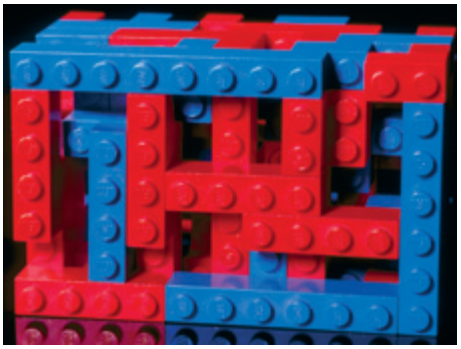
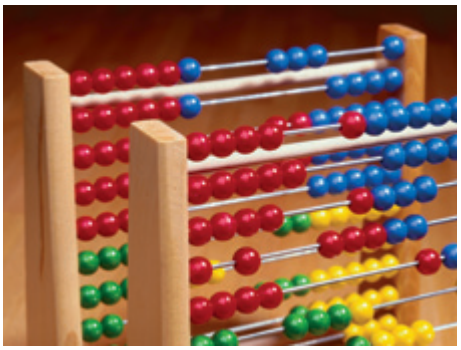
ITWM

Fraunhofer Institut
Techno- und
Wirtschaftsmathematik





Annual Report 2002

Imprint

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Annual Report 2002

Fraunhofer-Institut für Techno- und Wirtschaftsmathematik ITWM

Contents

Preface

The Fraunhofer Institute for Industrial Mathematics is still growing strongly. The operating budget for 2002 again shows a two-digit growth with economic profits which have been stabilized at a high level in spite of well-known problems in the economic environment.

The strategy planning, which is usual in the Fraunhofer-Gesellschaft, has mostly been concluded for the ITWM. An essential result are more strongly focusing branches which will meet the growing challenges of the market: computational fluid dynamics (CFD), numerical algorithms, high performance computing, financial mathematics, inspection, monitoring and control, simulation of production processes, mathematics in life sciences, optimization and simulation in logistics, microstructure analysis and virtual material design, as well as virtual product design.

These branches still represent a wide range of different subjects. However, it is exactly this wide range – which also reflects the range of industrial customers - which has decisively contributed in the past to the financial success of the ITWM, rendering it to a large extent independent from market fluctuations.

Mission and task of the institute remain unchanged: the ITWM meets complex challenges in the fields of technology, medicine, logistics, communication, and finances by the application of modern mathematical methods. Our research is a contribution to the further development of applied mathematics by innovative ideas and its practical application within research and development projects together with industrial partners. The large number of our costumers and the high quota of subsequent orders from industry prove that this mission is successfully fulfilled. The basis for this success are mostly autonomous departments with creative and highly qualified colleagues.

In addition, we have support from Munich. Experiences with many colleagues from our central administration have been very positive, exceeding what one usually expects from a central institution. We are particularly impressed by the personal identification of our partners with their work and their engagement for the requirements of the ITWM, apart from their professional competence.

This is especially the case also with respect to the support which the ITWM receives from the ministries of the *Land*. The doors in Mainz are always wide open, proceedings are short, and decisions are taken quickly and as unbureaucratically as possible. Particularly important for the ITWM is the generous financial support for the construction of the new Fraunhofer Center in Kaiserslautern by the ministries for science and economics.

A large part of the ITWM`s economic profits still stem from projects with small and medium-sized enterprises of the region. We need the SMEs and they need us – an excellently well-functioning symbiosis! We will keep on fostering this market and continuously extend our product range in the field of software and simulation for material development and production processes.

The increasing performance of computers constantly creates new potentials for industrial simulation tasks, where the networking of computers for the generation of sufficient performance for numerical simulation and visualization has a growing central importance. The activities in the field of high performance computing are summarized at the ITWM in a Competence Center for High Performance Computing. This is also our reaction to a dramatic change of paradigms with respect to the availability of high performance computing for industrial applications. Supercomputers are substituted by PC clusters. Parallel computer systems and grid computing, which could only be found in a few large research institutions and in meteorology a few years ago, are starting to move into industry. The ITWM is one of the pioneers with respect to the application of such PC clusters for industrial simulation problems. Our own software products are already basically prepared for their application with parallel computer systems.

Grid computing is one of the main subjects of the sixth EU framework program which are interesting for the ITWM. We will take part in a series of proposals for integrated projects, based on our already existing European cooperations, which we will further extend. The European networking process of research institutions is in full progress and is massively promoted by the support instruments in Brussels. The Fraunhofer-Gesellschaft has a very good reputation in Europe, because the name "Fraunhofer" stands for excellent quality and practical research in European industry.

However, from my point of view the Fraunhofer-Gesellschaft can still do more with respect to European research cooperations. The ITWM will stick to its international orientation and will reinforce its European activities, not only because of an easier access to European research funds, but also because we are firmly convinced that a successful substantial acquisition in a European economic market is only possible if based on strategic alliances with "local" research institutions.

When you read through our report, the many pictures of toys will surely strike you, and you may ask yourself whether the ITWM wants to bring back your childhood – after having encouraged your appetite for all different kinds of food in the last annual report. Why not? It is a fact that childhood playing is one of the most important means for the acquisition of social competence and a constructive consideration of the world.

Scientific work also needs creative and playful breaks. Knots in the brain are resolved, and the head becomes clear and free for purposeful work. However, more decisive than such a temporary regeneration – since you can also go for a walk – is something which cannot be substituted so easily: the striving for aesthetics, beauty, and harmony, the free playing of the mind which may first produce apparently useless ideas. European science and culture has only been able to reach its excellent present state due to the joining of the "contemplative free human being", the homo ludens, and the homo faber, the "technically creative" human being.

Both elements are decisively important for the progress of each science, and maybe for mathematics in particular. They complement and are based on one another. In their book "Schlüssel zur Mathematik", Helmut Neunzert and Bernd Rosenberger describe this idea very nicely: "Mathematics is not a dry science, it is full of fantasy. Not boring, but full of beauty, logical, but nonetheless of enormous creativity, ancient, but full of new ideas. Like playing and like art, mathematics is a part and in fact a particularly sensitive representative of culture and not least also an indispensable means of natural sciences, technology, and economy".

From this point of view, please take our annual report also as a plea for the technology of mathematics as a "tool and a game".

Prof. Dieter Prätzel-Wolters, Director

The Institute for Industrial Mathematics was founded in 1995 by members of the research group Technomathematics of the University of Kaiserslautern. As a research institution of the *Land* Rhineland-Palatinate, it was managed from the beginning by the Fraunhofer-Gesellschaft. After a successful evaluation in 1999, it became a member of the Fraunhofer-Gesellschaft at the beginning of the year 2001 as the first mathematical research institute.

Up to now, the following branches have been established at the Fraunhofer ITWM:

- flow dynamics (CFD)
- numerical algorithms
- high performance computing
- financial mathematics
- inspection, monitoring and control
- simulation of production processes
- mathematics in life sciences
- optimization and simulation in logistics
- microstructure analysis and virtual material design
- virtual product design

A team of more than 120 scientists, organized in six departments – mainly mathematicians, but also physicists, engineers and computer scientists -, deals with research and application problems, especially focused on medium-sized enterprises. The product range of the ITWM includes software components, consulting and support, as well as system solutions. Simulation software is not only used at the ITWM, but also developed here, often in cooperation with leading software enterprises.

Cooperation partners are companies from very different branches, e. g., automobile industry and IT, producers of materials and components, banks, electronic industry, companies from the entire range of textile industry, and glass industry. Service providers, such as public transport companies, also belong to the range of customers, as well as research institutes and institutions from the medical sector.

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

Objectives

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 the 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.

Competences and Main Subjects

- fluid-structure interaction
  - filaments and sheets in flows
  - production of nonwovens
- product and process design in continuum mechanics
  - optimal heating and cooling
  - acoustics
- grid-free methods
  - compressible and incompressible methods
  - airbag deployment
  - refueling processes
- radiative transfer and kinetics
  - thermal radiation in glass
  - strongly scattering media
- parameter identification
  - indirect measurement methods
- simulation of porous materials
  - moisture and heat transport
  - filtration and filter design
- microstructure simulation and virtual material design
  - computation and optimization of material properties
- algorithms for complex geometries and boundary areas
  - effective methods for flow and structural mechanics
  - methods for free boundaries
- flood and risk management
  - for municipal sewer systems and natural watersheds
- filling and casting processes
  - casting simulation
  - simulation of filling and immersion processes
  - injection molding of fiber-reinforced thermoplastics
- structure optimization and component design
  - shape and topology optimization
  - coupling with process simulation
- surface inspection
  - defect detection on textured and colored surfaces
  - image analysis and classification methods
- 3d image processing and analysis
  - geometric characterization of 3d structures
  - modeling of microstructures
  - 3d image processing
- railway monitoring systems
- analysis of image and video sequences
  - content-based image search engine
  - image compression by wavelet-based methods
- cryptology
- CAD for analog circuits
  - symbolic analysis
  - numerical simulation
- monitoring and control
  - control
  - system identification
- diagnosis support in life sciences
  - data mining
  - expert systems
- prognosis of material and product properties
  - blackbox and greybox identification
  - neural networks
- multiscale structural mechanics
  - viscoelastic materials with memory
  - homogenization methods for composite materials
- global logistics
  - supply chain management
  - sales area management
  - location planning
- in-house logistics
  - planning of material flow, scheduling, and production control
  - simulation and optimization
  - hospital logistics
- traffic management
  - secure connections in multi-modal public transport
  - planning of stations and lines
  - traffic models
- knowledge management and e-commerce
  - integration of knowledge management and e-commerce
  - virtual product and process consulting
  - tools for multi-criteria decision support
- decision support in life sciences
  - multi-criteria radiation therapy planning
  - real-time decision support
  - planning of time-optimal radiation therapy
- financial mathematics
  - credit risk
  - option evaluation
  - portfolio optimization
  - interest modeling
  - financial time series and statistics
  - exotic derivatives
  - Basel II
- high performance computing and visualization
  - cluster and grid computing
  - performance analysis
  - visualization
  - parallel algorithms
- Fraunhofer Chalmers Research Centre for Industrial Mathematics
  - material fatigue and load analysis
  - quality engineering
  - finite element technology

Customers and Cooperation Partners

For many years now, the ITWM has successfully cooperated with enterprises of different sizes and from many branches. In the following, those partners of 2002 are listed who have accepted to be cited.

- ABB, Västeras, Sweden
- AGFA Gevaert AG, Munich
- Amaranth Advisors, New York
- aquinto AG, Berlin
- ARNOLD & RICHTER Cine Technik, Stephanskirchen
- Atmel Germany GmbH, Heilbronn
- Audi AG, Ingolstadt
- Bayrisches Staatsministerium für Landesentwicklung und Umweltfragen, München
- BGS Systemplanung, Mainz
- BMW AG, Munich
- Caparol, Ober-Ramstadt
- Carl Zeiss, Oberkochen
- DePfa Bank, Wiesbaden
- Deutsche Gesellschaft für Onkologie e. V., Köln
- Deutsche Rückversicherung AG, Düsseldorf
- Deutscher Wetterdienst, Offenbach/Main
- Deutsches Krebsforschungszentrum, Heidelberg
- Die Sprinter – Kurierdienst und Speditionsgesellschaft mbH, Mannheim
- ESI-Group, Paris
- Eurofilters AG, Overpelt, Belgium
- Faurecia, Sassenburg
- Freudenberg Vliesstoffe KG, Weinheim and Kaiserslautern
- gbo AG, Rimbach
- geomer, Heidelberg
- GE Transportation Systems, Bad Dürkheim
- Hager Electro GmbH, Ensheim
- Harvard Medical School, Boston, USA
- HegerGuss GmbH, Enkenbach-Alsenborn
- Hilti AG, Schaan, Liechtenstein
- Human Solutions GmbH, Kaiserslautern
- HypoVereinsbank, München
- i^2t^3 – Industrial Innovation Through Technological Transfer, Florence, Italy
- IBS Filtran GmbH, Morsbach
- Infineon Technologies AG, Munich
- Institut für Gießereitechnik GmbH, Düsseldorf
- Institut für Verbundwerkstoffe IVW, Kaiserslautern
- J. Wagner GmbH, Markdorf
- Johns Manville Europe GmbH, Bobingen
- Landesbank Baden-Württemberg
- Landesbank Rheinland-Pfalz, Mainz
- Lehr- und Versuchsanstalt für Viehhaltung Neumühle, Münchweiler/Alsenz
- Linux NetworX, Salt Lake City (USA), Kaiserslautern
- m2k Informationsmanagement GmbH, Kaiserslautern
- MAGMA Gießereitechnologie GmbH, Aachen
- Mannesmann-Rexrodt AG, Lohr a. Main
- Mannheimer Morgen, Mannheim
- MiniTec GmbH & Co KG, Waldmohr
- MRC Systems GmbH, Heidelberg
- MSC / GAC, Buchenau,
- Odenwald-Faserplattenwerke GmbH, Amorbach
- OperaThing GmbH, Hürth
- Pfleiderer AG, Neumarkt
- Pierau Planung, Hamburg
- Procter & Gamble, Cincinatti (USA)
- psb GmbH, Pirmasens
- Roche Diagnostics, Mannheim
- Römheld & Moelle, Mainz
- Sandler AG, Schwarzenbach (Saale)
- SAP AG, Walldorf
- Schott Glas, Mainz
- SIEDA Software GmbH, Kaiserslautern
- Siemens AG (KWU), Mülheim/Ruhr
- Stadt Kaiserslautern
- Steinbichler Optotechnik GmbH, Neubeuern
- tecmath AG, Kaiserslautern
- Tehalit GmbH & Co KG, Heltersberg
- Thomas Josef Heimbach GmbH & Co., Düren
- Ultrafilter international AG, Haan
- Universität Kaiserslautern
- Universitätsklinik Tübingen
- Universitätskliniken des Saarlandes, Homburg / Saar
- Verein Deutscher Gießereifachleute (VDG), Düsseldorf
- Verkehrsverbund Rhein-Neckar GmbH (VRN), Mannheim
- Verkehrsverbundgesellschaft Saar mbH (VGS), Saarbrücken
- Verotec GmbH, Lauingen/Donau
- Volkswagen AG, Wolfsburg
- WestLB, Düsseldorf

The Institute in Numbers

Budget

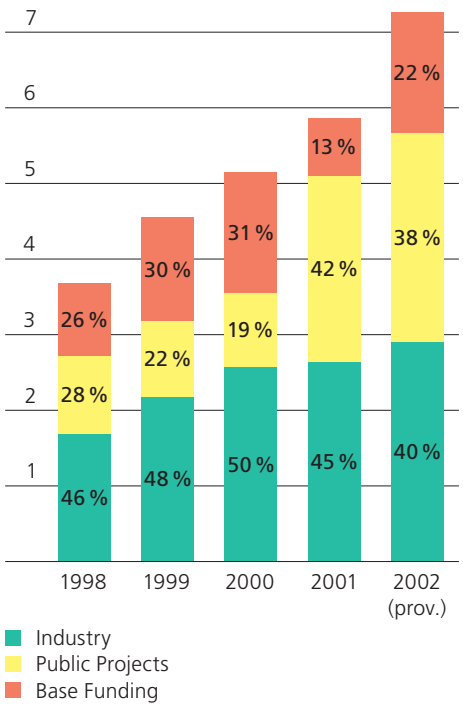
The ITWM continues to prosper and has been growing considerably also in the year 2002, so to say stone by stone. The operating budget increased by a significant 24 per cent, the overall budget even by 28 per cent. However, the last number should not be overrated because a relatively large sum was available for investments in 2002.

As a member of the Information and Communication Technology Group, the ITWM profited from the merger projects financed by the BMBF also in 2002. In contrast to the year before, however, these financial means represented less than 20 per cent of the profits from public projects. It is not only in the public sector where a wide range of possible funds has positive effects. Especially in times of strong economic fluctuations, the ITWM's wide range of customers is invaluable. The realization of this year's high economic profits has only been possible due to this background.

In the last year, the ITWM was also able to profit increasingly from the internal programs of the Fraunhofer-Gesellschaft. These means enable the ITWM to take concrete measures with respect to an efficient positioning on the market and the development of a computer infrastructure which is competitive worldwide.

Budget Development [Thousand €]	1998	1999	2000	2001	2002 (provisional)
Operating Budget	3681	4550	5147	5866	7260
Investments	459	382	244	756	1233
Total	**4140**	**4932**	**5391**	**6622**	**8493**

Operating Budget Development
in Million €



In the year 2002, the operating budget reaches approximately 7.3 million €. Almost 5.7 million € are the institute's own profits, of which 2.9 million € represent profits from industrial projects.

According to all the prognoses which have been made up to now, the year 2003 will probably also show a growth of more than 20 per cent.

Personnel development

In the year 2002, the ITWM has been able to further increase its personnel quota by 15 per cent. Meanwhile, almost 120 colleagues are working at the ITWM (72 scientists, 34 PhD students, and 12 colleagues in central services), as well as 75 research assistants and trainees.

With respect to the recruitment of scientists, the ITWM has profited in particular from its manifold international activities, as well as from the English language study programme held at the Department of Mathematics. Thus, we have succeeded in convincing highly qualified young scientists to come to Kaiserslautern or to stay here. The quota of scientists from foreign countries has meanwhile risen to 22 per cent and even to 63 per cent with respect to the PhD students.

Although the quota of female colleagues at the ITWM has already increased considerably in the last few years, a stronger increase is still desirable. From this point of view, it is of course helpful that the ITWM profits from the internal Fraunhofer program for the promotion of young scientists on the condition of equal opportunities, by which two additional grants for female PhD students are financed.

Symmetries are especially fascinating for mathematicians. Therefore, the year 2002 really invites to the following small game with numbers:

The most important parameters of the ITWM for 2002 are (modulo 2%):

profits from industrial cooperation:
$20 \times 02 = 40\,\%$

number of colleagues:
$20 \times (02)^2 = 80$

operating budget growth:
$20 + 02 = 22\,\%$

total profits:
$20 \times (02)^2 = 80\,\%$

operating budget:
$(20 - 02) \times 0{,}2 \times 02 = 7{,}2$ Mio €

An "adapted" equation leads to the following – not quite unrealistic – projection of the ITWM's operating budget for the next years:

2003	2004	2005	2006	2007	2008
8,83	10,15	11,21	12,02	12,58	12,92

If we have made you curious, try out the basic equation.

Personnel Development	1998	1999	2000	2001	2002
Scientists and Technicians	43	45	54	63	72
PhD Students	13	17	19	30	34
Central Services	6	7	8	10	12
Research Assistants	29	48	60	70	75
Other Employees	8	8	11	13	16
Total	**99**	**125**	**152**	**186**	**209**

Board of Trustees

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

Prof. Achim Bachem
German Aerospace Center DLR, Cologne

Dr.-Ing. Erwin Flender
MAGMA Gießereitechnologie, Aachen

Wolfgang Habelitz
member of the ministry for science, education, research, and culture, Mainz

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	Adaptive Systems	Dr. Patrick Lang	+49 (0) 6 31/2 05-28 33
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Fraunhofer Group Information and Communication Technology

The Fraunhofer ICT Group consists of 15 institutes with more than 2000 employees and has an annual budget of more than 200 million, thus being the largest research alliance for information and communication technology (ICT) in Europe, and one of the largest worldwide. It was founded in the middle of the year 2001, when the Society for Mathematics and Data Processing (GMD) merged with the Fraunhofer-Gesellschaft. Complementing main subjects of the member institutes cover a wide range of subjects of the ICT branch.

