using MD for molecular material design requires:

- atomic interaction potentials
- dynamic equations, in the simplest case the well-known Newtonian equations, and numerical methods for propagating a systems of atoms in time
- definition and "measurement" of (time-dependent) quantities corresponding to observable material properties
- high-qualitity software tools for the numerical solution of the dynamic equations and for pre- and post-processing of the simulation.

However, MD simulations are often computationally too demanding to calculate material properties directly. Scaling from the atomistic description of MD to the dynamics of quantities relevant to engineering, such as residual stress (see below), is absolutely necessary for molecular material design.

At the Fraunhofer ITWM, the atomistic part of this multiscale aspect of material science is modelled, and then validated by experiments by ITWM's partners. The ITWM is meeting this challenge in several interdisciplinary projects. One objective is the development of a scalable, parallel MD kernel with interfaces to external "plug-and-play" modules. The MD kernel and its interfaces have been specified completely, and first implementations are currently tested. The first production runs of the software are scheduled for mid-year 2004.

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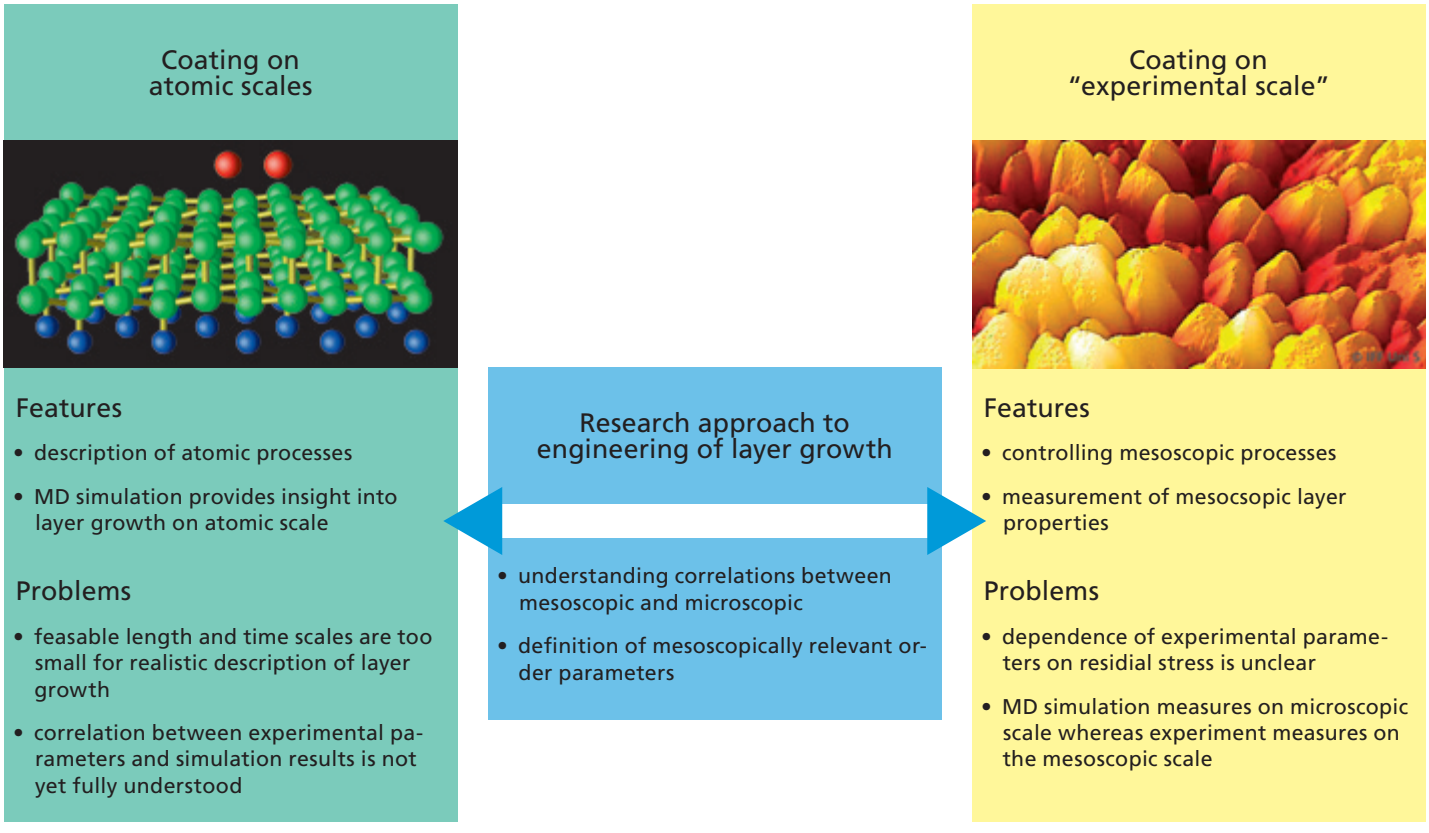
Coating simulation

Apart from pure software development, the Fraunhofer ITWM also works on specific problems of applied material science. In a joint DFG project with the Institute of Industrial Manufacturing and Management of the University of Stuttgart, we are simulating the coating of silicon surfaces with copper. The basic approach of this project is illustrated in the figures below.

The focus of the project is the dynamics of the important residual stress in thin layers during the coating process. It is known from experiments that residual stress is the main reason for the failure of coatings. However, its correlation with experimental process parameters is still largely unknown. Therefore, residual stress and its dynamics are engineering parameters which we plan to investigate in this project.

A PhD thesis examines the coupling of atomistic and continuum descriptions in order to reduce the size of the simulation problem. These descriptions are valid on different length and time scales. The system of ordinary differential equations of MD has to be coupled to the partial differential equations of continuum mechanics. A good model and a reliable numerical implementation of the coupling are necessary to avoid unphysical behavior such as reflections of sound waves at the coupling interface.