Members of the group are the following institutes:

- Fraunhofer Institute for Autonomous Intelligent Systems AIS
- Fraunhofer Institute for Computer Architecture and Software Technology FIRST
- Fraunhofer Institute for Applied Information Technology FIT
- Fraunhofer Institute for Open Communication Systems FOKUS
- Fraunhofer Institute for Industrial Engineering IAO
- Fraunhofer Institute for Experimental Software Engineering IESE
- Fraunhofer Institute for Computer Graphics Research IGD
- Fraunhofer Institute for Integrated Circuits IIS
- Fraunhofer Institute for Information and Data Processing IITB
- Fraunhofer Institute for Media Communication IMK
- Fraunhofer Institute for Integrated Publication and Information Systems IPSI
- Fraunhofer Institute for Software and Systems Engineering ISST
- Fraunhofer Institute for Industrial Mathematics ITWM
- Fraunhofer Institute for Algorithms and Scientific Computing SCAI
- Fraunhofer Institute for Secure Telecooperation SIT

The Fraunhofer ICT Group develops common strategies and visions for applied research in the field of information and communication technology. The group pools the individual competences of the institutes in joint research programs, and supports the members with respect to technology transfer and research marketing.

On behalf of the BMBF, the group develops a common program for applied basic and preliminary research, which is titled "Leben und Arbeiten in einer vernetzten Welt". Seven research programs comprise the main subjects of a future information and communication technology, among which are: new technologies for the next internet generation and for mobility support, new methods of knowledge management, secure solutions for binding acts in the network, as well as new forms of dialogue between human beings and computers. Computer simulation, visualization, and virtual reality are integrated into digital environments for industrial product development.

The portfolio of competences of the Fraunhofer ICT Group is available to partners from industry and the public sector, including especially tailored IT solutions, competent technology consulting, as well as preliminary research for new products and services. International research programs provide a worldwide cooperation network of the member institutes with companies and research enterprises of the ICT branch. The central bureau of the Fraunhofer ICT Group in Berlin connects appropriate partners.

The rapid development of IT technologies offers immense possibilities for individual enterprises. However, the user remains almost unable to decide on his/her own which investment will provide definite competition advantages. Besides, short innovation cycles turn IT knowledge into a rapidly perishable merchandise.

We support enterprises by our know-how, so that their necessary investments in new basic technologies are profitable.

In order to provide a long-lasting collaboration between our customers and our member institutes which is based on confidence, we offer:

- technology and innovation consulting
- contact to experts and partners
- realization of your ICT projects by our members

Central Bureau

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The Fraunhofer-Gesellschaft at a Glance

The Fraunhofer-Gesellschaft undertakes applied research of direct utility to private and public enterprise and of wide benefit to society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration. The organization also accepts commissions and funding from German federal and Länder ministries and government departments to participate in future-oriented research projects with the aim of finding innovative solutions to issues concerning the industrial economy and demands faced by society in general.

By developing technological innovations and novel systems solutions for their customers, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. Through their work, they aim to promote the economic development of industrial society, paying particular regard to social and environmental concerns.

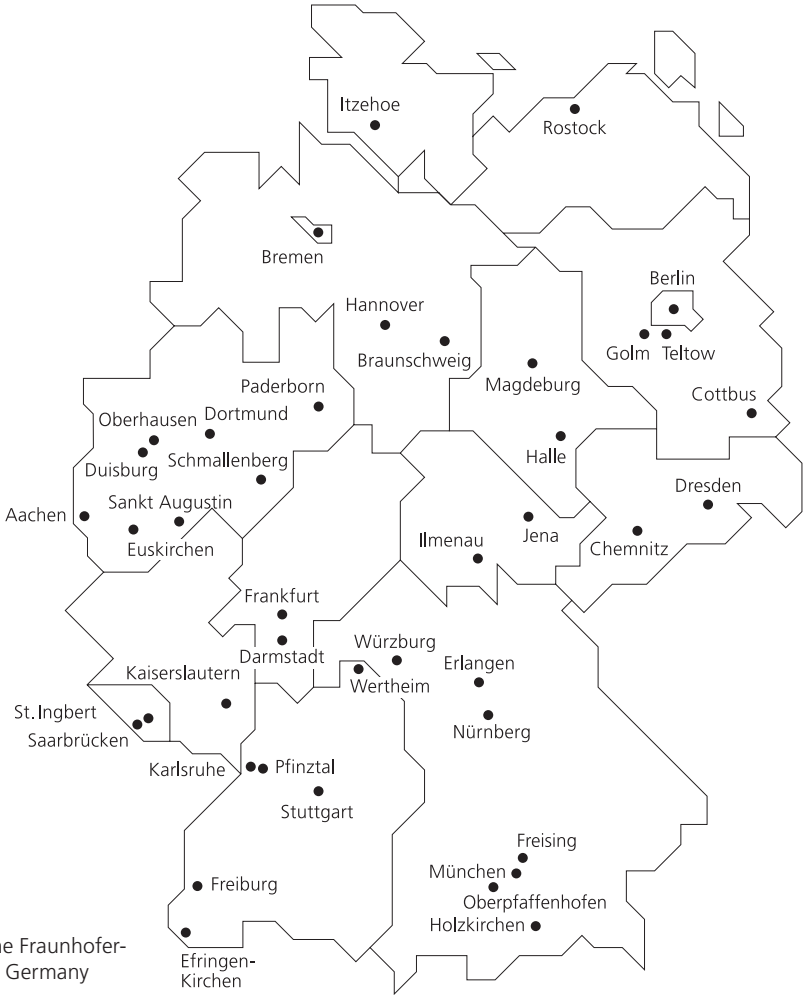
As an employer, the Fraunhofer-Gesellschaft offers a platform that enables its staff to acquire the necessary professional and personal qualifications to assume positions of responsibility within their Institute, in industry and in other scientific domains.

At present, the Fraunhofer-Gesellschaft maintains roughly 80 research units, including 57 Fraunhofer Institutes, at over 40 different locations in Germany. A staff of some 13,000, predominantly qualified scientists and engineers, work with an annual research budget of around one billion euros. Of this sum, approximately 900 million is generated through contract research. Roughly two thirds of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. The remaining one third is contributed by the German federal and Länder governments, as a means of enabling the Institutes to pursue more fundamental research in areas that are likely to become relevant to industry and society in five or ten years' time.

Affiliated Research Centers and Liaison Offices in Europe, the USA and Asia provide contact with the regions of greatest importance to future scientific progress and economic development.

The Fraunhofer-Gesellschaft was founded in 1949 and is a recognized non-profit organization. Its members include well-known companies and private patrons who help to shape the Fraunhofer-Gesellschaft's research policy and strategic development.

The organization takes its name from Joseph von Fraunhofer (1787-1826), the illustrious Munich researcher, inventor and entrepreneur.



Locations of the Fraunhofer-Gesellschaft in Germany

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Transport Processes

The main competence of the DEPARTMENT OF TRANSPORT PROCESSES is the mathematical modeling of complex industrial problems and the development of efficient algorithms for their numerical solution (simulation). The research is mainly focused on:

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

The problems belong to a technical scientific context (fluid dynamics, radiative transfer, acoustics, structure mechanics, etc.) and can be formulated mathematically as partial (integro-) differential equations which are mostly to be characterized as transport equations. Industrial customers typically require the optimization of products, the technical design of production processes, or simulation-based measurement methods. Here, the department offers, e. g., cooperation projects with those R&D departments of partner enterprises which are focused on scientific engineering, studies including design and optimization proposals, concept development, as well as software solutions.

Previous year's economic profits of the department, which had already been very good, could even be increased considerably in all areas. Essential reasons were the following subjects, whose contents will be described in detail in the main subjects below:

- further development of the modeling and simulation competence in specific application fields (fluid-structure interaction, radiative transfer, and kinetics)
- successful combination of analytical and numerical methods (continuum mechanical product and process design)
- development of an individual basic software in the field of fluid and continuum mechanics (grid-free methods)
- extension of the mathematical spectre especially to the solution of inverse problems (parameter identification)

The research foundation of this positive development is particularly represented by the numerous PhD projects and graduation theses in the department.

Fluid-Structure Interaction

In the field of fluid dynamics, a special modeling and simulation competence has been developed in the last few years through several projects with respect to fluid-structure interaction. Generally speaking, the interaction of flows and 3d objects is examined. In particular, however, these are mostly objects whose extension can be reduced in the model by one or more dimensions: in the period covered by this report, these are droplets and particles (mass points), filaments during the spinning and depositing process (line shape objects), and sheets of paper (planar objects). In all the mentioned cases, the dynamics of the structures is 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 also be simulated. An impressive example is the project with respect to fleece production which will be described in the following; it is impossible to deal with up to 1000 filaments in a turbulent flow in a complete continuum mechanical model without appropriate simplifications. In this case, it is essential to consider the filaments as asymptotically one-dimensional objects and to neglect the effect of the filaments on the flow. The basic fluid dynamical problems of the respective projects are usually simulated by software tools such as FLUENT® and CFX®, which are then coupled with individual software for the simulation of the structures' movement.

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Movement of filaments in air flows

During the production and processing of artificial fibers, the filaments are subject to forces leading to particular fiber movements. The simulation of this fiber dynamics creates a new means for the acceleration of methods, the process design, and their optimization, or even allows for the development of such methods for the first time.

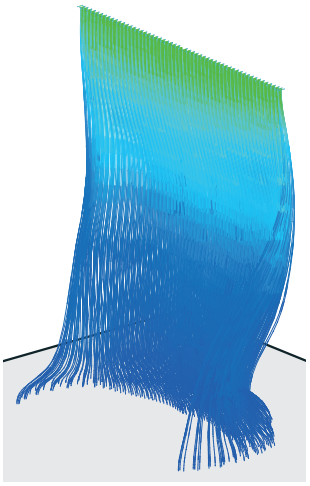
The fiber dynamics can be formulated by a Newtonian equation of motion:

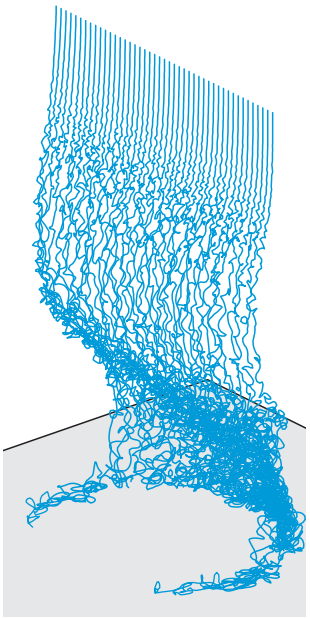
$$\sigma \ddot{x} = \partial_s (T \partial_s x) - S_k \partial_{ssss} x - \sigma g e_\perp + f_L$$
$$\|\partial_s x\| = 1$$

Apart from the internal stresses and bending forces and from gravitation, the leading effect of air flows is of decisive importance here. The possible contact with walls or between filaments can be referred to in a similar way. In typical applications, the air flow is so strong that the effect of the fibers on the flow is of secondary importance and can be computed independently from the fiber movements.

At the Fraunhofer ITWM, a numerical algorithm has been developed and implemented for this kind of model. The use of parallel computers thus allows for the simulation of a large number of filaments. Exemplary results of two application projects together with Freudenberg Vliesstoffe KG, with whom we have been cooperating for many years now, are visualized by the streamlines and the respective fiber movements. One example refers to the simulation of a fiber band subject to a variable air flow, the other to the simulation of a bundle of fibers interacting with a wall. The movements of the filaments basically follow the flow direction; differences mainly occur due to the additional forces to which the filaments are subject.

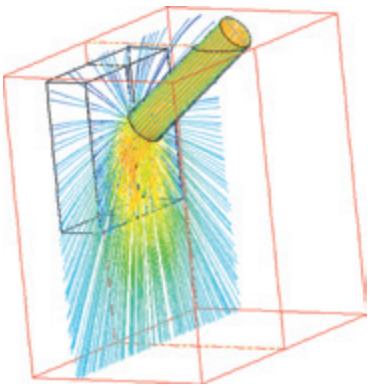
The formation of nonwovens is finally simulated by the observation of the movements of spinning filaments and their deposition on a transport belt with respect to time. The position of the filaments and their deposition order almost completely describe the structure of the resulting nonwoven. The analysis of these data with respect to weight per unit area distribution, direction distribution, flow resistance, or firmness can decisively support and improve the technical process optimization and the construction of new production plants.

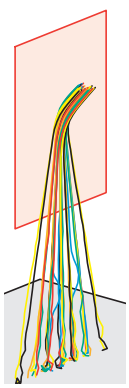




Above: streamlines for the simulation of a variable air flow; below: movement of a fiber band in a variable air flow

Left: streamlines of the contact of an air flow with a wall; right: contact of a bundle of fibers with a wall





Continuum Mechanical Product and Process Design

This main subject comprises those projects of the department which mainly focus on the technical design and optimization of products and production processes. Previous year's projects with respect to products were the convective cooling of floodlights, the simulation of air springs, and the vibration optimization of complex optical systems. In the field of production processes, the subjects were cooling problems of a printing press, flow optimization during the spinning process, optimal temperature control during glass production, design of a fleece production process, and metal cutting production processes. Besides, a concept for the coupling of logistic and process engineering simulation methods is developed together with the Department of Optimization and further partners of the Fraunhofer-Gesellschaft.

Most generally speaking, the common basis of the mentioned projects are continuum mechanical models (i. e. fluid dynamics, heat conduction, radiative transfer, structure mechanics, etc.). Here, projects evidently focus on heat and flow problems. Analytical and numerical methods are applied for the solution of the industrial problems, which are simulated by commercial software products (FLUENT®, CFX®, ANSYS®), individually developed software, and hybrid software solutions. A special competence of the Fraunhofer ITWM is the coupling of different models (multiphysics) determining the entire problem on very different scales with respect to space and time. The project described in the following is a very good example. Frequently, such problems particularly require an adequate model reduction for reasons of complexity. From an analytical point of view, asymptotic and system theoretical methods are especially important, whereas on the numerical side, e. g., superelement methods for complex FEM models are developed and successfully applied.

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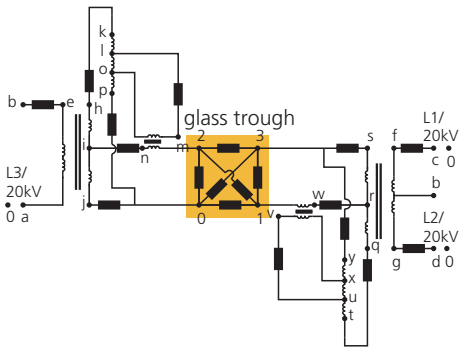
Electrical heating of a glass tank

During the industrial production of glass, its ingredients are mixed in a melt which is contained in a glass tank of 10 to 20 cubic meters and heated by electric power. Typical electrode diameters are approximately 20 cm. In order to optimize the production process systematically, the company Schott, a producer of special glass, is searching for a simulation environment which reproduces all heating aspects realistically. The development of the temperature and electric fields in the tank can be computed by commercial software such as FLUENT® if the electrode potentials are known. The connected electric network can, e. g., be handled by SPICE® if an equivalent circuit diagram of the glass tank is given. However, for the coupled simulation of this hybrid system, which is described partly by ordinary and partly by partial differential equations, until recently a concept has not been available. Such a concept has now been developed at the Fraunhofer ITWM and has been applied for a two-dimensional model tank under FEMLAB® for demonstration purposes. Especially networks with nonlinear components such as thyristors can be handled now.

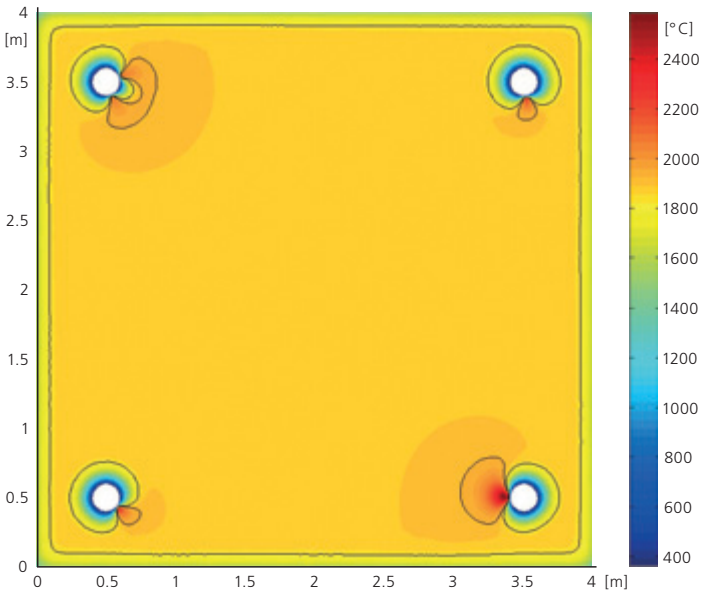
The coupling is essentially based on two pillars. First, it considers the fact that temperature and electric field change on very different time scales, the former during minutes and hours, the latter at a 50 Hz clock pulse. Thus, in the network simulation the heated tank can be represented by a set of ohmic resistances over many oscillation cycles. Besides, the production of Joulean heat only depends on the electrode potentials over their averaged correlation with respect to time. The second pillar are the so-called basic potentials, which are those dimensionless potentials occurring if one electrode has the potential 1 and all the remaining electrodes are grounded. Due to the temperature dependence of conductivity, these potentials change on the rough time scale. The basic potentials can on the one hand be used for the computation of the resistances of the equivalent circuit diagram representing the glass tank in the electric network. On the other hand, they help to determine the input of Joulean heat from the correlations of the electrode potentials at each point of the tank.

Apart from the basic feasibility, the application under FEMLAB® shows a real effect which cannot be reproduced without a coupled simulation: the formation of electric current channels. If more current flows through a particular part of the electrode surface, the glass is heated there and becomes more conductive. Finally, the current flow only concentrates in this area. It could be shown that the position of the current channels sensitively depends on the history of the power supply.



Simplified circuit diagram of the connected electric network for the heating of a glass tank; the glass tank is represented by a network of ohmic resistances.

Temperature distribution in a two-dimensional model tank with four electrodes (after 7 200 s, contours at 1 500 °C and 1 550 °C): the formation of the current channels reacts sensitive to the history of the power supply. In order to avoid numerical influences, the computational grid around the electrodes must have a fine structure and smooth resolution.



Grid-free Methods

The Finite Pointset Method (FPM), which has been developed in the department, is an individual, independent basic software for simulation tasks in a wide area of flow and continuum mechanical problems. FPM is a particle method, i. e. a grid-free method which, in contrast to classical numerical methods, such as Finite Elements or Finite Volumes, does not require a grid or mesh. Thus, it can excellently be applied in the case of all time-dependent problems, where grid-based methods reach their limits due to the necessary remeshing. Examples are fluid dynamical problems with free surfaces, multiphase flows, fluid-structure interactions with a strong change of the computing domain, or structure mechanical problems with substantial structure changes.

In the field of compressible gas flows, research has made the largest progress. However, last year we have also been very successful in the field of incompressible flows, where a method based on the projection method of Chorin has been developed and implemented. In the field of structure mechanics, first progress has also been made. In all these cases, the software is always developed according to industrial application problems. In the field of compressible flows, the cooperation with the French software house ESI with respect to the simulation of airbag deployment has been continued (cf. annual report 2001). In the field of incompressible flows, a BMBF project has been carried out together with Volkswagen AG for the simulation of the refueling process in the case of motor vehicles. The modeling of the resulting foams and their dynamics as well as the integration of these models into FPM simulations represent a further interesting aspect of the research activities. The following project example shows the successful application of FPM in the case of different problems of the glass producing industry.

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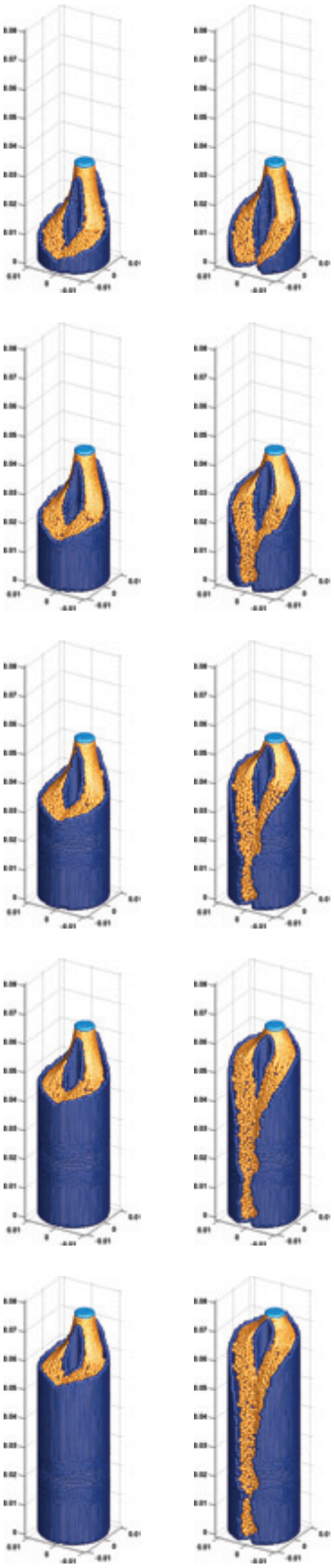
FPM for the simulation of flow problems during glass production

FPM can be used excellently for applications in glass industry because of frequently occurring problems with free surfaces, e. g., during the casting process of glass into molds or the transport of molten glass in open channels. Additionally, there are problems of moving geometry with respect to time. An example presented last year is the design of stirrers which ought to be able to produce a state of the molten glass as homogeneous as possible, and to avoid possible pollutions.

For the company Schott Glas, the Fraunhofer ITWM has simulated the simple filling of a hollow cylinder with an extremely "short" glass. Such a glass is characterized by a strongly increasing viscosity of the material if the glass temperature decreases, the increase showing an exponential character. In order to fill the cylinder, a pipe is inserted between the external and internal wall of the cylinder, moving upwards during the filling process according to the upward movement of the free surface. One of the interesting technical problems now is which filling temperature must be selected in order to guarantee a sound filling of the cylinder without a solidification process starting too early. A directly connected problem is the adjusting of the temperature at the cylinder walls, where the melt cools fastest. If the solidification starts too early, this is usually due to an insufficient heating of the walls.

The series of images on the left side shows the filling process of a hollow cylinder at an acceptable wall temperature. There are no early solidification processes; instead, an almost quasi-stationary inlet and spreading behavior of the molten glass can be recognized. The series of images on the right side, however, shows a filling process where the wall temperature has evidently been selected too low. The solidification of the melt starts before it has completely spread in the cylinder ring. In this case, the production parameters – especially the wall temperature - ought to be changed in order to reach an acceptable result.



Filling of the cylinder at a wall temperature of 600 °C (left column) resp. 500 °C (blue: wetted cylinder walls, yellow: free surface, light blue: inlet boundary)

Radiative Transfer and Kinetics

The research at the Fraunhofer ITWM with respect to radiative transfer started with the modeling and simulation of the cooling process of glass for the company Schott Glas in Mainz. The coupling of heat conduction and thermal radiation, which is connected to the modeling of this problem, results in a seven-dimensional (space, time, direction of radiation, frequency) system of integro-differential equations, for the solution of which a special numerical method has been developed in the past allowing for an efficient simulation of realistic problems. This method, derived by asymptotic analysis, provides the basis why the radiative transfer can be accounted for in good approximation by a geometry-depending adjustment of the coefficient of heat transfer in the heat transfer equation, for such frequency domains where the glass can be considered as optically thick. Based on this research, parameter identification problems (see following main subject) have also been examined recently in the vicinity of the radiative transfer equation.

Last year, projects focused on scattering media. The numerical foundations for the handling of such problems have been built in the project described in the following. Besides, an important application problem is currently examined in a project with respect to the dose computation in radiation therapy in the case of tumors (see page 76). The interaction of photons and electrons in the biological tissue leads to models whose complexity is particularly reflected by the occurring scattering kernels. For an efficient numerical computation, different approximations have been introduced whose quality is currently examined by simple examples. The entire research with respect to radiative transfer is embedded in the more general subject of kinetic equations, as they occur, e. g., in the above case of the modeling of the electrons.

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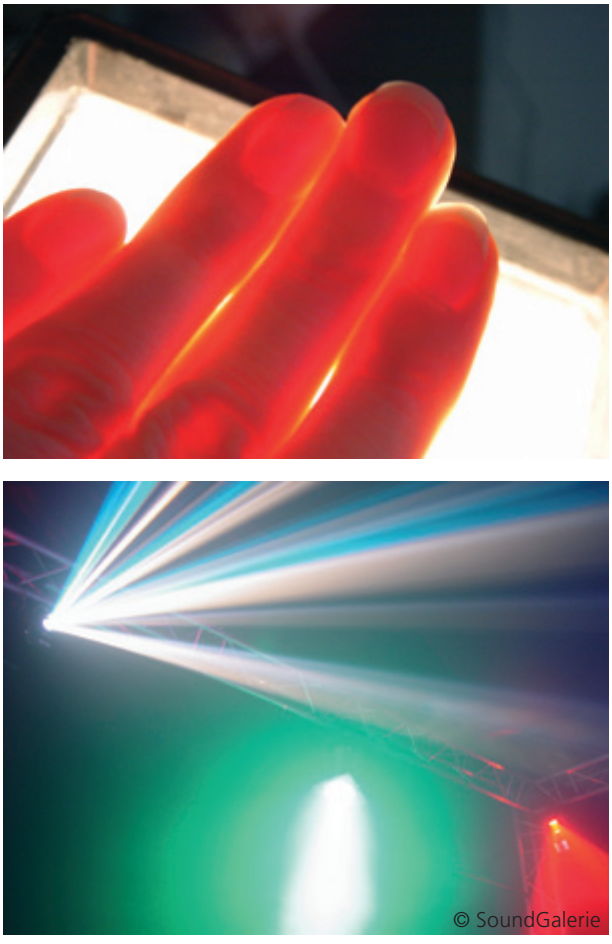
Radiative transfer in scattering media

The production, processing, and also the use of glass and ceramic materials as fireproof materials are considerably influenced by processes of radiative transfer. The cooling of hot glass melts essentially happens due to radiation. In life sciences, photon and electron beams have already been applied for some time now for diagnostic and therapeutic purposes. Computer tomography in cancer diagnostics or dosimetry in cancer therapy, e. g., are acknowledged therapy methods. Optical tomography is explored worldwide in order to detect structures and properties of the human tissue.

Such and similar processes from the fields of industry and medicine are described by the radiative transfer equation – an integro-differential equation. In the case of isotropic respectively linearly anisotropic scattering, this integro-differential equation can be transformed into an integral equation. Apart from the smaller number of unknowns, such a formulation as integral equation has enormous advantages with respect to the numerical solution (secured stability, symmetry, well-conditioned systems, application of fast iteration methods). However, the discretization of the integral equation results in large, non-sparse systems of equations. It has been shown that, in the case of a very strong scattering, the resulting system of equations is ill-conditioned (small errors, e. g., truncation errors, can falsify the solution extremely), requiring adequate preconditioners. Due to the non-sparse matrix, it does not make sense in practical applications to store the matrix in its original form. Matrix compression methods, as they are used in the case of boundary element methods, appear as efficient solution methods and have been applied to radiative transfer. Due to the exponential damping, the efficiency of this solution method in the case of radiative transfer is strongly depending on optical thickness. The method, which has been developed on the basis of the integral formulation, has been compared with the Discrete Ordinate (DO) Method, which is currently very popular in publications. In the case of an optically thick and strongly scattering medium, the formulation as integral equation is not recommendable. However, in the case of an optically thin medium, where the DO method requires a large number of discrete directions, thus becoming inefficient, the integral formulation in combination with the matrix compression leads to very good results. In the case of local heat sources, the integral formulation is also superior to the DO method and should be considered as an alternative for the solution of practical problems.



Scattering media: biological tissue and mist

Parameter Identification

If you want to derive the coefficient of heat transfer from temperature data of an experiment with respect to heat conduction, this is a typical parameter identification problem in the context of partial differential equations. In contrast to the direct problem – in this case, the solution of the heat transfer equation -, this is called an inverse problem. Such problems are usually ill-posed, i. e. they cannot be solved uniquely or they have the property of small measurement errors resulting in large reconstruction errors. So-called regularization strategies are developed in order to overcome this problem. These can elegantly be accounted for in our context by the formulation of the problem as a continuous optimization problem with differential equation constraints.

In the previous years, the department has successively developed know-how for the solution of parameter identification problems respectively inverse problems. Unfortunately, the projects of the period covered by this report are not intended for publication for reasons of confidentiality or because the application for a patent is planned. Instead, the potential, especially with respect to the development of new indirect measurement methods, will be explained here by an example which has been the subject of the institute's own research and of a master's thesis: suppose that, for a heat transfer problem with known material law, boundary temperatures and energy fluxes across the boundary are known for the interesting time interval. One piece of this information, together with one initial condition, would already be sufficient in order to determine the internal temperature at every time. The additional information at the boundary can now be used with the strategies mentioned above in order to reconstruct the unknown initial temperature and thus the entire temperature gradient. In such a way, the internal temperatures of, e. g., a cooling metal block can be measured indirectly by the observation of the boundaries resolved with respect to time.

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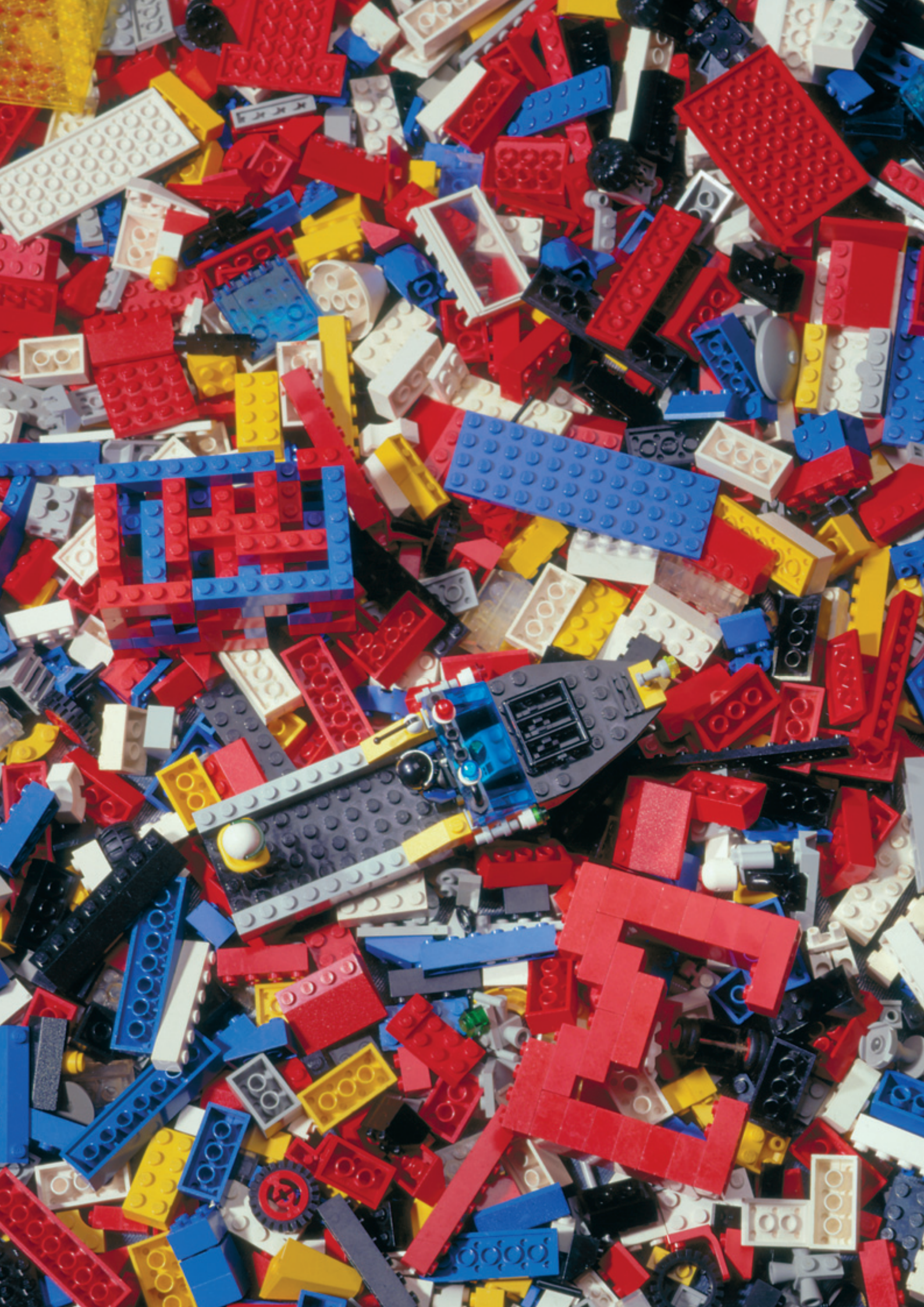


Flow and Complex Structures

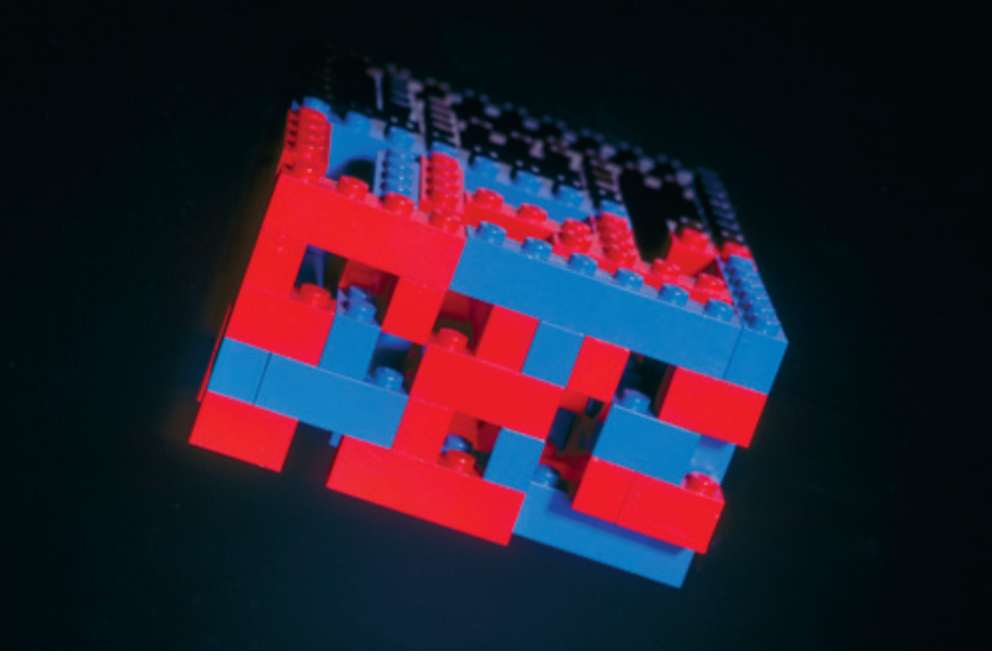
The department FLOW AND COMPLEX STRUCTURES develops mathematical models and adequate numerical methods for the simulation and optimization of mostly fluid dynamical processes in complex applications. The main subjects are:

- simulation of porous materials
- microstructure simulation and virtual material design
- algorithms for complex geometries and interfaces
- flood and risk management
- filling and casting processes
- optimum structural design

Services range from consulting and studies to computation of component design and the delivery of software solutions. Customers are, e. g., producers and users of technical textiles, filters, composite materials, building materials, and molded parts. Our research is focused on the effects of the production processes on material properties and application behavior.

The year 2002 was characterized by a relatively large number of changes in the department. Apart from moving to the new location PRE-Park, the department had to overcome a short-term decline in new orders in the first six months, as well as to substitute three colleagues who had been working here for many years. Nevertheless, the year 2002 was closed economically successful at a continuous growth due to the strong commitment of all our colleagues. In the course of the year, the expansion of the group "High Performance Computing" resulted in the foundation of an independent Competence Center (see page 91).

The name of the department has slightly changed because specific competences with respect to the handling of complex three-dimensional geometries (such as Lattice-Boltzmann methods, level set methods, immersed interface techniques, fictitious domain methods, adaptive multigrid techniques) have been further developed consequently, and can now partly be applied to more than fluid dynamical processes. Level set techniques, e. g., are not only applied for the shape optimization of molded parts, but also for the computation of interfaces in the case of multiphase flows.



Simulation of Porous Materials

The world is porous! – Well, maybe not entirely. Nevertheless, porous materials occur in almost all the fields of everyday life. Many hygienic products, textiles, air, soot, and oil filters in automobiles, insulating materials, sands or sponges can be considered as porous materials. They also play a decisive part in many industrial production processes. The common feature of these media is their porous microstructure, whose design determines macroscopic properties such as thermal and moisture conductivity, filter efficiency, or acoustic absorption rate. Apart from these fluid dynamical aspects, the mechanical behavior such as bending and tensile strength is often interesting.

A producing company of porous media requires the improvement of its products, which is where the Fraunhofer ITWM comes in as a competent partner in the field of modeling and simulation. An image of the porous medium is created on the computer by imaging methods (see microstructure simulation, p. 32), allowing for the solution of the relevant model equations on the microscale by numerical simulation. Macroscopic material parameters can then be computed on the basis of the solution by upscaling methods, i. e. homogenization or volume averaging. Sometimes, these parameters already contain the quality information the producer is interested in. However, very often additional macroscopic simulations are necessary in order to determine, e. g., pressure gradients in filters. If the simulation step is completed, the path is free for an optimization of the porous material. Currently, a project supported by the DFG deals with the development of models and simulation methods for the computation of non-Newtonian fluids in the context of polymer infiltration in glass fiber preforms. Besides, in the framework of numerous other projects and PhD theses, research is carried out in the fields of filter design and paper production.