Approach for the development of a multiscale coating simulation



Distributed Computing Research Lab (DCRL)

The Research Lab "Distributed Computing" is integrated into the "Research Platform for Small and Medium-sized Regional Enterprises" (see page 6). Its main subjects are the improvement of management methods for distributed PC systems and the development of new distributed applications which are defined by the demands of the market.

The research platform is characterized by different markets of the project partners, different applications, and common problems of software technology. At the same time, a competence center can be established whose effects go far beyond regional boundaries, so that it is also attractive for other companies working in similar fields.

The Linux Networx Research Lab, which has been established since 2002, has been integrated into the DCRL. Other regional companies (tecmath AG, Mobotix AG) have committed themselves by personnel and financial contributions. We are working on the following research areas:

- software technologies for the improvement of the reliability of distributed computer systems
- on-demand computing – grid computing
- benchmarking and performance analysis
- development of new parallel applications

The establishment of the European Headquarter of the enterprise Linux Networx has also provided Kaiserslautern with a new employer, who is strengthening the growing local IT sector and offering new jobs.

Apart from a diligent hardware configuration, the system management is the key to productivity concerning the operation of productive PC clusters. This includes control of the hardware and the operating system, their monitoring, load distribution, account management, and software management. The cooperation with Linux Networx has resulted in the development of solutions for high-availability cluster systems by the integration of application and cluster management, the porting of the management system Clusterworx to the Linux distribution of the company SuSE, and its expansion by new functions.

Service offers of the Competence Center

- development and porting of parallel applications
- performance analysis and tuning
- benchmarking of cluster systems and applications
- consulting with respect to the introduction of cluster systems and the entry into grid computing
- visualization of very large amounts of data
- HPC system consulting
- software design for parallel applications

Technical equipment of the Fraunhofer ITWM

- Top500 PC cluster with 128 P4-CPUs (linpack performance: 400 Gflop)
- high-performance storage and backup systems
- VR laboratory for the visualization of large data sets
- PC cluster for the testing of new technical concepts

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Fraunhofer Chalmers Research Centre for Industrial Mathematics FCC

The Fraunhofer Chalmers Research Centre for Industrial Mathematics has now been working since September 2001. It is closely cooperating with the Fraunhofer ITWM and the Chalmers University of Technology, thus occupying a special position among the Swedish and European institutes of applied research.

According to the business plan of March 2001, the FCC will increase the turnover of 1.7 million for the first budgetary period to 2 million for 2004. This level was reached already in 2003, with the following distribution of income:

42 per cent industrial projects, 20 per cent public projects, 36 per cent Fraunhofer-Gesellschaft and Chalmers, and 2 per cent other income.

During its initial phase in September 2001, the FCC had six employees, whose number is to increase to 20 until the end of 2004 according to the business plan. At the end of 2003, 18 colleagues were already working at the FCC, including one scientist from the ITWM. Thus, the FCC now has approximately the size of a department of the ITWM.

Up to now, an entire number of 80 projects in cooperation with numerous customers of different size and from different branches have been initiated at the FCC; 50 of these projects have already been concluded successfully. The number of industrial partners has meanwhile increased to more than 40, which has not remained without effects for the ITWM because of the growing volume of common projects of FCC and ITWM.

Four fields of competence will be described on the following pages:

- material fatigue from a statistical point of view
- bioinformatics and system biology
- quality engineering
- financial and insurance mathematics

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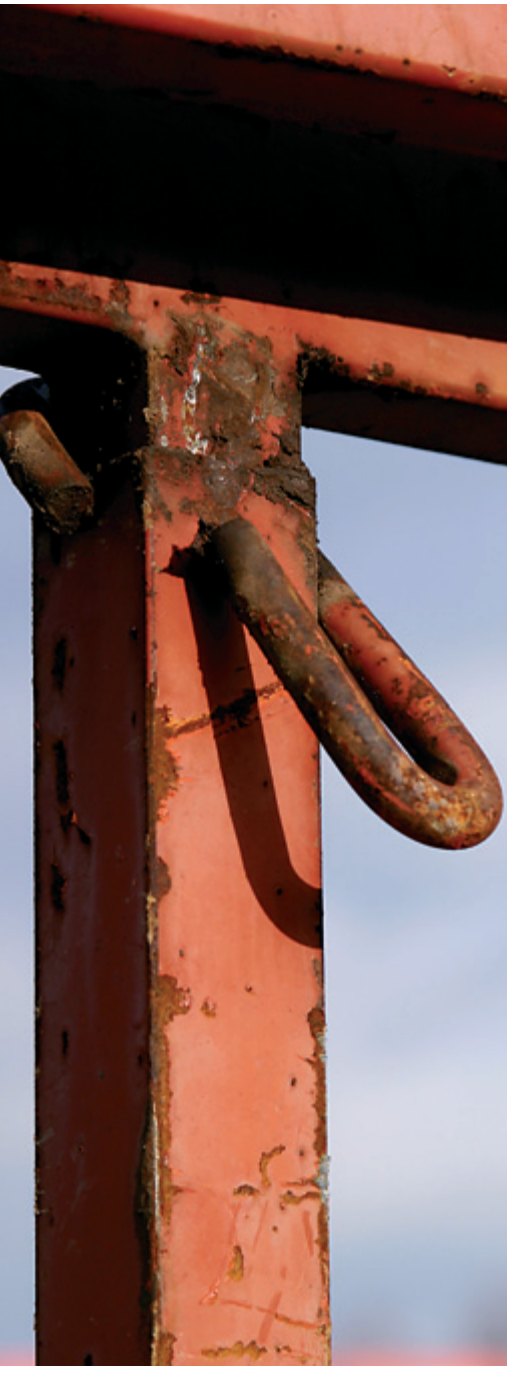
Material Fatigue from a Statistical Point of View



Statistical methods complete the image of reliability of mechanical constructions with respect to fatigue strength. Thus, the most efficient steps towards the improvement of a product's quality can be determined.