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Virtual design of dewatering felts used in paper machines

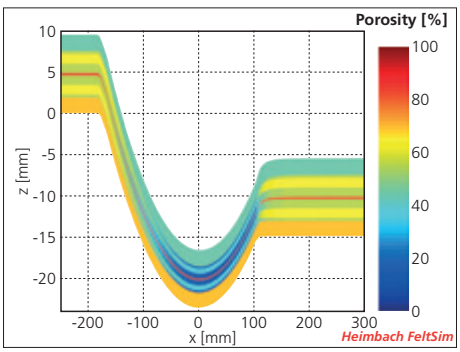
Process understanding and product optimization – two concepts which every producer is permanently bearing in mind, e. g., Heimbach GmbH & Co. KG in Düren, a producer of paper machine felts and filters. The idea of the project was a better understanding of the paper dewatering mechanisms in the pressing section of a paper machine in order to optimize the company's own dewatering felts on the basis of the simulation results. A further intention was the development of a simulation tool which the company's R&D engineers can apply in order to substitute at least in part costly experiments with new felt developments.

The pressing section of a paper machine consists of several press nips. In the simplest case of a roll press nip, the paper-felt sandwich is transported between two rolls where it is compressed, the paper sheet being dewatered. Generally, the dewatering performance depends on a large number of parameters. Everything must be accounted for, from the profiles of the press to the elastic and fluid dynamical matching of the felt layers with one another. The objective is to reach a high dewatering performance, in order to reduce the costs of thermal dewatering in the drying section of the paper machine.

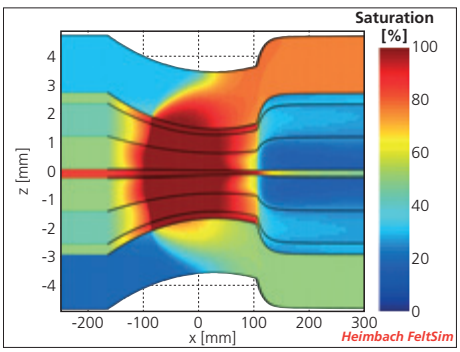
At the Fraunhofer ITWM, a model has been developed comprising the relevant elastic and fluid dynamical process parameters and their relations. This model allows for, e. g., the computation of the flows in the felt and in the paper sheet in the direction of the machine and in vertical direction, as well as the local visualization of processes such as dewatering or re-wetting of the paper.

An aspect which must be exactly considered for the first time during the validation of the model is the reliable determination of the model parameters. Several parameters are available at once from the machine specifications, others must be determined experimentally. Microstructure simulation (see next page) offers a unique option here, allowing for the determination of permeabilities (fluid conductivities) layer per layer by numerical simulation – a possibility which is difficult to realize experimentally.

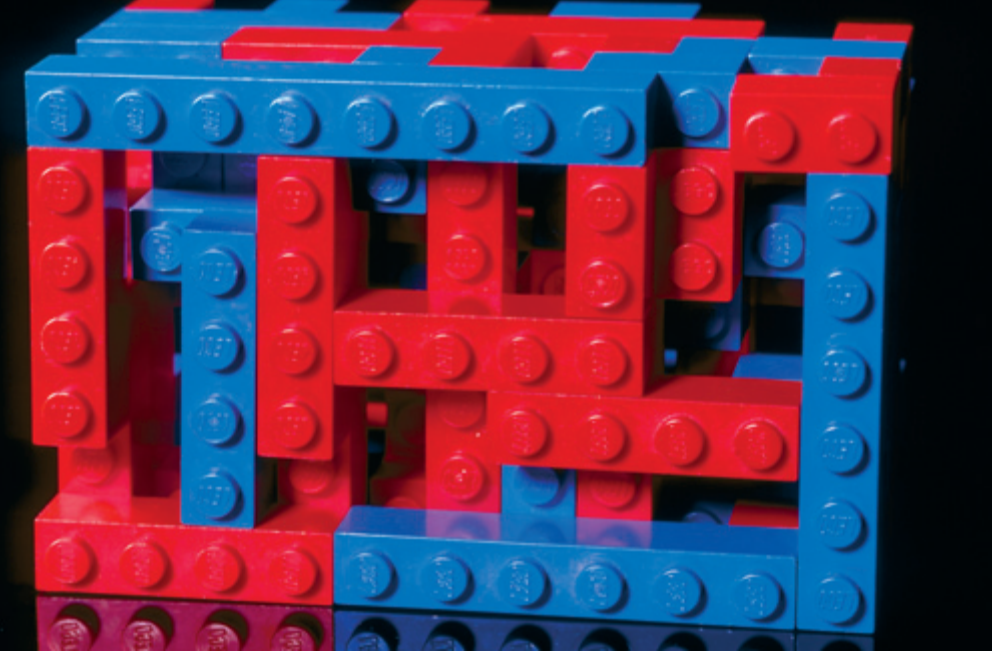
After a successful model validation by a comparison of simulation and experimental data with the experimental paper machine of the STFI in Sweden, the version 1.0 of the simulation tool FeltSim has recently been applied successfully at our customer's location.



Simulation with top and bottom felt in a shoe press, showing the porosity distribution



The same simulation, showing the saturation (for a better visualization, the geometry has been transformed)

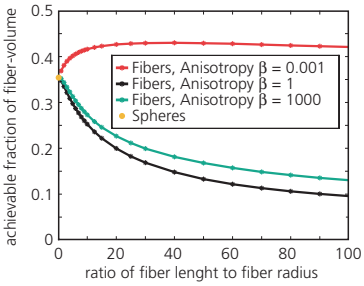


Microstructure Simulation and Virtual Material Design

The modeling of three-dimensional material geometries and their discretization is a central element of microstructure simulation. The equations of fluid mechanics, structure mechanics, heat conduction, and acoustics are solved in the discretized geometries, in order to determine the macroscopic functional properties of the material, such as the effective coefficient of heat conduction, flow resistance, or acoustic absorption.

Models with only a few stochastic parameters are transformed into randomized three-dimensional images. In the case of fiber geometries, such parameters are, e. g., the fiber volume fraction, as well as the distributions of fiber radii, fiber lengths, and fiber directions. A random selection of the positions, radii, directions, and lengths according to the given distribution results in a different image for each run of the program. Nevertheless, the images all show the given statistical properties. An adequate selection of the parameters allows for the computation of real materials, which are microscopically at random due to the production process. The figure on the next page shows the user interface of the structure generator GEODICT, developed at the Fraunhofer ITWM, and a cross-section of a microstructure filled by 80 per cent with spheres of four different diameters.

Besides, statistics with respect to such realizations can help to explore the possibilities of the material geometries, e. g., the dependence of the packing density on the fiber orientation and on the fiber axis ratio, i. e. the ratio of length and radius. The packing study (left) shows three curves representing almost parallel fibers and fibers oriented arbitrarily in space or within a plain. Along the curves, the axis ratio varies from 1 (degenerated case of a sphere, orange) to 100. The highest packing density for a random placement results from parallel fibers, the lowest from fibers arbitrarily oriented in space.



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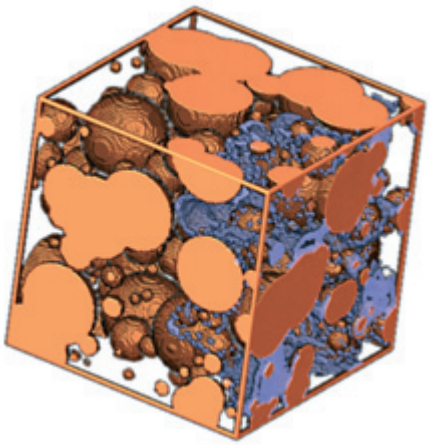
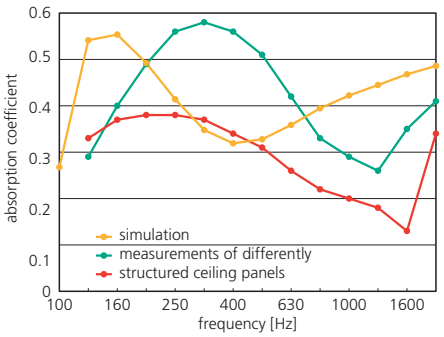
The acoustics of ceiling panels

The company Verotec produces acoustically efficient ceiling panels from four grain size distributions of expanded glass, synthetic resin, and a fire protecting agent. The exact grain size distribution within the four fractions is unknown. Thus, the question is how the acoustic absorption of the panels depends on these distributions.

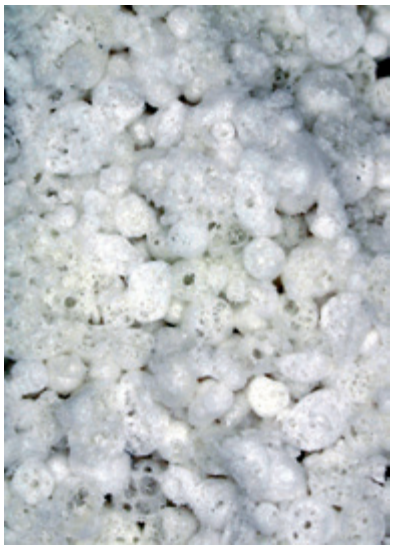
This question is answered in three steps. First, several random realizations of sphere geometries with appropriate statistical properties are simulated by GEODICT. The model assumptions are verified by special image acquisition techniques (left figure below). The next step is the determination of the flow conditions within these geometries by the ITWM solver ParPac, which is shown in the figure above on the right side. Averaging leads to the flow resistance which, together with the thickness of the panel, is the basis for a prediction of the panel's acoustic absorption. The middle figure on the right side shows measurements at ceiling panels and simulation results according to the Biot theory, which includes, apart from the flow resistance, further parameters which unfortunately are difficult to measure.



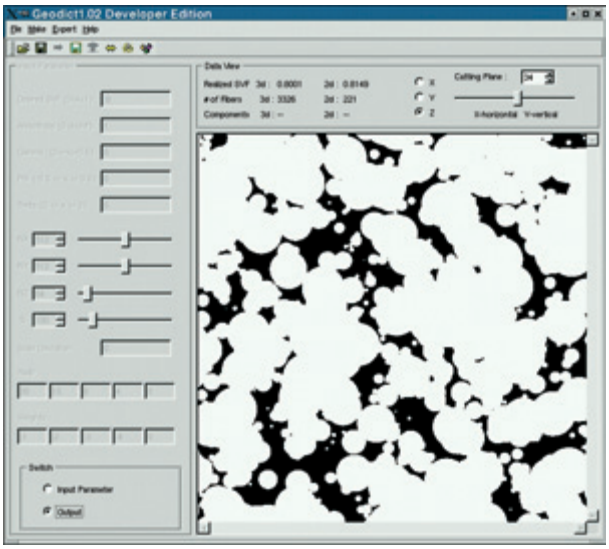
Simulation of a fluid flow through a cube filled by 40 % with spheres



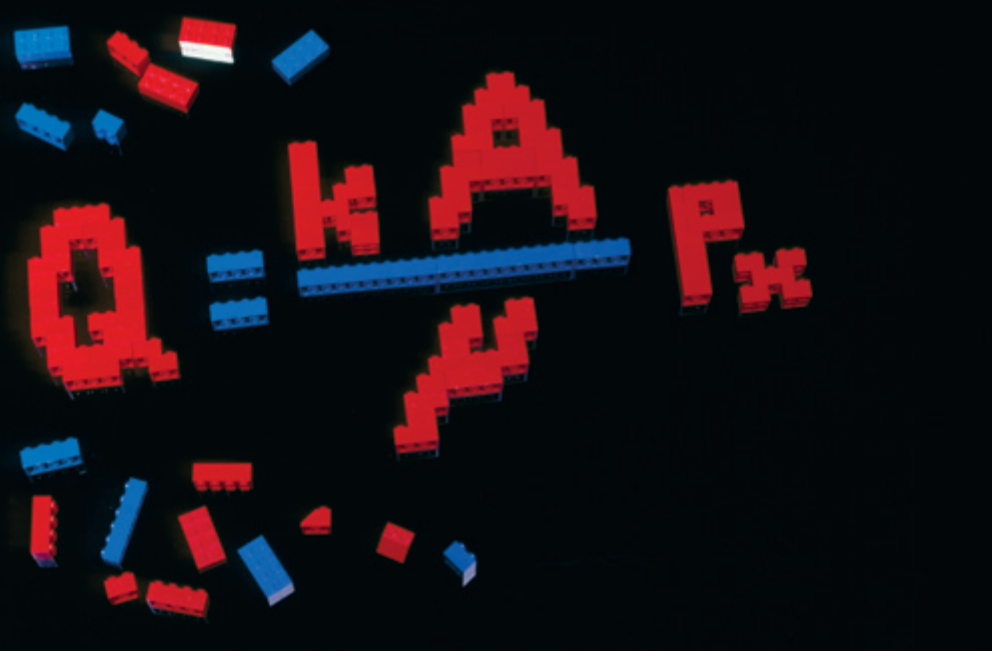
Measurement and simulation of the absorption of ceiling panels



Detailed image of the ceiling panel (area: 10 × 14 mm)



Section view by GEODICT: sphere geometry with radii 30 (10 %), 15 (20 %), 8 (30 %), and 4 (40 %)



Algorithms for Complex Geometries and Interfaces

In many areas of computer-based simulation of technical processes, e. g., with respect to structure optimization and flow simulation, the user can refer to wide-spread and thoroughly researched methods which have been successfully used in many applications. If, however, multifield problems occur in an application, if the underlying geometry shows a certain complexity, or if components of different materials are concerned, the standard algorithms often yield inefficient solutions or useless results.

We develop special methods for the exact and efficient solution of multifield problems with interfaces and material discontinuities on the basis of finite volume, finite differences, and finite element methods for specific application fields. E. g., adaptive local grid refinements, fictitious regions methods, level set and multigrid techniques are further developed and applied in order to receive exact, efficient, and application-specific algorithms.

Besides, ParPac, a parallel solver for complex three-dimensional flow problems based on the generalized Lattice-Boltzmann method, is continuously improved and updated. The generalized Lattice-Boltzmann method describes mathematical models of fluid dynamics by the simulation of a simplified particle dynamics. Currently, modules are available for the filling simulation, microstructure simulation, simulation of non-Newtonian fluids, as well as for the computation of multiphase flows. A result of a current DFG project is the exact computation of arbitrary boundaries, so that moving geometries and arbitrary boundary surfaces can now be resolved exactly. Within a project supported by the BMBF, the possibility of an adaptive refinement of the computational grid in the context of the generalized Lattice-Boltzmann method is examined.

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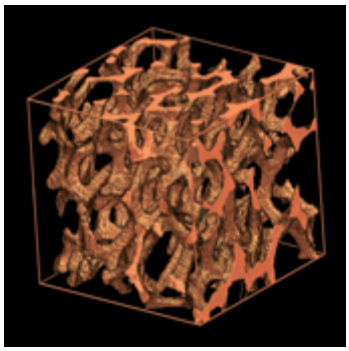
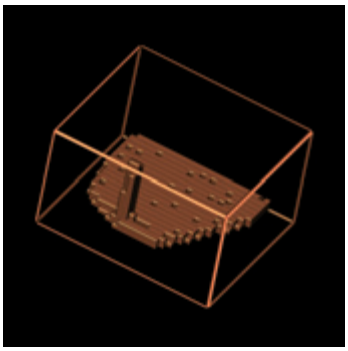
Simulation of three-dimensional moving surfaces by the level set method

The increasing performance of computers allows for the handling of three-dimensional structures of growing complexity and, above all, for their modification on the computer. Such structures can be, for example, complex microstructures (see following figure), but also components given in detail (see middle figure).



Tomographic image of a nickel foam, volume data, visualized by PV-4D (see p. 94)

Filter box of the company IBS-Filtran: CAD data as a triangulation in geomview



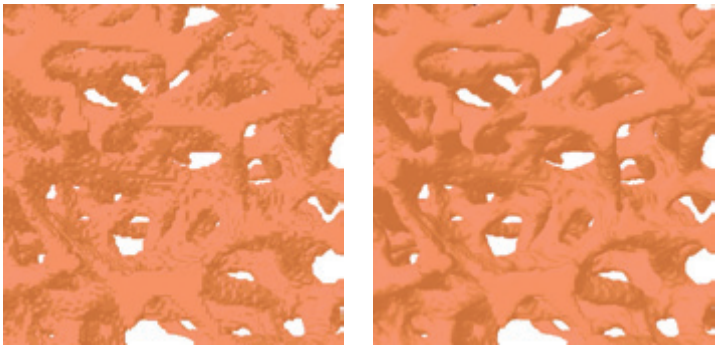
Grid representation of the interior points of a filter, visualized by PC-4D

Generally, we distinguish between volume data (attaching values to a mostly structured Cartesian grid in space, see above figure), and surface data (often given as triangulations, see figure in the middle column). The individual steps of the level set method do not only allow for the movement of surfaces, but also for a comfortable transformation of surface data into volume data and vice versa.

The first step is the so-called initialization, where a signed distance function on a structured grid (or on the intersection of a structured grid and an environment of the surface) is determined for a given surface representation. The sign allows for, e. g., the computation of an approximation of the „interior" defined by the surface, which is then saved as a set of volume data (see figure in the right column).

The next step is the so-called propagation, where the surface is implicitly moved and modified by a deliberate manipulation of the newly generated level set function (by hyperbolic partial differential equations and given velocities along the surface). The particular feature of the level set method is the simplicity by which the topological variations of the surface – e. g., "from pretzel to banana" – can be described (see figures below).

In the third step, the new zero contour of the level set function (respectively specific properties of this contour, such as normal vectors and curvatures) are determined, and the zero contour is transformed back into a triangulated surface.



Surface triangulation of a nickel foam: initial state and smoothing

Flood and Risk Management

In the case of heavy rainfall, flooding occurs in urban areas, whose consequences are large damages to buildings and the city infrastructure. This situation is the basis of a series of research projects of the main subject Flood and Risk Management:

- computation of flow paths at the surface in urban and natural watersheds on the basis of a digital elevation model (DEM) and geographic information systems (GIS)
- development of physically-based simulation models (e. g., by shallow water equations) for the surface water
- coupling of the flow in the sewer system and at the surface
- visualization of simulation results and parameter fields in the GIS and, e. g., by MATLAB®

The results of this research are applied with respect to projects in the following areas:

- modeling and computation of floodwater events in (peri-) urban areas, including the estimation of flooding risk by model rainfall (so-called Euler rainfall)
- computational proof of official regulations (European general water directive EN 752: „Drain and sewer systems outside buildings")
- determination of damage quantity and quality, e. g., depending on the water level
- planning scenarios for the connection of new building sites to the drainage system and for the renewal of entire partial systems
- problems of insurance industry
- emergency management

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Project study Erlenbach

The project in cooperation with the city of Kaiserslautern with respect to the flooding of the Erlenbach district in May 2000 represents a typical application of the software developed within the main subject Flood and Risk Management.

A heavy rainfall of the order of magnitude 70 mm per hour, fallen on the watershed of Illerbach and Ellerbach, which has an approximate size of one square kilometer, resulted in a massive flooding of the district of Erlenbach. The objective of the project is the determination of the flow processes of that event and the estimation of the flooding risk for the district by simulations of the run-off behavior after model rainfalls of given return periods. On the basis of the results, building measures are to be examined – also based on simulations – with respect to their capacity of decreasing the number of flooding risk.

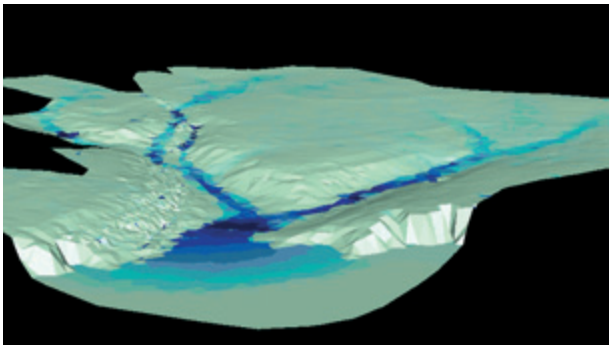
In the simulation, simplified shallow water equations are solved for the computation of water levels at the surface depending on space and time. The model representation includes the topography and surface parameters, such as permeabilities and roughnesses. All the necessary data are extracted by the GIS and positioned on a triangular grid of adaptive cell size. Large model areas with only smoothly varying parameter distributions, as they occur in the domain of the natural watershed, are to be combined with model details to be determined exactly, such as streets and brooks, as well as with the slope separating the urban area from its watershed. The urban area is located at the back and can only be flooded by water from the watershed if the sewer inlets at the bottom of the slope are closed or if their capacity is exceeded, so that the basin in front of the slope cannot cope with the inflowing masses of water any longer.

The simulation of the run-off processes in the case of the heavy rainfall of May 2000 shows that the mentioned flooding case occurs although the channel inlets are open. We can conclude that, in the case of rainfalls of the intensity observed at that time, there is a high risk potential for the district due to inconvenient run-off conditions. Rainfalls of a 50 year return period will probably cause flooding. Different relief measures can now be dimensioned and tested after their implementation into the computer model.

Flooding of cities

Within the EUREKA project E!2255 RisUrSim, a GIS-based simulation and planning tool is developed by an interdisciplinary international consortium, headed by the Fraunhofer ITWM and consisting of computer scientists, urban water management experts, local authorities, insurance companies, and mathematicians in Norway, Italy, and Germany. The flow on the surface is coupled with the events in the sewer system. Test areas are different urban areas in the participating countries. A further part of the project is an ensuing data processing dealing with the damage situation in the case of flooding.

In the framework of a PhD thesis, the modeling of water flows across edges and out of gully holes is developed by modified shallow water equations.



Computed water levels in the watershed and in the urban area as a consequence of the real heavy rainfall; the slope protecting the urban area is flooded.

Filling and Casting Processes

Our activities with respect to filling and casting processes not only refer to the simulation of processes in the fields of iron casting and injection molding of plastics by the commercial software package MAGMASOFT of the company MAGMA in Aachen, but also to the simulation of special flow processes by the software package ParPac, which has been developed at the Fraunhofer ITWM.

As an experienced user of MAGMASOFT, the ITWM does not only support foundries by training courses for their staff, but also by consultations with respect to special problems resulting from the application of the simulation software for the solution of complex problems of casting technology. The main subject of the cooperation with the company HegerGuss, which has already become traditional (since 1996), is the utilization of the enormous performance of the ITWM's HPC cluster, where the parallelized version of MAGMASOFT has been installed. New in this area is a consulting project with the foundry Römheld & Moelle in Mainz, where company-specific problems with respect to the application of the iron casting module of MAGMASOFT are examined.

The research and development projects of the Fraunhofer ITWM in cooperation with the company MAGMA GmbH in the field of injection molding of plastics refer to the computation of the fiber orientation for short-fiber reinforced thermoplastics. Main subjects are theoretical examinations with respect to the numerical solution of the orientation equations (robust integration methods, final approximations) and the computation of the spatial variation of the fiber concentration during the mold filling process. Besides, the research has been focused on numerical methods for the flow computation in weakly compressible, non-Newtonian fluids.

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The glass fiberization process during the production of thermal insulating materials

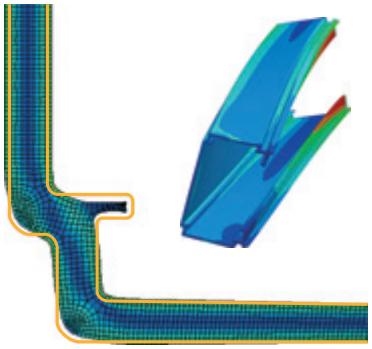
In a previous microstructure simulation project in cooperation with the company Pfleiderer Dämmstofftechnik (see Annual Report 2001), we have proved that the efficiency of thermal insulating materials consisting of glass fibers decisively depends on the thinness of the glass fibers and on the possibility of a precise adjustment of the fiber radius distributions.

Therefore, the objective of a successive project was the mathematical-physical representation of the glass fiber production process, in order to develop a foundation for a systematic, computer-based fine control of this process. An essential part of the project consisted in the scientific determination of the decisive parameters for the glass fiber quality which might be influenced in the complicated multiphysical production process. During the production, hot glass of a temperature of approximately 1000 °C flows from a nozzle, dropping onto a rotating disk spinning at high velocity. Due to the centrifugal forces, the glass mass is pressed against a perforated disk where the primary filaments are produced. For each process step, equations have been derived by a simplification of the general fluid dynamical and thermal equations specifically with respect to the physical situation. These equations can easily be integrated into the production. The validity of the basic approximations has been tested in a complex simulation by the software ParPac. The simplified equations allow for a relatively easy computation of the mean temperature gradient of the glass from the nozzle outlet to the contact with the perforated disk, depending on the mass flow and the geometry of the rotating disk. The thickness of the resulting glass film in the rotating disk can also be determined very easily, depending on the geometry of the rotating disk and the glass temperature. The flow in front of the perforated disk has turned out to be especially sensitive for the glass fiber production process. Due to the fast rotation of the spinning disk, the glass is subject to a force corresponding to 800 times the acceleration due to gravity.

The derived theory will in the future enable the company Pfleiderer to control the profile of the glass film resulting from this force, the flow in the glass film, and the height-dependent glass flow through the holes of the perforated disk, which is especially important for glass fiber production. Thus, the company will be able to improve the quality of the thermal insulation mats it produces.

Facility for the production of thermal insulating materials

Optimum Structural Design



During the design phase of the product development process, the following objectives are often worked on simultaneously: optimum use of the material, at the same time reduction of the necessary amount of material to a minimum. A minimum amount of material means lower weight, often the consumption of less energy, and lower costs of the product. Subject to external loads, the stresses in the component should not exceed a critical value, in order not to restrict functionality or even result in a failure of the component. Finally, the production process of the component must be accounted for in the design. A more complicated shape is often connected to a more complex production process, which not necessarily compensates the weight reduction. The Fraunhofer ITWM develops structural optimization tools for the automatic computation of an optimum shape of the component with respect to these objectives. These tools support the engineer during the design of new and the improvement of already existing products.

In a cooperation project with the companies Audi AG, Faurecia, and Sandler AG, compression molded parts, e. g., for the headliner of automobiles, are optimized with respect to their acoustic efficiency. In the framework of an Integrated Product Policy, all the phases of the product life cycle (fibers – nonwoven – compression molded part – assembly – use – dismounting – recycling) are accounted for during the optimization process for the design of the compression molded parts.

For the company TEHALIT GmbH, several profiles for running of cables have been improved. The stiffness of the profiles has been increased without simultaneously increasing the area of cross-section of the profile and thus the amount of necessary material. The figure on the left shows a comparison between initial (orange boundaries) and optimized (colored) geometry of a partial cross-section. The computed optimized profiles have a higher torsional stiffness, as well as a stronger moment of resistance if the upper and lower sides are pressed together. The optimized running of cables subjectively show a higher stability, which is an important sales argument. Transport and wall mounting become easier. The deformation of the running of cables by the load of the cables decreases with respect to the profile which has not been optimized.

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Not in the photograph: PD Dr. Heiko Andrä, PD Dr. Oleg Iliev, Dipl.-Ing. Iuliana Matei, Dipl.-Math. Inga Shklyar


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Models and Algorithms in Image Processing

The main subjects of the department MODELS AND ALGORITHMS IN IMAGE PROCESSING are:

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

The successful year of 2002 was characterized by balance in every field. Our main focus was the development of complex algorithms for image and signal processing, and their implementation into efficient software within complete systems.

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 and evaluation of textured surfaces (e. g., paper, textiles, nonwovens, wood). Here, we have succeeded in acquiring several new customers, for whom especially tailored inspection systems for industrial applications have been developed. Unfortunately, only very few aspects of this positive development can be described in the current Annual Report, mainly for reasons of confidentiality.

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. The research at the Fraunhofer ITWM is focused on the determination of geometric features of material microstructures by methods of stochastic geometry. On this basis, 3d models of these materials are developed which reflect the geometric structures very well, thus simplifying or even allowing for the first time computations and simulations. 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.

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, has been started in cooperation with partners. The system will presumably be available in the year 2004.

Surface Inspection

In many cases, the quality of a product depends on the quality of its surface. A unified approach is difficult due to the variety of possible surfaces. Almost every type of surface has its own quality measure, depending on very different properties. In the case of products such as paper, textiles, or metal products, possible defects occur locally, so that it makes sense to search for local deviations from a global homogeneity. In the case of other products (nonwovens, wood products, carpets), however, properties are considered which characterize a larger section of the sample or even the entire sample.

Very often, the tasks of surface inspection are still carried out by especially trained controllers, an approach which frequently only allows for the examination of random samples, often according to criteria that are not objective. Therefore, a complete online product control and the guarantee of a constant quality are not possible.

The Fraunhofer ITWM has a wide range of experience with respect to the development of algorithms for an automatic surface control. Within the **MASC** series (**M**odular **A**lgorithms for **S**urface **C**ontrol), a number of tools and system components have been developed which are ready for application. The components are organized according to a modular structure, offering an adequate basis for fast and flexible solutions for almost every individual task.

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

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Surface inspection of gaskets

At the company MSC/GAC in Eisenach, 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 a manual hundred-per-cent-control afterwards. This last step partly took place considerably later.

The considered gaskets are rubber-laminated metal parts of different geometries which can show different surface defects, such as bubbles, contaminant, 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/production time considerably. The automatic defect detection reaches a degree of objectivity which is almost impossible in the case of manual controls. Besides, the fast detection of serial defects becomes possible, which otherwise could lead to large amounts of waste during production.

The method consists of several steps, always observing the top and bottom side of each gasket. Due to the partly 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-part. 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-parts, and the detected defects are being classified. The 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.

Surface inspection of a gasket (from left to right): original image, defect areas, marked defects

Inspection of paper surfaces

In the paper producing industry, the quality control is also frequently still performed by especially trained personnel. This method of control is laborious and time-consuming.

At the Fraunhofer ITWM, a system for the automatic paper inspection has been developed. The inspection system SPOT does not only improve the quality of the previously manual inspection by objective criteria, it also controls the paper at high velocity. High velocity is important because an automatic inspection system is supposed to be directly integrated into the production process without slowing down the production.

In the center of the system is a fast image processing algorithm (approximately 70 ms) which detects and simultaneously classifies defects, e. g., spots and scratches, on the homogeneous paper surface. Input data of the algorithm are digital images of the paper surface, provided by cameras installed above the conveyor belt for the paper sheets.

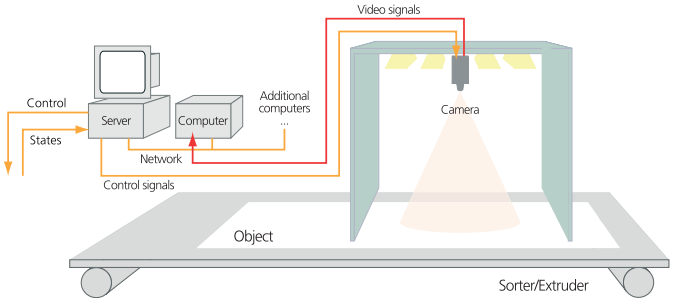
Image processing

As a first step of the image processing algorithm, the camera image is reduced to the relevant region, i. e. the section of the image showing only the paper sheet. After this "recognition of boundaries", defects are detected in the image and marked by so-called ROIs (Regions of Interest). On the basis of the features provided by the ROIs, the algorithm classifies the defects. Only this step determines whether the detected defect is a point-like defect or a spot etc.

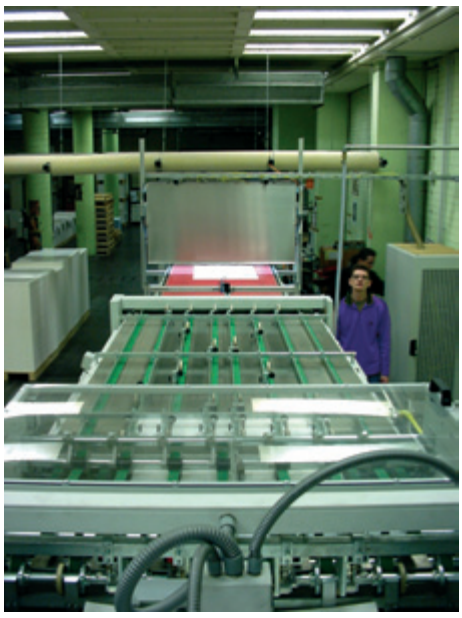
System setup

The SPOT system is directly integrated into a paper sorting machine. Above the conveyor belt, several cameras are installed which observe the entire width of the paper sheets. Each of these cameras is connected to one of the clients of the SPOT system. These clients run the image processing algorithms. Each client consists of a double processor system where several image algorithms run simultaneously. This parallelization is finally responsible for the high performance of the SPOT system.

A central server collects the results of the clients and notifies the sorting machine whether a sheet is "good" or "bad". Moreover, all the occurring defects are collected by the server, so that an overall statistics can be provided at the end of an inspection cycle.



The left figure shows the structure of the inspection system. The central server (SPOT server) controls the entire system and the image processing clients, where the acquired images are processed. On the right hand side, we can see the SPOT system applied by the paper producing company Hoffmann and Engelmann.



3d Image Processing and Analysis

Worldwide, an increasing number of three-dimensional images of microstructures are acquired for the examination of materials, e. g., by micro-computer tomography (µCT) or confocal laser-scanning microscopy (CLSM). The advantages with respect to other imaging methods are obvious:

Microstructures are usually three-dimensional. 2d images resulting from conventional microscopic methods, such as polished and edged microsections, cannot be used for the reconstruction of the 3d microstructure, or only if very complex methods are applied.

Problems of sample preparation are solved very simply. The preparation of planar sections or microsections is very complex or even completely impossible for very soft, fragile, or highly porous materials. Such a preparation is unnecessary in the case of microtomography.

3d images usually contain much more information than 2d images. Frequently, one 3d image is sufficient for the characterization of a microstructure.

If the attenuation contrast between the components of the microstructure is strong enough, the 3d images resulting from µCT are high-contrast images and thus perfectly appropriate for a subsequent image processing and analysis. Already for some time now, very good methods have been developed for the visualization of the respective 3d data sets, which often also include components of image processing. However, until recently, the technologies for the analysis of 3d images of complex microstructures were insufficiently developed.

In the framework of publicly supported and industrial projects, the mathematical foundations for 3d image processing and analysis have been developed at the Fraunhofer ITWM, and the respective algorithms have been implemented. Meanwhile, a commercial system of 3d image processing and analysis has been developed in cooperation with the company aquinto AG and is now available on the market. The high modularity of the system components allows the solution of a wide range of different industrial and research problems.

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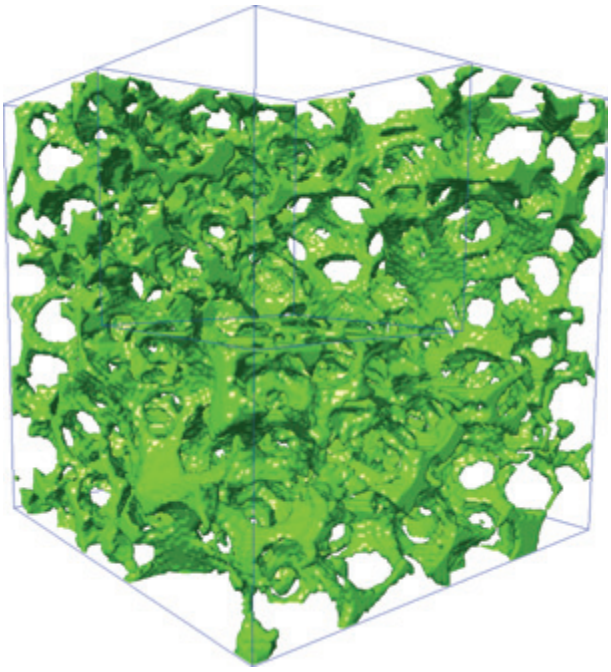
Pixel neighborhood

A basic property of digital images is the pixel neighborhood. Almost all the algorithms of image processing and analysis depend on the selection of the neighborhood, especially in the case of skeletonization, watershed transform, labeling, and the measurement of object features and field features. Visualization algorithms (e. g., surface rendering) are also influenced by the selected neighborhood. The algorithms used within a software must be based on the same neighborhood. Besides, the results of an analysis depend on the pixel neighborhood (see figure below); therefore, a flexible selection of the pixel neighborhood, depending on the problem, is desirable.

A systematic examination of the pixel neighborhood in 3d images has been carried out. Apart from the neighborhoods already known from publications (6-pixel and 26-pixel neighborhood), further neighborhoods (two 14-pixel and one 16-pixel neighborhood) have been introduced which are self-complementary, i. e. if one of the two 14-pixel neighborhoods or the 16-pixel neighborhood is selected for the foreground pixels of an image, the image background is connected with respect to the same neighborhood. Such a complementarity of pixel neighborhoods leads to a simplification of algorithms and an improvement of the results of 3d image analysis.



The microstructure of an autoclaved aerated concrete (AAC): the figure shows a visualization based on a surface rendering. The image was acquired by X-ray computer tomography (µCT). An important feature of the pore space is the connectivity, which determines the thermal conductivity as well as the mechanical properties of the AAC.

Spectral analysis

At the Fraunhofer ITWM, the spectral analysis of random sets was placed on a solid mathematical foundation. First, the existence of a characteristic parameter for random sets in inverse space was proved, the so-called Bartlett spectrum, which is connected to a quantity of second order in the position space, the covariance. On this basis, an effective method for the image analytical determination of the covariance by the fast Fourier transform was developed.

Essentially, the results of the theoretical research do not depend on the space where the random sets are defined. The image analytical methods were implemented for practically relevant cases. The spectral analysis offers a series of advantages compared to other image analytical methods:

- It is a fast measurement method (if the fast Fourier transform is applied).
- The measurement is robust, i. e. the interference positions in the measured Bartlett spectrum are mostly insensitive with respect to variations of the image acquisition conditions.
- The measurement values can easily be interpreted by the user (due to the similarity of the measurement method and diffraction experiments).