Reliability is a combination of the material strength of a component and the load to which it is subject. Material strength is determined by fatigue tests, whereas the load is measured during operation, on test tracks, or on test rigs. The relation between strength, load, and material fatigue is represented by simple physical models. The determination of strength and load is a difficult problem, which is why the modeling of these parameters is subject to specific uncertainties. A statistical consideration allows for a combination of all the uncertainties and variations in the form of a comprehensive reliability analysis, by which the models can be improved during operation on the basis of the results. The following areas can especially be identified:

- planning and evaluation of fatigue tests

  Established statistical methods are applied, such as statistical planning of experiments, regression analysis, prediction and confidence intervals. These are adapted to the different specific applications in engineering.

- analysis of real loads during operation

  The theory of stochastic processes and the rain flow count analysis are used here. Besides, problems of the relations between laboratory experiments and loads during operation are also accounted for.

- dispersion in comparison to uncertainty

  A statistical approach allows for a comparison of model uncertainties and random variations of loads or materials, in order to determine the optimal complexity of the modeling.

In the framework of a project together with five industrial partners, a method for the estimation of the service life curve on the basis of tests with different amplitudes has been developed. The service life can thus be predicted for arbitrary loads during operation or arbitrary ranges of design load. In contrast, traditional methods are based on laboratory experiments with load sequences of constant amplitudes. However, during the operation of the products, the occurring loads are of more stochastic nature and show variable amplitudes. Therefore, laboratory experiments with variable amplitudes can improve the prediction of service life.

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Bioinformatics and System Biology

Bioinformatics combines genetics, mathematics, and computer science in order to allow for the handling of the sequence and gene expression data generated by biotech and pharmaceutical industry. Research in bioinformatics involves the development of tools for the modeling, analysis, and visualization of complex biological and medical data. Today, computer-based biology is a key for a better understanding and exploitation of the enormous and complex amounts of data produced by biotech and pharmaceutical industry. However, many existing tools are not adapted to the new situation.

System biology uses methods from system and control theory, signal processing, and information theory in order to gain understanding of biological processes from a systems perspective. Research includes the modeling of gene and protein interactions, the analysis of metabolic and biochemical networks, the analysis of gene expression data from a systems perspective, etc.

It is the objective of statistical genetics to determine the exact position in the genome which is responsible for a specific disease. Biostatistics, and especially survival analysis, contributes to the determination of influences of genetic and environmental effects on individual lifetimes or the development of a disease. Medical data either consist of individual measurements of genes, or of measurements of genetic similarities between relatives at prespecified positions in the human genome. The objective of the analysis is the determination of those positions which initiate the disease among the studied population.

The FCC has developed different approaches for the solution of this problem in cooperation with two partners at Lund University – the Wallenberg Laboratory at the Malmö University Hospital and the Centre for Mathematical Sciences. The first approach uses genetic measurements of individuals together with their levels of the disease. This has resulted in a description of genetic variations influencing the development time of diabetes. Especially interesting are the gene-environment effects. Another approach is the use of family data, i. e. the use of the so-called IBD counts of relatives who are also affected. The objective is the development of tools for the simultaneous study of the effects of gene variations at two positions on the genome. The methods are robust with respect to the type of human population and the type of disease.

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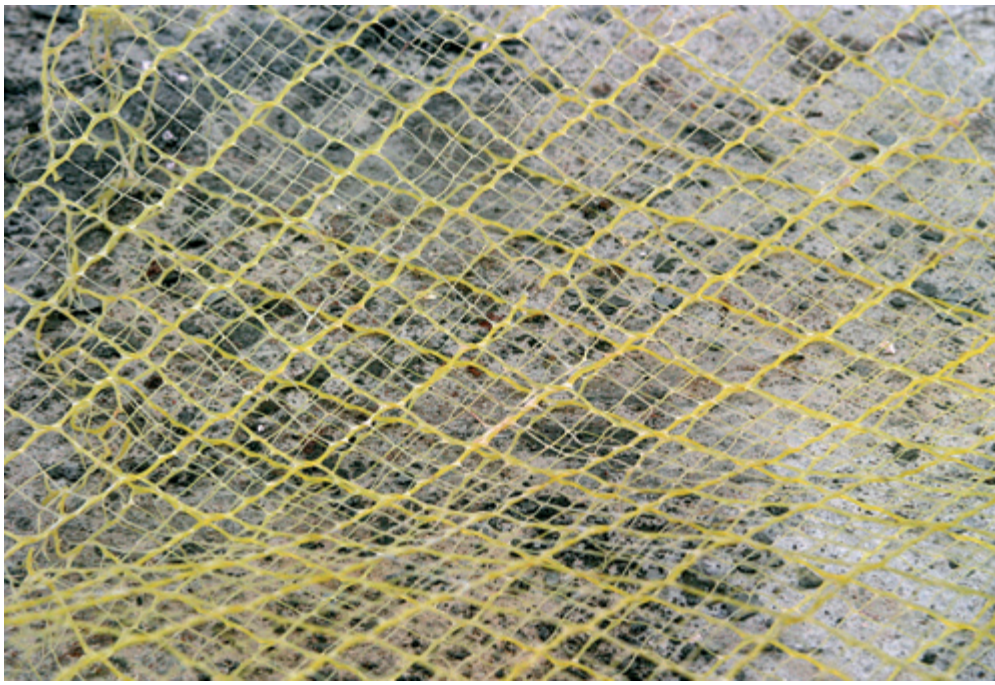

Financial and Insurance Mathematics

At the beginning of the year 2003, Dr. Gerald Kroisandt from the department of Financial Mathematics of the Fraunhofer ITWM came to the partner institute FCC in order to support the establishment of a research group of financial and insurance mathematics there. Up to now, the subjects have been "Basle II" and insurance mathematics, as well as "classical" financial mathematics with respect to option pricing, where at the moment close cooperation is initiated with a company producing trading systems. Thus, a continuation of the competence field, which has been started very promisingly, is guaranteed.