Segmentation

In several cases, elementary methods of image analysis allow for a satisfactory segmentation if the quality of the 3d images is sufficient. These methods are:

- binarization of a grey tone image by one or several given binarization thresholds
- labeling, i. e. the detection of topologically connected objects
- watershed transform, where the watersheds again are connected with respect to a given pixel neighborhood

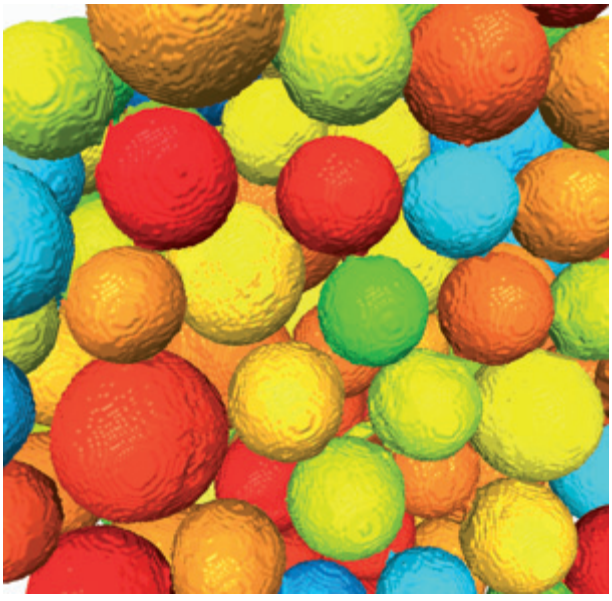
The result of a binarization is a binary image, where the foreground can be interpreted, e. g., as a cut-out of a (detected) microstructure component. The field features of such a binary image can be measured directly.

However, the resulting binary image may also undergo a labeling for the detection of objects.

In contrast to the above mentioned methods, the watershed transform can be applied directly to grey tone images, so that a binarization, which may be very instable or even senseless under certain circumstances, can be avoided.

The result of a labeling or a watershed transform is a label image, usually representing the basis for the detection of object features. However, it can also be used as a basis for certain filters, e. g., for the elimination of small objects (noise).

Nevertheless, in most cases these simple segmentation strategies are insufficient. For a reliable segmentation of low-contrast images respectively of topologically complex geometric structures, integrated methods must be applied. Therefore, combinations of image preprocessing and watershed transform have also been tested successfully for most images. Apart from simple smoothing filters, morphological transforms and distance transforms (Euclidean and Chamfer distance transforms) are also used for the preprocessing.



Particle segmentation in a sintered copper material by the watershed transform

Monitoring for Railway Systems

For several years now, our institute has been cooperating with GE Transportation Systems in Bad Dürkheim within a project concerning the chassis monitoring sleeper (FÜS), for which the Fraunhofer ITWM develops and maintains almost the entire software. Particular problems are problems of signal analysis and system management.

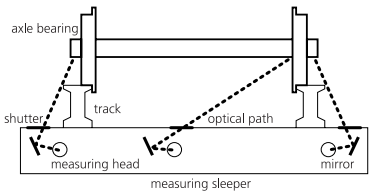
The monitoring of overheated axle bearings and stationary brakes on passenger and freight trains requires a remote measurement method. In the solution selected here, the temperatures are measured by registering the infrared profile of the passing chassis, the data being transferred to a PC. The system works without human control, therefore an appropriate self diagnosis system for the hardware and software must also be 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 were modernized basically for the new generation of the chassis monitoring sleeper, resulting in a considerable extension of the software developed at the Fraunhofer ITWM, which is, however, still compatible with the old hardware.

New projects, such as the concept of an archive server, increase economic effectiveness, reliability, and availability of the systems. Measurement data and protocols from several systems are saved centrally. The information provided by these data and the application in practice over several years represent the basis for the refinement of the evaluation algorithms.

More than 400 systems are working successfully in several European countries.



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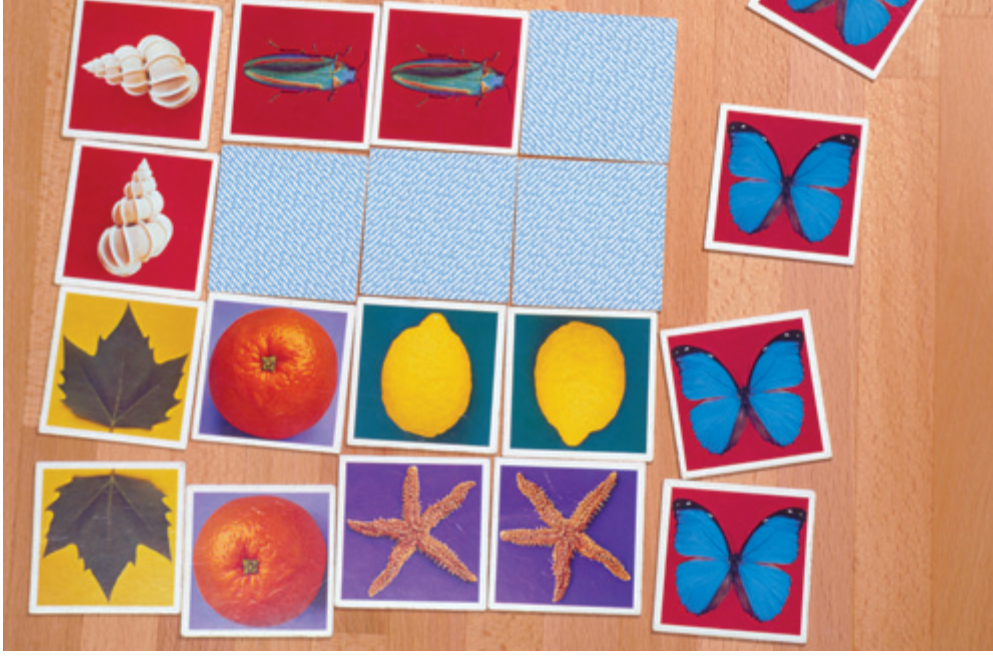

Analysis of Image and Video Sequences

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 foundation for a high-performance contents-based video and image search engine.

Important application scenarios, for which I-Search is expected to drive forward the technological development, are the following: the current subject of security involves, e. g., the task of searching for a lost piece of luggage at an airport monitored by intelligent webcameras, 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.

Similar requirements with respect to the methods come from the fields of broadcasting and internet, where the main problems are the fast finding of scenes in media archives (taboo clips, selection of shooting locations) or the contents-based search for images on the internet.

In order to meet these challenges, 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. These projects are carried out in cooperation with partners from industry and research. The Fraunhofer ITWM develops a strongly component-oriented parallel software architecture which allows for the application of the system on SMP(PC) super clusters and computing grids, as well as on highly distributed systems of small high-performance computers, as they are occasionally offered in the webcameras.

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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 cryptographic methods is necessary. The application of public key cryptosystems, also called asymmetric methods, is essentially important for achieving the objective of secure communication.

The most well-known asymmetric cryptosystem today is RSA. Its security is based on the fact that the factorization of a "large" integer number which is the product of two primes is generally considered to be difficult. The current factorization record is held at 158 decimal digits for the composite number. Even 512-bit RSA keys cannot guarantee security any longer. Therefore, it is important that alternatives are available. However, most of the proposed cryptosystems have not been able to compete with RSA with respect to run time and security per key length.

Nevertheless, 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 already for small keys. Therefore, they are especially used in the case of Smart Cards and other environments where only limited memory is available.

Hyperelliptic curves are generalizations of elliptic curves. The Jacobians of hyperelliptic curves can be used for the construction of secure and efficient cryptosystems comparable to RSA. Their advantage with respect to elliptic curve cryptosystems is the larger selection of appropriate parameters and the resulting higher security.

Within a project in cooperation with the company BGS Systemplanung AG, we have developed algorithms for the determination of subfields and the explicit computation in the ring of endomorphisms of hyperelliptic function fields. These algorithms allow a test with respect to possible weaknesses of the selected parameters and provide information about the structure of the Jacobian.

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Adaptive Systems

The main subjects of the department ADAPTIVE SYSTEMS are:

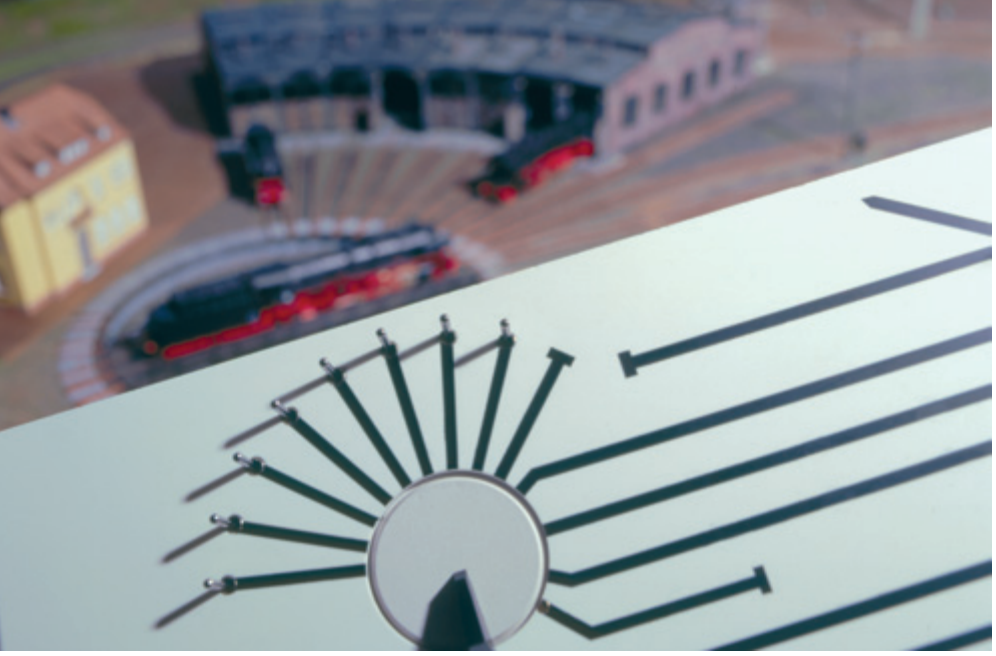
- CAD for analog circuits
- monitoring and control
- diagnosis support in life sciences
- prognosis of material and product properties
- multiscale structure mechanics

The research with respect to the problems resulting from these main subjects is based on the mathematical main competences 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 consequent new and further development of the department's own software is primarily important. Since February of the year covered by this report, version 2 of Analog Insydes has been available, a CAD tool for the support of analog circuit design. Besides, the series of monitoring tools for rotating machinery has been extended by the products TorStor and TorFat. The further development of the nutrition expert system with respect to special user groups has also been continued as planned.

In the year covered by this report, the department was able to increase the number of industrial customers considerably with respect to the marketing of the department's own software products, as well as with respect to contract research, which is a very positive development. New customers have particularly been acquired in the field of Prognosis of Material and Product Properties, resulting in a whole series of new and interesting projects.

In the year 2003, the department's objective is a further development of its own software products and competences. The PhD and graduation projects carried out in the department will represent particular contributions here.



CAD for Analog Circuits

The Fraunhofer ITWM has developed the software tool Analog Insydes, a tool for the modeling, analysis, and sizing of linear and nonlinear analog circuits by symbolic methods. Up to now, apart from numerical simulation methods, only very few tools have been available to the circuit design engineer in industry in order to get a more detailed insight into the behavior of a circuit. However, there is a high demand for computer-based methods particularly with respect to the industrial development of integrated circuits. Analog Insydes is a valuable tool which helps to increase design security and to shorten development time. The software is based on mixed symbolic/numerical algorithms for linear and nonlinear differential algebraic systems of equations (DAE systems). The work within the project is supported by cooperation with the Centre of Computer Algebra of the department of mathematics of the University of Kaiserslautern.

Besides, the department also deals with the simulation of heterogeneous systems. Circuit components are, e. g., coupled with physical or chemical processes within a system simulation. In such a way, the interactions of the individual subsystems and especially the integration of the circuit components can already be examined before a prototype is realized. Here, the ITWM offers customer-specific simulation environments.

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Analog Insydes version 2

In February, the official version 2.0 of Analog Insydes was released, after the completion of the software components, the detailed documentation, and the package design. Analog Insydes is merchandized via a worldwide reseller distribution network of Mathematica®, supported by Wolfram Research Inc. Besides, the product is also directly marketed by the ITWM. Apart from a special upgrade price for users of Analog Insydes 1.0, different license models of the new version are offered. In order to support application in research and development, a considerably reduced price is available here.

In contrast to version 1.0, Analog Insydes 2.0 supports the platforms Windows (95, 98, NT 4.0, 2000, XP) and Solaris, as well as HP-UX and Linux. Besides, the new version is compatible with Mathematica 3.0 up to the current version 4.2.

A fully functioning free demo version can be downloaded for a limited period of 30 days from the following address: *www.analog-insydes.de*

Current research

The work within the European joint research project Anastasia+ was continued as planned. Main subjects were methods for the automatic generation of nonlinear behavioral models and their translation into the behavioral description language VHDL-AMS. Methods of index control have especially been developed for the generation of transient behavioral models.

The research in the field of interval arithmetic has been continued. The objective is a reliable prediction of the effects of component tolerances which are due to production on the circuit behavior. The combination of a Newton interval method with symbolic preprocessing and standard numerical methods allows for a fast and exact solution of the systems of equations.

User seminars

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

Monitoring and Control

The research work of this group is mainly focused on developments and implementations of mathematical methods of system identification, model updating, as well as of observer and controller design. Application areas are technical systems, such as turbine generator shaft lines or test rigs for automobiles.

Modeling of a system

At the beginning of a project regarding a technical system, an appropriate mathematical model must usually be developed first, which represents the interesting system aspect as exactly as possible. The selection of the mathematical methods to be applied depends on the analysis of the available system information. If only the input-output behavior is known – a so-called black box –, the first attempt is a system identification by linear methods. If these approaches are not successful, more complex nonlinear methods like neural networks are applied. If, on the other hand, the structure and physics of a system are partially or completely known, the modeling must account for this information. This is called a gray box or white box modeling. The torsional behavior of turbine generator shaft lines, e. g., is modeled by the finite element method resulting in the so-called equations of motion.

Design of observers and controllers

On the basis of the identified system models, mainly methods of robust control theory are applied for the design of observers and controllers, apart from the classical methods. The advantage of these methods is that the resulting observer or controller is robust with respect to model uncertainties and other system disturbances. In the case of a strongly nonlinear system behavior, however, these methods are usually not sufficient any longer, so that further developed methods must be applied, e. g., for the solution of tracking problems with respect to the control of automobile test stands. If the system to be controlled is additionally subject to strong time-dependent variations, adaptive rigs control methods are applied.

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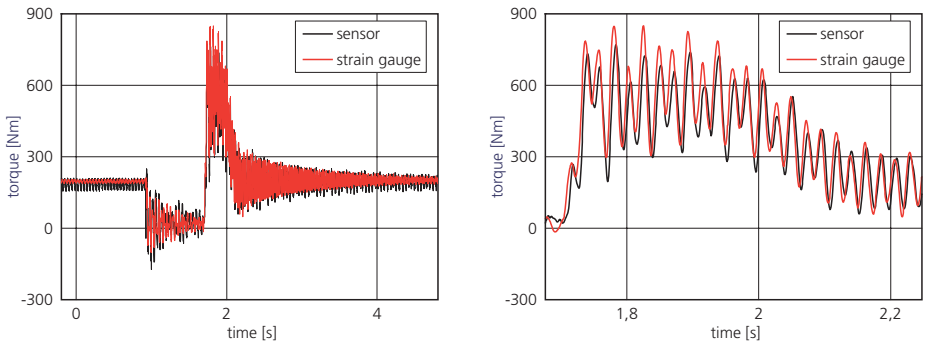
Monitoring of the torsional behavior of rotating machines

Apart from the software TorAn, which has been developed in the last few years, two additional software products, TorFat and TorStor, have been developed for the monitoring of the torsional behavior of rotating machines, in cooperation with our partner, Prof. Stefan Kulig from the University of Dortmund. TorStor is a tool for the determination of relevant torsional oscillations on the basis of torque measurements. The resulting data are available to the user for a further processing. Moreover, TorFat carries out a fatigue analysis of the shaft element at the measuring point for the disturbances which have been determined, giving the user the results of this analysis on the graphic user interface.

The software product TorAn has been developed for rotating systems whose torsional behavior must also be monitored online due to the technical restrictions of inaccessible components. TorAn estimates online the torsional oscillations at the interesting shaft sections by a robust, model-based observer. Apart from the exciting moments, TorAn also requires the measurement of the torsional moments at a shaft element. TorAn detects disturbances at every monitored component, subsequently carrying out a fatigue analysis of the selected shaft elements. The results of the fatigue analysis are available via the graphic user interface of TorAn. A visualization of the stored time series in time and frequency domain is also possible for all the software products due to an integrated visualization tool.

Contactless torque sensor

The measurement of the torsional moments required by the different tools is carried out by a contactless torque sensor, which is exclusively marketed by the ITWM. The concept of the sensor is based on the anisotropic magnetostrictive effect in ferromagnetic shaft surfaces. Depending on the mechanical torsional stress at the measuring point, this effect causes a different magnetic permeability in the direction of the tensile and compressive stresses. The sensor measures the permeability variation, which is proportional to the torsional stress at the shaft surface for a large measuring range. Via a data acquisition board, the signals provided by the sensor are made available to the different software tools for further analysis.



Comparative measurement of contactless torque sensor and strain gauge (DMS)

Diagnosis Support in Life Sciences

The research group deals with the application of data- and knowledge-based methods for the diagnosis of complex systems in the field of life sciences and for the prognosis of their behavior. A typical feature of the considered processes and systems is that a description by explicit models is at best possible in parts, due to lacking information or extreme complexity. Hence, their examination must be based upon systematic data mining of measurement data, as well as on empirical 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. In order to be integrated into an automatic process, expert knowledge must first be formulated appropriately, which is principally possible by the object-oriented approach known from the theory of programming languages, and by the so-called rule-based approach.

The main research area of the group is computer-based diagnostics in medicine. Within the project "Diagnosis support in regulation thermography", supported by the BMBF, expert knowledge is implemented into a medical expert system by fuzzy logic according to rule-based approaches.

Two further projects also deal with system diagnosis: "Automatic detection of arrhythmic heartbeat in electrocardiograms" and "Expert systems for nutrition consulting". In all these cases, the final product is a computer program whose accuracy with respect to prognosis and diagnosis is estimated by methods from non-parametric statistics, such as bootstrapping.

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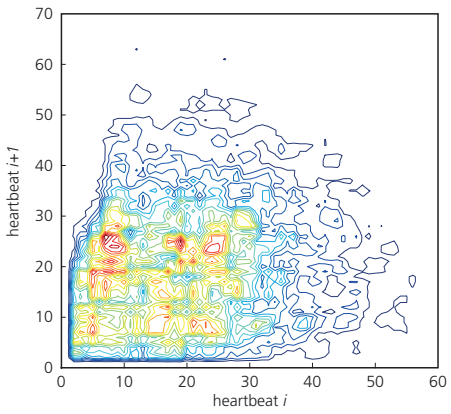
Automatic detection of arrhythmic heartbeat

Variations of the "normal" heartbeat cycle are described as arrhythmic heartbeat in medicine. They can have short-term or long-term negative consequences for a patient's health. Usually, arrhythmic heartbeat is diagnosed by an electrocardiogram, which requires considerable experience. A diagnosis support by pattern recognition is therefore very desirable and has already been applied in several cases. The subject of a current project is the detection of atrial fibrillations, which are difficult to diagnose on the basis of an electrocardiogram, by characteristic patterns occurring in the time intervals between successive heartbeats. The initial data are provided by an electrocardiogram of a resting patient, taken over a period of approximately one hour. The time series of the heartbeat intervals is analyzed according to a so-called Lorenz plot, i. e. a graphic representation of a time series showing dynamic information in the form of a geometric pattern. The objective of the project is the implementation of a diagnosis support method into a measuring instrument which is easy to handle.