The first large project has been realized in cooperation with the Swedish Insurance Federation. Currently, the regulations concerning security funds of insurance companies ("Solvency II") are revised, analogously to "Basle II" with respect to banks. This is happening on a European as well as on a national scale. The task of the FCC was the support of the development of the Swedish regulations concerning the two large areas of "risk standards" and "interest rate models".

In the case of interest rate models, there is no standard such as the Black-Scholes model for options. Therefore, the advantages and disadvantages of the different classes of models were examined. The main distinctive criterion was the distribution of the short interest rate, i.e. whether the model resulted in a normal distribution, a log normal distribution, or a chi^2-distribution. Besides, possibilities and limits of single-factor and multi-factor models were discussed respectively.

Risk standards are subject to four assumptions which must be satisfied. The objective was the examination of standard models for premium computation with respect to the question whether they might be used for the computation of risk standards, too. The application of a model for premium computation also for the computation of risk standards is supposed to guarantee transparency of the calculations for the regulatory authority. Interestingly enough, the requirements to a model for premium computation can be identified with those to a risk standard relatively well.

The main problem of the method of standard deviations and variances is lacking monotony. Other methods (semi-variance principle, constant risk aversion) yield "sensible" risk standards, i.e. a coherent or convex risk standard. Convex risk standards are also interesting with respect to premium computation because they support the diversification of the portfolio.

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Sensitive products and production concepts are often confronted with quality problems leading to a belated introduction on the market, entailing in lost revenues. The simulation and visualization of variations and tolerance results, in combination with diagnosis tools, is an important success factor of quality improvement. Fewer variations concerning products and processes result in a substantial profit for a company due to lower costs for adjustments, rejects, and complaints. Quality is one of the most important decision criteria for customers. Hence, quality control is a very important part of business strategy.

In cooperation with the Wingqvist Laboratory of the Chalmers University of Technology, the FCC supports companies with respect to a systematic reduction of variability in processes and products in the following key technologies: robust design, optimization of inspection planning, analysis of measurement systems (QS 9000), as well as process control and root cause analysis. A long-term vision in the field of production technology is the virtual factory with a high level of reality and functionality. Programming, simulation, and visualization of virtual production equipment plants allow for a reduction of the ramp-up time in the real factory. Although modern industries are already applying virtual prototypes in order to substitute physical ones, to visualize assembly processes, and to program industrial robots offline, the full potential of a virtual factory will not be reached for a long time yet. One limit is represented by the time required for the programming of robots. Most of the programming with respect to the movement and the paths of robots and equipment is done manually, because already existing support for an automatic path planning is very limited.

A project in cooperation with Volvo Car Corporation has the objective of determining collision-free paths for robots automatically, from the initial configuration up to the final position, simultaneously accounting for minimum cycles, path lengths, and joint wear. The simulation software for automatic path planning is based on a virtual 3d model which describes kinematics and geometry of an assembly unit, simultaneously allowing for the interaction with a collision tester.

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Talks

Andrä, Heiko et.al.:
Computer Modeling and Design of Non-Woven Acoustical Trim
Vibro-Acoustics Users Conference Europe, Leuven, Belgium, January 2003

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Rechnergestützte Optimierung der akustischen Wirksamkeit von Nonwovens
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Boehm, Martin; Maasland, Mark:
Online Inspektion von laminierten Metalldichtungen und glänzenden Verschlüssen
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Göb, Norbert:
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Grosan, Teodor:
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Werkstofftag 2003, Ober-Ramstadt, November 2003

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On a multigrid adaptive refinement solver for non-Newtonian flow in porous media
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MACSI-net WG-14 Workshop "Filtration problems in porous media and paper manufacturing", Stuttgart, November 2003

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Kehrwald, Dirk:
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Towards a consistency proof for immiscible lattice BGK
GAMM-Konferenz 2003, Abano Terme, Italy, March 2003

Klein, Peter; Baumann, Petra; Gottwald, Bernhard; Sommadossi, Silvana; Gemmler, Armin:
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4th Asian-European International Conference on Plasma Surface Engineering AEPSE 2003, Jeju, Korea, September 2003

Knaf, Hagen:
Daten- und wissensbasierte Diagnoseunterstützung in der Medizin
Arbeitsgruppentagung 2003 "OR im Gesundheitswesen", Kaiserslautern, March 2003

Korn, Ralf:
Mathematische Modelle für optimales Investment
TU Brunswick, June 2003

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Non Probabilistic Crash Modelling with Applications in Finance and Insurance
DFG-Schwerpunkt, Berlin, April 2003

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Portfolio-Optimierung im Wandel der Zeit
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Practicality of Transaction Cost Approaches in Continuous-Time Portfolio Optimisation
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Krüger, Kai:
A glimpse into the future of Singular: Dynamic Loading
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Finite-Pointset method, a meshfree flow solver
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Finite-Pointset method, a meshfree flow solver with applications to glass industry
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Latz, Arnulf:
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Latz, Arnulf:
Simulation of Depth filtration in realistic three dimensional fiber Structures
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Production System Design: Formal Semantics, Intuition, and Missing Links
Hosei University, Tokyo, Japan, July 2003

Linn, Joachim:
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MAGMASOFT User-Meeting, Vaalsbroek, Netherlands, October 2003

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Marheineke, Nicole:
Die Rolle der Mathematik bei der Gestaltung des 21. Jahrhunderts
CJD, Malente, May 2003

Marheineke, Nicole:
Fibre-Fluid Interactions - Slenderbody asymptotics for a fibre in an incompressible air flow
OCIAM, Oxford, March 2003

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Mesh-less method for the homogeneous handling of fiber-fluid interactions
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Melo, Teresa:
Dynamic multi-commodity facility location: A mathematical modelling framework for strategic supply chain planning
Symposium on Operations Research, Heidelberg, September 2003 and Meeting of the Euro Working Group on Locational Analysis – EWGLA XIV, Korfu, Greek, September 2003

Merten, Dirk:
Integrated Performance Analysis of Distributed Computer Systems IPACS
Workshop on Performance Characterization, Modeling, and Benchmarking for HPC Systems, Emeryville, May 2003

Neunzert, Helmut
Lernen für die Schule oder für das Leben?
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Neunzert, Helmut
Mathematik als Schlüsseltechnologie
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Was man mit Mathematik so alles machen kann und warum
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Mathematics as a Technologie
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Neunzert, Helmut:
Technomathematik- Schwächen und Stärken eines neuen Studiengangs
Tagung "Technomathematik", TU Dresden, September 2003

Nickel, Stefan:
Dynamic multi-commodity capacitated location: A mathematical modeling framework for strategic supply chain planning
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Simulation und Optimierung zur Planung und Steuerung von Kommissioniersystemen
VDI-Seminar über Optimierte Kommissioniersysteme, Karlsruhe, February 2003

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3D-Bildanalyse der Mikrostruktur offenporiger Schäume
22. BV-Forum, Sinsheim, May 2003

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Anwendung der 3D Bildanalyse zur Charakterisierung der Mikrostruktur offenporiger Schäume
12. Arbeitstagung Quantitative Bildanalyse, Darmstadt, June 2003

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Bildanalytische Charakterisierung der Graphitanordnung in stabil erstarrten Gusseisenlegierungen - Ergebnisse eines Ringversuchs
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Estimation of the Euler number of sets discretized with respect to homogeneous lattices
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Processing and Analysisof 3d images from microstructures of macroscopically homogeneous materials
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Pfreundt, Franz-Josef:
An XML-based Framework for Loosely Coupled Applications on Grid Environments
GGF 7, JSDL BOF, Tokyo, March 2003

Pfreundt, Franz-Josef:
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Pop, Serban Rares:
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Vom Bremer Modell zum Fraunhofer-Institut
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Rief, Stefan:
Modeling and Simulation of Dewatering Processes in the Pressing Section of Paper Machines
LSSC 2003, Sozopol, Bulgaria, June 2003

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Modellierung und Simulation von Entwässerungsprozessen im Pressspalt von Papiermaschinen
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AnSiM – ein GIS-basiertes Decision Support Tool für die Anschlusssicherung
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Akustikoptimierung am Beispiel eines PET-Dachhimmels
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Creating a Knowledge Box for Multi Criteria Decision Making
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TU Berlin, December 2003

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TU Kaiserslautern, summer term 2003

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Einführung in die FEM
TU Kaiserslautern, summer term 2003

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Mathematik
FH Wiesbaden, winter term 2003/04

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Kneip, Frank:
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TU Kaiserslautern, Mathematics Department

Korn, Ralf:
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Financial Mathematics II
TU Kaiserslautern, winter term 2003/04

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PraMa: Stochastische Methoden
TU Kaiserslautern, winter term 2003/04

Korn, Ralf:
Finanzmathematik für Lehrer und Lehramtsstudenten
TU Kaiserslautern, winter term 2003/04

Kraft, Holger:
Finanzmathematische Grundlagen der modernen Portfolio- und Kapitalmarkttheorie (im postgraduierten Studiengang "Immobilien-Portfoliomanagement")
European Business School, Oestrich-Winkel, summer term 2003

Latz, Arnulf:
Hydrodynamik
University of Mainz, winter term 2002/03

Latz, Arnulf:
Aspekte von Unordnung in kondensierter Materie
University of Mainz, winter term 2003/04

Lavrov, Alexander:
Block-Seminar zu "Aspekten der Nebenläufigkeit in Produktionssteuerung"
National Technical University der Ukraina, September - October 2003

Melo, Teresa; Lavrov, Alexander:
Seminar on Logistics Management: Models and Methods
TU Kaiserslautern, winter term 2003/04

Müller, Marlene:
Semiparametrische Modelle
Humboldt-University of Berlin, winter term 2003/04

Nickel, Stefan:
Standortplanung und strategisches Supply Chain Management
University of Saarland, winter term 2003/04

Nickel, Stefan:
Operations Research I, II
University of Saarland, summer term 2003 and winter term 2003/04

Schladitz, Katja; Ohser, Joachim:
Image Analysis and Mathematical Morphology II
TU Kaiserslautern, summer term 2003

Schneider, Torsten:
Strukturen des Notfall- und Rettungswesens in Deutschland
TU Kaiserslautern, summer term 2003

Andrä, Heiko:
Computer Modeling and Design of Non-Woven Acoustical Trim
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Boland, Natashia; Domínguez-Marín, Patricia; Nickel, Stefan; Puerto, Justo:
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Briehl, Boris; Urbassek, H. M.:
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Carizosa, Emilio; Nickel, Stefan:
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Fraunhofer ITWM Reports, No. 52, 2003

Domínguez-Marín, Patricia; Hansen, Pierre; Mladenovic, Nenad; Nickel, Stefan:
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Krause, E.; Jäger, W. (Eds.): High Performance Computing in Science and Engineering '02, 2003, Springer Verlag, Berlin