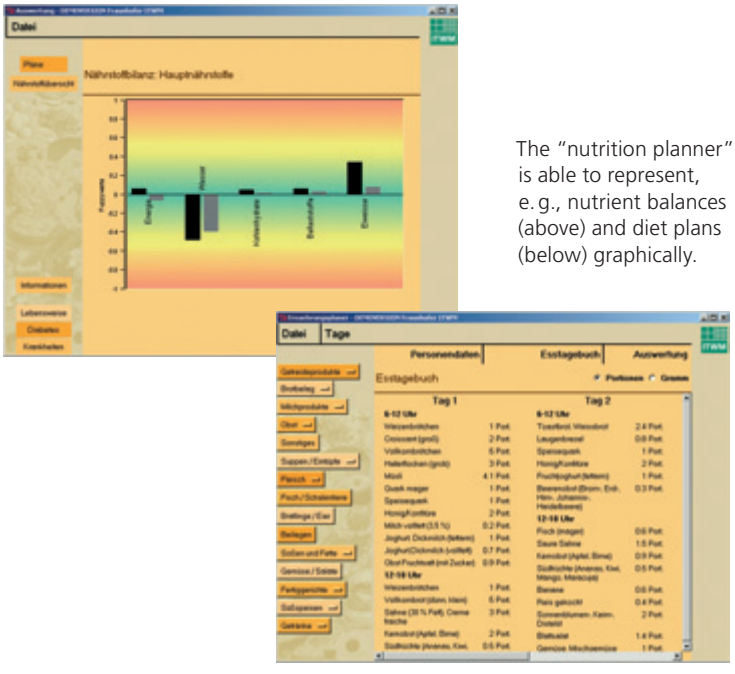
Two-dimensional Lorenz plot of an electrocardiogram



Nutrition consulting

A nutrition consulting software is supposed to support the user's decisions with respect to the evaluation and possible change of his/her usual diet. Whereas many nutrition programs follow a relatively strict strategy by, e. g., prescribing recipes, the Fraunhofer ITWM develops a system which is based on the actual habits of the user, thus allowing for a step-by-step optimization of the nutrition plan. First, the software evaluates a nutrition plan, which has been taken down by the user over a period of several days, with respect to his/her current supply with the most important nutrients. The optimization provides proposals for an improvement of the nutrition behavior by accounting for personal habits and preferences. The objective is to support a learning process resulting in a healthy nutrition instead of prescribing ready-to-use recipes. Additional information is available to the user by a comparison of actual and improved nutrient supply in the form of understandable graphic representations and tables, as well as by individually tailored information texts.

The nutrient optimization is controlled by weighting functions individually defined for each nutrient, as well as by a supply index computed for the entire nutrition plan. These functions are determined in cooperation with a nutrition scientist.



The "nutrition planner" is able to represent, e. g., nutrient balances (above) and diet plans (below) graphically.

Prognosis of Material and Product Properties

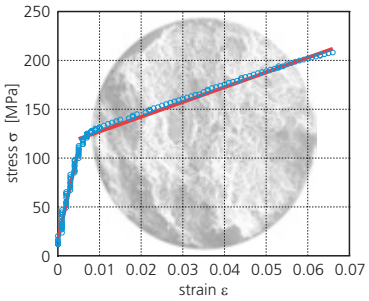
In many complex systems and processes, it is often completely unclear at the beginning on which potential influence factors a selected performance parameter depends. This is due to a lack of adequate physical models. In particular, the known dependences are frequently nonlinear, varying with the state of the considered dynamic system.

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

Examples for interesting performance parameters of material design are crash behavior and tensile strength. Partial influence factors are geometry parameters, material composition, and production methods.

Within the Fraunhofer-WISA (Economy-Based Strategic Alliance) study "Magnesium", the tensile properties of dashboard supports in automobiles, which are made of magnesium by a special casting technology, are to be determined. So-called sigma-epsilon curves are given which have been determined by systematic experiments. Each of these curves represents the material behavior at one point of the dashboard support while the tensile force increases until a material failure finally occurs.

Our computations 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 higher probability for the task variable to behave in the desired way under the considered loading scenarios.



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Multiscale Structure Mechanics

In industry and technology, there is a wide range of applications for composite materials. Due to a specific combination of different components, these materials show special properties determined by the behavior of the individual components, their geometric structure, as well as the interactions between the components.

The Fraunhofer ITWM develops mathematical models and asymptotic homogenization algorithms by which the effective structure mechanical properties of such materials can be determined on the basis of their microstructure and their micro-properties.

These methods are the foundation for a highly efficient simulation of mechanical or chemical processes in systems of composite materials. In contrast, a direct simulation of such multiscale systems is extremely complex, because not only the macroscopic structure of the entire system must be considered, but also the microscopic structure of the individual materials.

The reason for the particular effectiveness of these homogenization techniques is that they allow for a separate handling of the macroscopic and microscopic structures. First, the effective properties of the material are computed on the basis of the microstructure, and are then applied for the simulation of the macroscopic system. Both steps can be carried out by the usual commercial FEM software packages.

The necessary computing time is essentially reduced compared to a direct simulation. Complex parameter studies, as they are necessary, e. g., for the optimization of the system geometry, may thus become possible for the first time.

Many effective material properties, such as stiffness, strength, fatigue, or wear, can be computed by this method. Multiscale systems where viscoelasticity, large deformations, and nonlinear material behavior are important can also be handled in such a way.

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Material modeling of filled molding compounds consisting of thermosetting resin

A further example from the wide field of applications is a current project laying the computational foundations for the modeling of thermosetting resin by accounting for reaction conversion and temperature.

The objective is to provide information about the strength and service life of such composite materials on the basis of their microstructure properties.

A special interest consists in dealing with materials which also show memory and creep effects. In contrast to usual materials, the stresses of these viscoelastic materials do not only depend on the current state of distortion, but also on the question how this state of distortion has been reached.

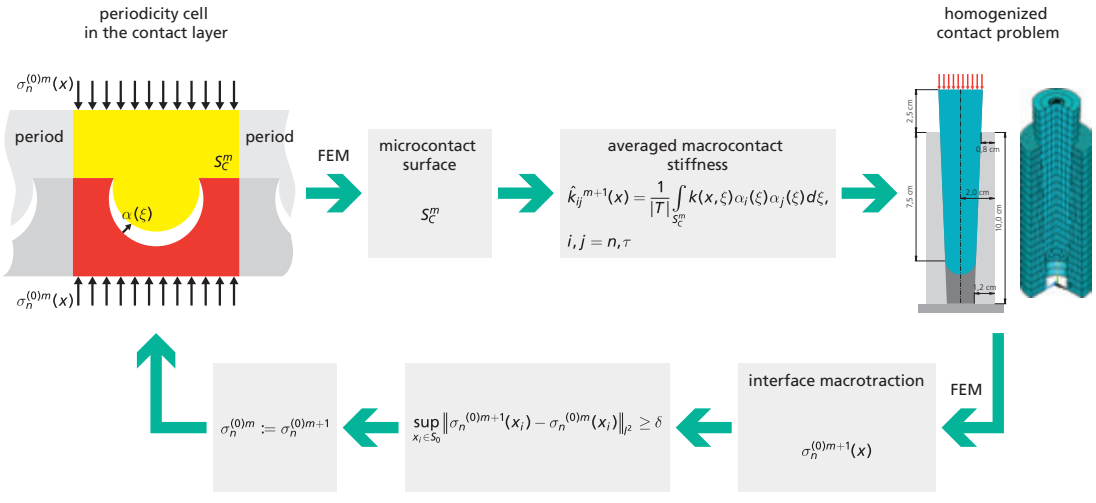
The mathematical description of these properties is based on convolution integrals with weakly singular kernels. However, commercial FEM software packages model the viscoelasticity only by simpler exponential integral kernels, which are not always sufficient. Nevertheless, the application of such a software is very interesting because its advantage is the handling of complex geometries. Besides, the software packages offer excellent tools for an explicit visualization of the simulation results.

During the first year of the project, an algorithm has been developed and tested numerically by a simple resin model. Plans for the future include the extension of the method to viscoelastic composite materials.

Prognosis of the properties of cementless hip prostheses

Homogenization applications comprise very much more than the mere computation of effective material properties. Homogenization can, e. g., also be applied in order to derive effective macroscopic contact properties of different bodies from their microstructure contact properties. This method has been used within the EU-CRAFT project "PRE-HIP" for the computation of the effective contact properties of a hip prosthesis with the hip bone. On this basis, a reliable determination of the elastic stress field within the bone became possible.

Scheme of the algorithm for the computation of the effective macroscopic contact properties of a hip joint prosthesis on the basis of the microscopic contact properties



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Optimization

The department OPTIMIZATION deals with the research and development of mathematical optimization models and methods for industry, the service sector, and the social sector. An especially important aspect is the development of the respective software in cooperation with the customer.

The spectrum of methods which are applied ranges from graph theory and special approaches of combinatorial optimization to large scale optimization. In some projects commercial solvers such as CPLEX® and XPRESS® are also used. Methods of online optimization and multicriteria optimization as well as logistic simulation are also developed and applied.

The year 2002 was a satisfactory year in spite of a slightly hesitating order placing on the part of industrial partners. Almost all the customers remained loyal, and several new customers could be acquired. First results of the two BMBF projects KogiPlan and SILVER were presented during the two big fairs in Hanover.

The department is divided into the following main groups:

- Internal Logistics
- Global Logistics
- Traffic Planning
- Decision Support in Life Sciences
- Knowledge Management and E-commerce

Within the group Internal Logistics, a research project with respect to the optimization of patient transports in hospitals could be started. Regarding Global Logistics, the cooperation with the company geomer was intensified in the field of GIS planning. In Decision Support in Life Sciences, cooperation with the company MRC Systems was initiated for the merchandizing of a common product with respect to radiotherapy planning. In the group Knowledge Management and E-commerce, despite the trend on the market a large project could be started which will at least remain actual during the year 2003.

The research is supported by cooperation with the research group Mathematical Optimization at the University of Kaiserslautern.

Internal Logistics

The group Internal Logistics deals with the planning, control, and optimization of technical and organizational processes. The research is mainly focused on

- examining system variants in detail already before they are applied in practice, adapting them, and thus preventing misinvestments, as well as on
- detecting profitable potentials in day-to-day business and developing the respective systematic solutions.

In close cooperation with developers and users, we help to exploit these hidden resources by our know-how. The complexity of the tasks ranges from traditional logistic problems to problems representing a scientific and technical challenge.

The applied decision techniques are based on the integration of simulation and optimization. Among others, methods of discrete event simulation (based, e. g., on the tools eM-Plant® and Automod®)and of linear and combinatorial optimization are applied, as well as meta-heuristics.

Several projects have shown that the mere application of more intelligent algorithms for the control of the material flow already resulted in considerable improvements of the production process, without requiring investments in additional hardware or reconstructions.

With respect to the software development, central project management problems refer to the quality assurance, the meeting of deadlines, and the containment of costs. In cooperation with the Fraunhofer IESE and the Fraunhofer FIT, a discrete event simulation model has been developed which represents the essential phases of software development in detail.

Among the most important industrial partners to be mentioned for the year 2002, there are Pierau Planung (Hamburg), psb GmbH Materialfluss + Logistik (Pirmasens), the newspaper Mannheimer Morgen (Mannheim), and the University Hospitals of Saarland (Homburg).

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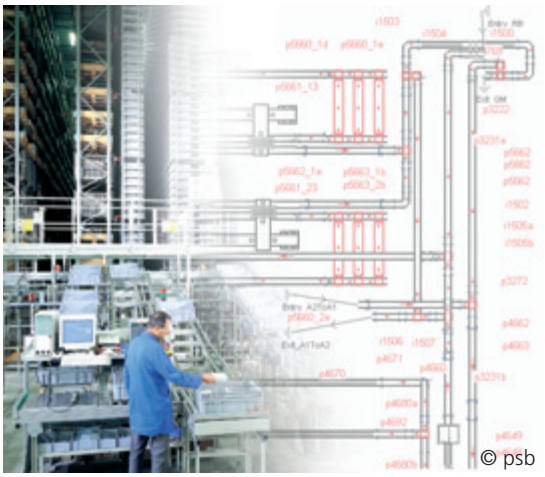
Optimization of the palette order picking system of a mail-order company

During the planning of the palette order picking system of a large mail-order company with several parallel order picking lines, it has turned out that strong temporal variations with respect to the workload of the personnel are to be expected, in combination with a frequent overtaxing of the order picking personnel. The planning of the solution which had been favored before, i. e. the availability of stand-by personnel during these phases has proved to be very difficult. The possibilities of a solution by extension or reconstruction were restricted.

Thus, methods were required which were able to provide uniformly high throughputs by the optimization of order sequencing, as well as the possibility of a reasonable management of the necessary personnel. Numerous technical and organizational restrictions also had to be accounted for.

The realized solution is based on methods stemming from the field of routing which have been adapted to the special requirements of the problem, such as multicriteria targets and real time capability. Priority rule-based load balancing and heuristics with dynamic target weighting resulted in a uniform load distribution, completely eliminating short-term overtaxing.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An extensive simulation and optimization-based examination allows for the finding of effective solutions already before they are applied in practice.

SILVER

SILVER stands for „Simulation-based Systems for the Integration of Decision Processes in Logistics and Process Engineering“. It is a joint research project within the BMBF program for the support of university-independent research in the field of information technology, in the framework of the merger of Fraunhofer-Gesellschaft and GMD (Society for Mathematics and Data Processing).

Usually, the process engineering and logistic subsystems of technical plants are simulated independently (e. g., a multiproduct plant on the one hand and the transport system on the other hand) during the planning phase. Frequently, the respective interactions are insufficiently accounted for, resulting in inefficient operation and misinvestments.

SILVER offers a concept and a framework for the coupling of logistic (discrete event) and process engineering (continuous) simulation tools for the integrated solution of planning and optimization tasks. In cooperation with the Fraunhofer Institutes FIT, IML, and UMSICHT, the Fraunhofer ITWM develops the coupling mechanisms, as well as algorithms and tools for target-oriented experiments with the coupled model and for an optimum system control.

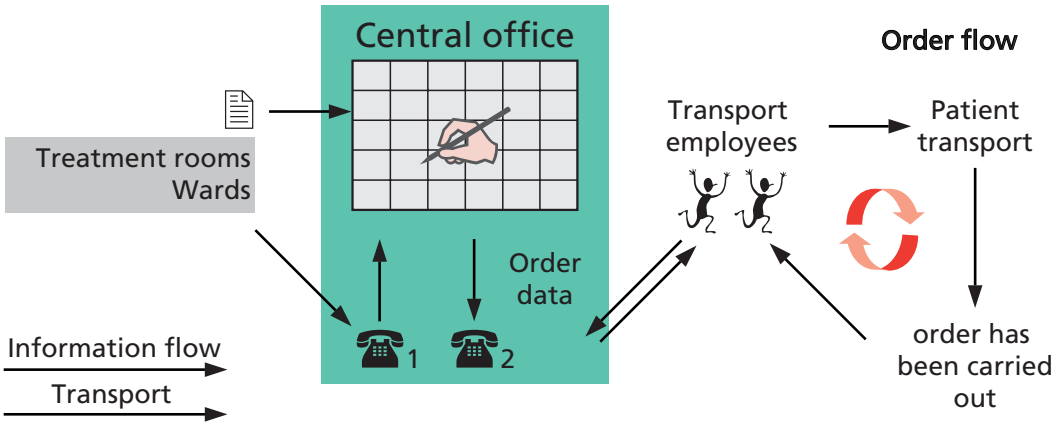
The respective methods are implemented as model-independent online optimization libraries. Thus, they can be integrated into the simulation, as well as directly into the control software of the real system. The methods based on mathematical programming and metaheuristics allow for, e. g., the planning of buffer and reactor assignment, the planning of incoming and outgoing deliveries, and an efficient scheduling.

Optimization of patient transports in hospitals

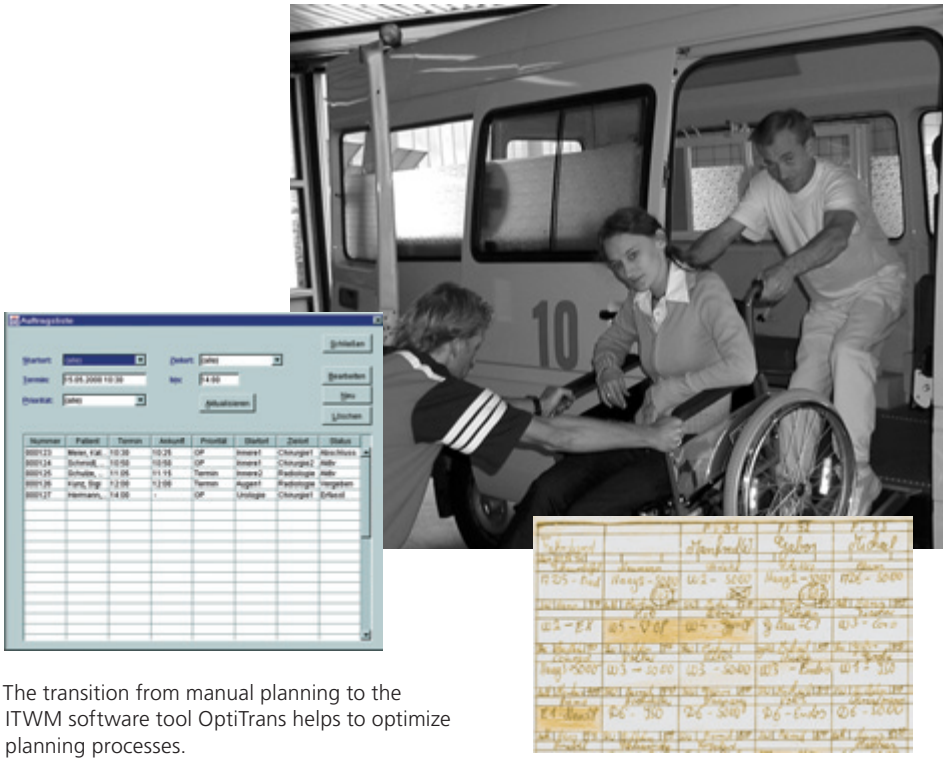
Improved logistics of patient transports in hospitals can help to shorten waiting times, simultaneously distributing the workload for hospital personnel and expensive examination devices more uniformly. Besides, the result is a data basis for the optimization of further processes within the hospital.