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Günther, Marco; Klar, Axel; Materne, Thorsten; Wegener, Raimund:
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Iliev, Oleg; Tiwari, Sudarshan:
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Müller, Marlene:
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Neunzert, Helmut (with Abele, Andrea; Tobies, Renate):
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Scientific Graduation Theses

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Álvarez, Armesto; Antonio, José:
Lattice Boltzmann equation in curvelinear domain
Master thesis, TU Kaiserslautern,
Mathematics Department

Bhattacharya, Avik:
Measurement of contact distribution functions on 2d binary images using image processing techniques
Master thesis, TU Kaiserslautern,
Mathematics Department

Domínguez-Marín, Patricia:
The discrete ordered median problem: Models and solution methods
Dissertation, TU Kaiserslautern,
Mathematics Department

Espinoza, Dirk:
Comparison of Algorithms for Territory Alignment with Special Consideration of Connectedness
Master thesis, TU Kaiserslautern,
Mathematics Department

Friedrich, Catharina:
Statisches Hedgen von Exotischen Optionen
Diploma thesis, University of Siegen

Garth, Lutz:
Boundary Control in Glass Cooling Including Radiation
Diploma thesis, TU Kaiserslautern,
Mathematics Department

Göb, Norbert:
Automorphism Groups of Hyperelliptic Function Fields
Dissertation, TU Kaiserslautern,
Mathematics Department

Jegorovs, Jevgenijs:
Optimal Shape of the Reflex Tube of a Bass Loudspeaker
Master thesis, TU Kaiserslautern,
Mathematics Department

Jost, Katrin:
Sortierkonzepte für private Postdienstleister - Logistische Abläufe und Optimierungspotentiale
State examination Thesis, TU Kaiserslautern,
Mathematics Department

Klier, Christian:
Evaluation, Entwicklung und Integration von Bildverarbeitungsbibliotheken in eine Java-basierte Hochgeschwindigkeits-Videoapplikation unter besonderer Berücksichtigung von Performanceaspekten
Diploma thesis, FH Brandenburg,
Department of Computer Science and Media

Krekel, Martin:
Some New Aspects of Optimal Portfolios and Option Pricing
Dissertation, TU Kaiserslautern

Kumar, Jitendra:
Simulation Studies of the Electret Effect in Filters
Master thesis, TU Kaiserslautern,
Mathematics Department

Kux, Georg:
Algebraic Correspondences between Hyperelliptic Function Fields
Dissertation, TU Kaiserslautern,
Mathematics Department

Laptev, Vsevolod:
Numerical solution of coupled flow in plain and porous media
Dissertation, TU Kaiserslautern,
Mathematics Department

Litzenburger, Ute:
Standortentscheidungen für Sortierzentren privater Postzusteller
State examination thesis, TU Kaiserslautern,
Mathematics Department

Lozano, Lucia:
Benders' Decomposition for Generalized Capacitated Location Problems
Master thesis, University of Sevilla, Spain

Parnitzke, Thomas:
Kreditscoring unter Stichprobenselektion
Diploma thesis, Humboldt-University of Berlin,
Department of Economic Science

Pereverzyev, Sergiy:
Inverse Problems for Radiative Heat Transfer in Glass
Master thesis, TU Kaiserslautern,
Mathematics Department

Polanski, Steffen:
Die LFMM Systemkomponente: Eine Monitoring- und Managementkomponente zur Lastverteilung und Fehlerbehandlung in der verteilten I-Search Architektur THING
Diploma thesis, TU Kaiserslautern,
Department of Computer Science

Ruiz Calvo, Manuel:
Total Absorptivity of Glass as a Weighted Sum of Gray Gases
Master thesis, TU Kaiserslautern,
Mathematics Department

Schlosser, Peter:
Matrix Compression Methods for the Numerical Solution of Radiative Transfer in Scattering Media
Dissertation, TU Kaiserslautern,
Mathematics Department

Seibold, Benjamin:
Optimal Prediction in Molecular Dynamics
Diploma thesis, TU Kaiserslautern,
Mathematics Department

Sting, Sandra:
Dynamische Standortplanung: Heuristische Lösungsansätze mit Nachbarschaftssuche
Universität-Gesamthochschule Siegen,
Mathematics Department

Will, Wolfgang:
Modelle zur Bewertung von Einzugsgebieten am Beispiel von Supermärkten
Diploma thesis, University of Saarbrücken,
Department of Law and Economic Science

Zimmer, Peter:
Storage Resource Broker und andere verteilte Grid Filesysteme
Diploma thesis, TU Kaiserslautern,
Department of Computer Science

Participation on Fairs and Conferences

ACHEMA 2003
Frankfurt on the Main, May 2003, Exhibitor

BMBF Workshop zum 6. Rahmenprogramm der EU
Hannover, March 2003, Participation

Case studies in Industrial Mathematics
Pisa, December 2003, Lecture

Cebit
Hannover, March 2003, Exhibitor

Chemiefasertagung
Dornbirn, Austria, September 2003, Exhibitor

Conf. on Numerical Analysis
College Station, Texas, January 2003, Lecture

Conference on Financial Methods in Insurance
Kopenhagen, February 2003, Lecture

Control 2003
Sinsheim, April 2003, Exhibitor

EAGE
Stavanger, Norway, June 2003, Exhibitor

edaForum03
Stuttgart, November 2003, Participation

Entwurfsplattformen komplexer angewandter Systeme und Schaltungen (EkompaSS), 2. Workshop
Hannover, April 2003, Software Presentation, Poster

ERC-Conference
Ankara, September 2003, Lecture

Euromech conference, ESMC 03
Thessaloniki, Greek, August 2003, 2 Lectures

Filtech Europe
Düsseldorf, October 2003, Exhibitor and Lectures

Fraunhofer Expertengespräch KRANKENHAUS-LOGISTIK
Kaiserslautern, March 2003, Organization and Lectures

Fraunhofer Workshop zum 6. Rahmenprogramm der EU
Brussels, July 2003, Participation

GAMM-Conference 2003
Abano Terme, Italy, March 2003, Lecture

GGF 7 and 9
Tokyo, March 2003; Chicago, October 2003

Glass-Days 2003
Eindhoven, November 2003, Co-Organization

18. Hofer Vliesstofftage
Hof, November 2003, Exhibitor

HUSUM Wind 2003
Husum, September 2003, Exhibitor

International Conference – Information Society and Modern Business
Ventspils, Latvia, January 2003, Lectures

International Symposium on Computed Tomography and Image Processing for Industrial Radiology
Berlin, June 2003, Lecture

Jahreskongress "Zulieferer Innovativ"
Audi Forum Ingolstadt, July 2003, Exhibitor

LSSC 2003
Sozopol, Bulgaria, June 2003

MACSI-net-Workshop "Industrial Challenges in Geometric Modelling and CAD"
Darmstadt, March 2003, Lecture

MACSI-net WG-14, Workshop "Flows in Porous Media"
Eindhoven, Mai 2003, Lecture

MACSI-net Event "CardioPoint"
Graz, Austria, June 2003, Organization

MACSI-net-Workshop "Industrial challenges in the numerical simulation of evolving interfaces"
Brussels, September 2003, Participation

MACSI-net WG-14, Workshop "Filtration problems in porous media and paper manufacturing"
Stuttgart, November 2003, Lecture

MACSI-net Workshop "Information Technologies and Computing Techniques for Agro Food Sector"
Barcelona, November 2003, Lecture

MAGMASOFT User-Meeting
Vaalsbroek, Netherlands, October 2003, Exhibitor and Lectures

Medica
Düsseldorf, November 2003, Exhibitor

Metallographietagung
Berlin, September 2003, Lecture

Multigrid course
Bonn, November 2003, Participation

Numerical Methods for Multidimensional Radiative Transfer Problems
Heidelberg, September 2003, Participation

OR-Tagung 2003
Heidelberg, September 2003, Lecture

rail # tec 2003
Dortmund, November 2003, Exhibitor on the Fraunhofer joint booth

SC2003
Phoenix, Arizona, November 2003, Exhibitor

Sensor 2003
Nuremberg, Mai 2003. Exhibitor

SIMPAT
Nuremberg, May 2003, Austeller

14. Technologie- und InnovationsFORUM Pfalz
Kaiserslautern, March 2003, Exhibitor

Techtextil 2003
Frankfurt on the Main, April 2003, Exhibitor and Lectures

The Art of Semiparametrics
Berlin, October 2003, Lecture

Topology Optimization Days
Schloss Thurnau, September 2003, Lecture

transport logistic
Munich, May 2003, Exhibitor

VehTec
Pirmasens, October 2003, Exhibitor and Lecture

Vibro-Acoustics Users Conference Europe
Leuven, Belgium, January 2003, Lecture

Virtual Material Design and Process Optimization, EU FP6 Integrated Project Proposal Kickoff Meeting
Kaiserslautern, February 2003, Organization

VR Creation
Stuttgart, July 2003, Co-Organization with MAGMA

Workshop "Stochastic Geometry and Stochastic Models"
Kaiserslautern, June 2003, Organization

Workshop "Brennstoffzelle und Wasserstoff"
Hamburg, November 2003, Lecture

Workshop "Fast Boundary Element Methods in Industrial Applications"
Söllerhausen, October 2003, Lecture

Workshop "Modelling and Simulation of Microfluidics Component"
Mainz, June 2003, Participation

Guests

Workshop "Recent advances in multiphase flow and transport in porous media"
Delft, June 2003, Participation

Workshop "Virtuelles Materialdesign textiler Werkstoffe"
Kaiserslautern, September 2003, Organization and Lectures

Workshop "Cardiovascular Respiratory and Metabolic Control Modeling"
Graz, Austria, June 2003, Organization

Workshop IWRMM
University of Karlsruhe, July 2003, Lecture

Zulieferer Innovativ 2003
Ingolstadt, June 2003, Exhibitor

4. Hannoversche Software-Tage für die Wasserwirtschaft
Hannover, March 2003, Exhibitor

6th Conference of the Swiss Society for Financial Market Research (SGF)
Zurich, April 2003, Lecture/Participation

7. GMM/ITG-Diskussionssitzung Analog 2003: Entwicklung von Analogschaltungen mit CAE-Methoden
Heilbronn, September 2003, Exhibitor

10. Jahrestagung der Deutschen Gesellschaft für Finanzwirtschaft (DGF)
Mainz, October 2003, Lectures

12. Arbeitstagung Quantitative Bildanalyse
Darmstadt, June 2003, Lecture

14. Technologie- und InnovationsFORUM Pfalz
Kaiserslautern, March 2003, Exhibitor

18. Hofer Vliesstofftage
Hof, November 2003, Exhibitor

21. Heidelberger Bildverarbeitungsforum "Bildfolgenanalyse"
Mannheim, March 2003, Participation

22. Heidelberger Bildverarbeitungsforum "Qualitätskontrolle mittels Bildverarbeitung"
Sinsheim, May 2003, Lectures

23. Heidelberger Bildverarbeitungsforum "Beleuchtung und Bildaufnahme"
Stuttgart, October 2003, Participation

54th Session of the International Statistical Institute (ISI)
Berlin, August 2003, Lecture

Prof. Ciegis, Raimundas (TU Wilna, Litauen)
Numerische Algorithmen zur Modellierung der Ausformung flüssiger Polymere
November 2003

Dahlgren, Martin (Universität Lund):
Impulse Control Problems in Finance
June to December 2003

Francis, Richard (University of Florida, USA)
Demand point aggregation for location models
June 2003

Kumar, Mayank: Master-Student (Indian Institute of Technology)
Testen und Analysieren von Software zur Simulation von Strömung in porösen Medien
Mai to July 2003

Kumar, Ratish (Indien):
Parallelrechnen
April to June 2003

Popov, Petr: Doktorand (Texas A&M University, College Station)
Fluid-Struktur-Interaktion und die Homogenisierung der Permeabilität deformierbarer poröser Medien
October to December 2003

Seiler, Werner M. (IWR Universität Heidelberg):
Numerische Integration impliziter Differentialgleichungen
July 2003

Semet, Frederic (University Valenciennes, Frankreich)
Management in real-time of fleets of emergency vehicles
September 2003

Dr. Starikovicius, Vadimas (TU Wilna, Litauen)
Numerische Simulation von Zweiphasenströmung in porösen Medien und iterative Methoden für nicht-newtonsche Strömung
May to June 2003 (HYKE fellowship)

Steffensen, Mogens (Universität Kopenhagen):
Finance and Life Insurance
April 2003

Touzi, Nizar; Bouchard, Bruno (CREST, Paris):
Malliavin-Kalkül und Simulation zur Lösung partieller Differentialgleichungen
September 2003

Dr. Vasileva, Daniela (Institut für Mathematik, Bulgarische Akademie der Wissenschaften, Sofia)
Algorithmen und Software für Computersimulation von Strömung in Ölfiltern und nicht-newtonscher Strömung in porösen Medien
September 2002 to May 2003 (ERCIM fellowship)

Wilmott, Paul (Wilmott Associates, London):
Workshop on Applied Finance
January 2003

Collaboration in Boards, Editorships

Dr. Dietmar Hietel

- Assistant Member in the Scientific Technical Council of the Fraunhofer-Gesellschaft (WTR)

PD Dr. Oleg Iliev

- Journal of Computational Methods in Applied Mathematics (Member of Editorial Board)
- Journal of Mathematical Modelling and Analysis (Member of the Editorial Board)
- Journal of Food Engineering (expert)
- Journal of Theoretical and Applied Mechanics (expert)
- ACTA Chinica (expert)
- Springer Lecture Notes in Computer Science (expert)

Dr. Hagen Knaf

- Moderator of the MACSI-net Working Group "Cardiac and Cardiovascular Models"

Prof. Dr. Ralf Korn

- Mathematical Finance (Associate Editor)
- Mathematical Methods of Operations Research (Associate Editor)
- DGVFM (Board member)
- Landesforschungsschwerpunkt von Rheinland-Pfalz "Mathematik und Praxis" (Speaker)

Prof. Dr. Alexander Lavrov

- Working Group "Praxis der Mathematischen Optimierung" der GOR (Assistant Chairman)
- Technical Committee "Modellbildung" of the VDI (Member)

Dr. Marlene Müller

- Computational Statistics (Associate Editor)
- International Association for Statistical Computing (Member of the BoD of the European Regional Section)
- Metrika (Appraiser)
- Journal of Time Series Analysis (Appraiser)

Prof. Dr. Helmut Neunzert

- Mathematical Methods in the Applied Sciences (Editorial Board)
- European Journal of Applied Mathematics (Editorial Board)
- Monte Carlo Methods and Application (Editorial Board)
- Springer Series on Industrial Mathematics (Editorial Board)
- Strategy board of MACSI-net (Chairman)
- Industrial Jury for "Wittgenstein- und Startpreise" in Wien
- Evaluation committee for mathematical programs of the finnish Academy of Sciences
- Evaluation committee of Mathematics in the project "Evaluierung der Lehre" of the Universities of Darmstadt, Kaiserslautern, Karlsruhe and of the ETH Zürich
- Evaluation committee for the center of Techno-Mathematics of the University of Bremen (Chairman)
- Correspendy Fellow of the Royal Society of Edingburgh, since June 2003

Prof. Dr. Stefan Nickel

- European Journal of Operational Research (Appraiser)
- Mathematical Methods of Operations Research (Appraiser)
- Mathematical Programming (Appraiser)
- Operations Research Letters (Appraiser)
- "Zentralblatt für Mathematik" (Appraiser)
- Mathematical Reviews (Appraiser)
- Associate Editor "Operations Research Letters"
- Member of the Editorial Board of "Computers & Operations Research"
- Member of: VDI-Fachausschüsse "Simulation und Optimierung" and "Modellbildung"
- Member of the program committee of the EWGLA XIV (Euro Working Group on Locational Analysis)

Prof. Dr. Joachim Ohser

- Working committee "Digitale Bildanalyse" in the technical committee "Metallographie der Deutschen Gesellschaft für Materialkunde e.V." (Chief)

Prof. Dr. Dieter Prätzel-Wolters

- ECMI – Council
- GAMM-Fachausschuss "Dynamik und Regelungstheorie"
- MACSI-net – Executive Committee
- Member of: Graduiertenkolleg "Mathematik und Praxis" of the TU Kaiserslautern
- Member of: rheinland-pfälzischer Landesschwerpunkt "Mathematik und Praxis"

Dr. Franz-Josef Pfreundt

- Global Grid Forum: Chair Production Grid Research Group
- Fraunhofer-Themenverbundes NUSIM (Speaker)
- PARCO2003 (Member of program committee)
- Mini-Symposium "Grid Computing" (Organization)
- D-Grid Konsortium

Ronald Rösch

- Fraunhofer-Allianz Vision (Member)

Dr. Norbert Siedow

- MACSI-net Newsletter (Editor)
- MACSI-net Working Group MACSIGLASS (Moderator)

Dr. Raimund Wegener

- MACSI-net Newsletter (Editor)

Contact

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