In cooperation with the company SIEDA GmbH, the software OptiTrans for commissioning automation is developed, according to modern mathematical methods from the field of online optimization. OptiTrans is provided with interfaces for all the usual hospital information systems, so that all the occurring transport orders during a hospital workday can be directly typed in at the wards.

The presentation of OptiTrans during the fair MEDICA 2002 was greeted by strong resonance on the part of press and experts.



The University Hospital of Homburg, where up to 400 of such transports occur per day, serves as an example here. First, the actual situation has been analyzed on the computer, accounting for the patients' transport data, covered distances, available personnel and means of transport, and even for one-way streets on the hospital grounds. According to this simulation model, different commissioning strategies can now be tested.



The transition from manual planning to the ITWM software tool OptiTrans helps to optimize planning processes.

Global Logistics

In order to be able to react quickly to customer requirements and market changes, enterprises are continually trying to improve their logistic processes. Within the group Global Logistics, these objectives are supported by the development and application of efficient computer-based optimization methods and algorithms. Planning problems occurring in this area include, e. g., the division of an area into sales districts, the strategic design of supply chain networks, and facility location problems.

Exact as well as heuristic methods of combinatorial optimization and computational geometry are the essential instruments for the optimization of complex logistic networks. The implementation of the developed solution methods is focused on a modular structure, which allows for the support of several planning areas and an easy adaptation to similar problems.

Within the joint research project KogiPlan, funded by the BMBF, different tools supporting the various planning phases of a decision process with respect to a facility location problem are integrated into a software system in cooperation with the Fraunhofer Institutes AIS and IGD. For further information about this project, please refer to *www.kogiplan.de*.

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Logistic concepts for mail service companies

A new market is currently developing in Germany in the field of private mail services. Small and medium sized companies depend on an optimal logistic concept in order to be able to compete with the Deutsche Post AG.

With respect to the sorting and delivery of mail, logistic processes are analyzed and methods for the optimization of the sorting concepts are developed. Simulations help to examine internal processes with respect to correctness and efficiency, to plan manual and machine work, and to decide about investments.

Although cooperation between individual mail service companies strengthens the position of the partners on the market, additional problems arise, e. g., the necessity of networking processes in order to integrate the cooperation partners optimally into the company's technical and organizational processes. Mathematical optimization methods are developed for decision support with respect to the planning of locations and investments (e. g., of central sorting centers and depots), as well as to the planning of personnel and routing (tours between partners, pick-up and delivery).

Decision support with respect to the planning of sales districts

The planning of sales districts is a frequent problem of companies which have to determine sales districts and locations for their sales representatives, or delivery districts for newspaper men.

Due to continuously varying market conditions and growing competition, a planner is obliged to check marketing and sales at increasingly shorter intervals and to restructure the respective districts if necessary. The application of computer-based methods for decision support becomes increasingly indispensable because of complex problem structures and high data requirements during the planning.

Objectives during the planning of sales districts are:

- grouping of small geographic units into larger connected and compact sales districts
- determination of the location of a sales center within each generated district in such a way that distances are minimized

The following aspects are accounted for:

- upper and lower limits, as well as balance criteria for the size of the districts to be generated with respect to several managerially relevant criteria, such as purchasing power, area, etc.
- maximum trading area
- different distance measurements, such as airline or road distance, traveling times or costs

Decisions are supported by methods of location planning, as well as by methods of algorithmic geometry. First, the problem of subdividing the area is modeled as a discrete location problem and solved by different heuristic and exact optimization methods. The second approach then is a repeated geographic subdivision of the planning area.

The developed methods have been integrated into the software library L.O.G.I.S. and are currently applied within the geomarketing software BusinessManager®, an ArcView® GIS extension of the project partner geomer.

Sales district planning: optimization components within GIS can reduce the planning complexity considerably.

Traffic planning

Within this group, projects are carried out in cooperation with public and private transport companies. These projects have the objective of supporting strategic decisions of long-term effects, or are focused on the improvement of daily operational procedures. Planning problems are examined by mathematical optimization methods based on models, and optimization potentials are exploited. The main focus is currently lying on public transport.

The planning of lines and stations according to actual requirements is of basic importance for a successful local public transport. Traffic models representing demand and the selection of transport means and paths are the foundation of a thorough and data oriented planning. Within a project in cooperation with Deutsche Bahn AG (German Railway), such a traffic model is developed for local railway traffic. Apart from representing the demand behavior, it also accounts for economic aspects.

A feature of good service in public transport is the quality of connections. The schedule must be optimized intermodally with respect to several means of transport, so that passengers will be able to continue their journey easily at those stations where they have to change lines. "Secure connections in multi-modal traffic", a project funded by the Foundation Rhineland-Palatinate for Innovation, has the objective of developing models for a connection optimization with respect to the entire public transport community. Besides, the models can be applied for the optimization of decisions in daily operation whether to wait for delayed busses/trains or not.

The mathematical methods applied in traffic planning are mainly discrete and combinatorial optimization methods, as well as tools from graph theory and location planning. The projects also include the efficient implementation of the developed algorithms and their application to frequently very large amounts of data.

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Planning of stations in local public transport

Which are the effects of new stations within an already existing public transport network? Will new passengers be acquired? Or will the transport company lose customers because more frequent stops result in a longer duration of the journey? Can a compensation of the costs for new stations be expected by additional revenues? These questions are examined in the project "Planning of stations in local public transport", in cooperation with Deutsche Bahn AG and the partners intranetz GmbH, Berlin, and the University of Konstanz.

Positive effects of new stations are, e. g.:

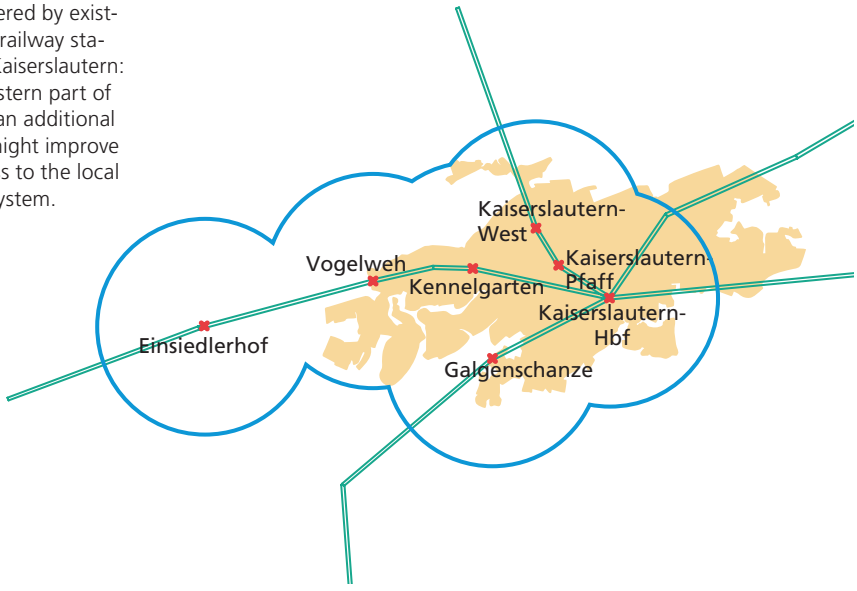
- improved connection of urban areas
- simpler access to local public transport
- shortened access times
- possibility of acquiring new passengers

On the other hand, additional stations increase costs (construction and operational costs, costs due to longer cycles), and customers might not accept more frequent stops and thus be lost to the transport company. The consequence are decreasing revenues.

However, a wholesale computation of the trade-off between positive and negative effects is impossible. Moreover, it is decisive at which points the new stations are located, which is where facility location planning comes in. Under simplifying assumptions the traffic network to be examined can be modeled as a node-edge graph. The search for a set of points within this graph which are optimal for the construction of stations under appropriately quantified weighting functions, is a typical task of mathematical facility location planning.

Within the project presented here, appropriate definitions for the weighting functions have been determined (e. g., for the effects on the revenue situation), and by their implementation and coupling with optimization methods a software tool has been developed which allows for the examination of the respective questions on the basis of real data.

A station of the local railway: the investment costs for the construction of such stops are not very high, but where are promising locations?



Area covered by existing local railway stations in Kaiserslautern: in the eastern part of the city, an additional station might improve the access to the local railway system.

Decision Support in Life Sciences

The difference between decision processes in life sciences and technical problems is essentially due to a central phenomenon: the evaluation criteria are frequently diffused and partly of limited rationality. The decision process is not influenced by general principles, but by subjective experience and opinions instead. A typical example is the decision about medical therapy. Physicians and planners are confronted with an enormous amount of information: general knowledge based on scientific research, objective laboratory or image data, and subjective anamnesis and diagnosis facts in the special case of the patient. Based on this large amount of "good" and "bad" information, decisions must be taken – often even under the pressure of time – whose effects may be existential for the patient and the physician who treats him/her.

Mathematical methods cannot completely solve this dilemma. However, they can be of help with respect to filing and structuring the amounts of data, and by providing models of the decision processes which are as transparent as possible. Here is a main competence of the main subject, where methods of economic operations research, numerical mathematics, and mathematical decision theory are transferred to problems of life sciences. The research is focused on methods of multicriteria decisions, online adaptation of process parameters, and visualization of information from appropriately structured data bases by interactive navigation tools.

Two projects from clinical radiotherapy currently form the center of scientific research within the main subject. Discrete optimization algorithms are currently applied for the support of the detection of replication origins in genome sequences within an in-house research project of the Fraunhofer ITWM, as well as multicriteria modeling of the decision about the adequate therapy in the case of diabetes mellitus.

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Radiotherapy planning by an interactive navigation tool

The project RADIOPLAN, funded by the BMBF, is a joint research project together with the Fraunhofer SCAI in St. Augustin in consultation with the research group of Prof. Bortfeld, Harvard Medical School in Boston. Although it is mainly concentrated on basic research, it ideally supports the practical project "A dynamic real time tool for the improvement of conformation radiotherapy planning", dealt with in cooperation with the German Center for Cancer Research and the University Hospital of Heidelberg.

Radiotherapy planning must find a compromise between a radiation dose which is sufficiently high for the tumor tissue, simultaneously not endangering the surrounding tissue as far as possible. The clinical quality of a therapy plan is judged according to different organ-specific evaluation criteria. Methods of multicriteria decision theory are used in the project in order to compute physical setups of radiotherapy plans, and to file them in a database.

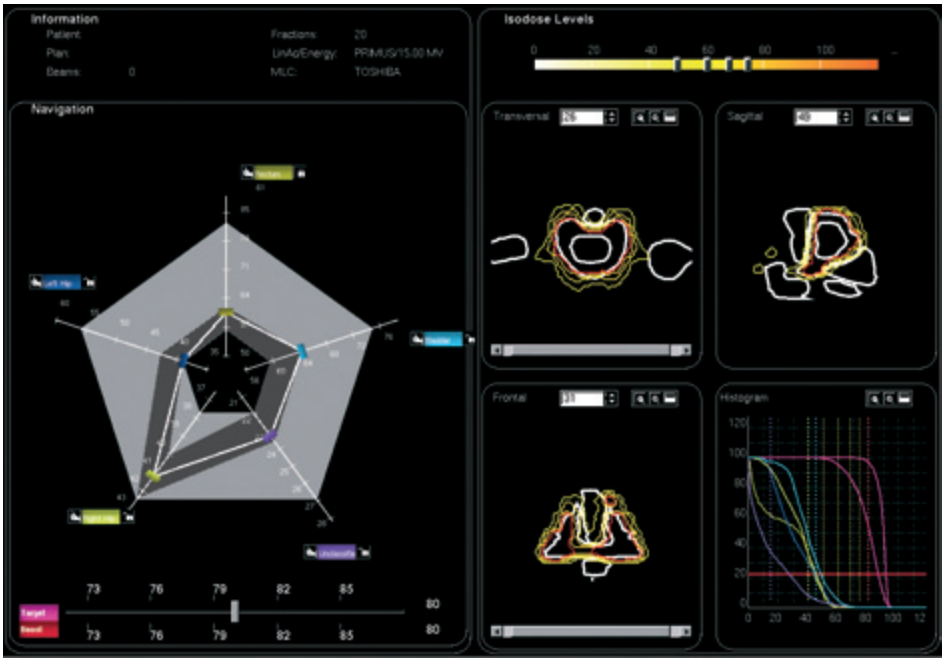
The radiation dose to which each organ relevant for the planning is subject – whether target volume or risk organ –, is represented in the database by a multistage "information pyramid": the broadest information basis is offered by the 3d dose distribution, visualizing the radiation dose absorbed at each volume point. EUD values (equivalent uniform dose) provide information about the dose distribution and serve as an algorithmic foundation for the computation of more efficient solutions, which are filed in the database.

The physician in charge of the treatment can search this database interactively by a navigation mechanism on a graphic user interface, for which the Fraunhofer ITWM has submitted a request for granting a patent during the preparation phase of the project.

In the navigation window, the physician selects dose levels on the roughest scale which he/she considers appropriate for the respective entities. Then, a real time solution is interpolated from the database which comes as close to the requirements as possible. Based on this initial solution, a fine-tuning process yields comparable solutions with the help of the dose volume histogram and the visualizations of the 3d dose distributions with respect to the EUD values. These solutions are locally more convenient.

Mathematically speaking, the problems of the project are multicriteria convex large-scale optimization problems. Their efficient numerical treatment by information aggregation and disaggregation, adaptive adaptation of the model parameters, as well as consequent utilization of weakly parallel computer architectures are essential elements of the research work.

The commercial partner for the merchandizing of the radiotherapy software is the company MRC Systems GmbH in Heidelberg.



User interface of the interactive radiotherapy planning tool developed at the ITWM

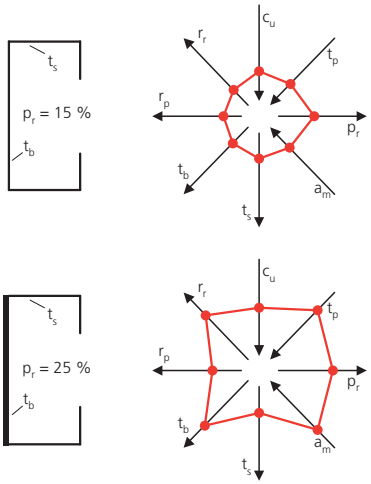
Knowledge Management and E-Commerce

The precondition for taking a decision is knowledge. This knowledge may already be available, generally in a database with qualitative and quantitative criteria variables, each record supplemented by manifold information, such as images, video sequences, or audio sequences. If knowledge is missing, it will be generated, e. g., by methods of identification, optimization, classification, or simulation – depending on the character (black or white box) of the considered multicriteria system. In each case, a mountain of knowledge must eventually be managed. Taking a decision or the correct decision then equals the "search for a needle in a haystack".

This is where the Decision Navigator comes in, a new tool for the multicriteria evolutionary decision support. Several of its attributes are:

- target-oriented, interactive, graphic exploration of knowledge databases
- visualization of the complete decision horizon
- stepwise aggregation of groups of criteria and the respective additional information
- qualitative, quantitative, and especially time-dependent criteria, to be analyzed selectively and parallel
- modifiable metrics and variable priorities on the databases
- transparent decision alternatives which can be represented objectively for efficient discussions
- access to the knowledge databases which can be personalized and changed anytime, and individual navigation paths

Within an industrial cooperation project, the optimal profile (see figure on the right) of a wiring channel has been determined by this tool, according to several criteria. The Decision Navigator can also be applied to projects concerning more than one department, such as Virtual Material Design and Decision Support in Life Sciences.



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Product and process innovation

The strong integration of knowledge management and e-commerce results in cooperation projects within this main subject with the companies Hager Electro, Tehalit, and MiniTec.

Innovation Navigator

A company can update its innovation process supported by the Innovation Navigator: the project manager takes blocks of tasks (tool construction, update of duties record books) or milestones (design freeze), placing them on the navigation board according to required time and scheduled dates. Next to the blocks, he places the responsible protagonists (tool designer, product development engineer), to whom he gives the respective documents to be worked upon (tool concept, checklist). During the process design, an agent in the background supervises each step with respect to its conformity to the rules, acting in support if necessary.

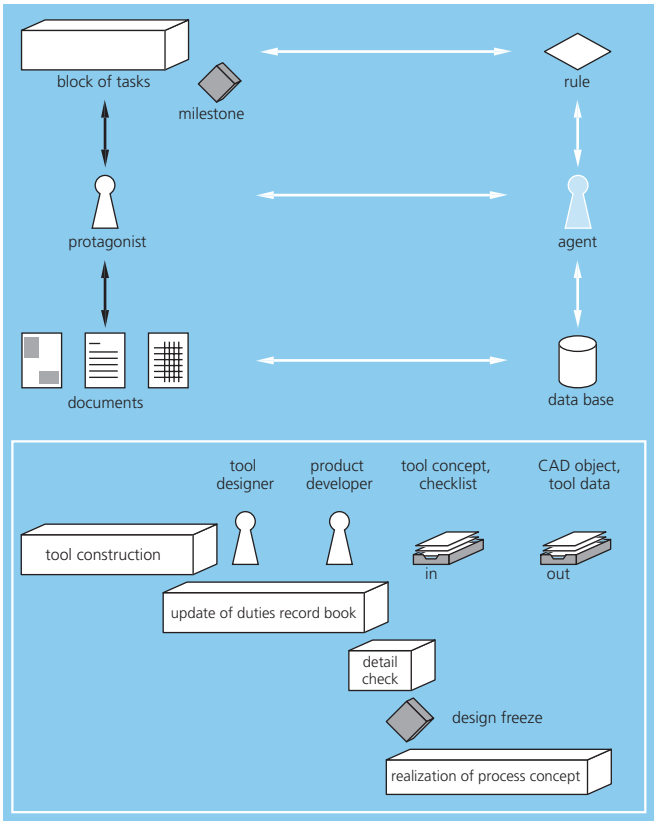
Additional agents are responsible for the following tasks:

- generation of documents with respect to the project and administration of different versions
- examination of processed documents with respect to completeness and correctness
- project control by adapted guidelines and checklists
- retrieval of knowledge from previous projects
- generation of new knowledge by AI methods
- "espionage" in public sources

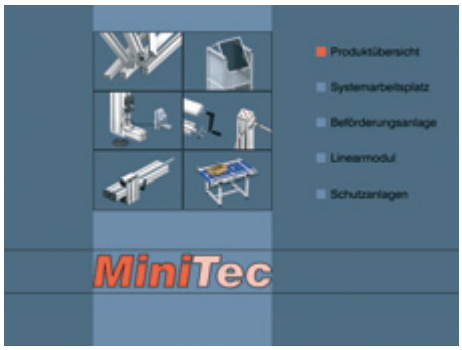
Product Configurator

Virtual consulting via internet: extensive, context-dependent knowledge about the product system is available online, thus continuously offering the user current information. Graphic and partly animated representations of technical dependences and dynamic rules support the interactive configuration of complex products from system components. The company gains decisive advantages

- in the sales division: e-commerce now also available for products requiring explanations
- in production: individual customer-specific pre-assembly
- in logistics: reduction of complexity and capital lock-up



Interactive process design: toolbox and process section



Virtual product consulting on the internet

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Not in the photograph: Dipl.-Math. Julia Kallrath, Dipl.-Math. Ahmed Saher Sultan Azizi


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BADSTRASSE
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ZUSATZ-STEUER
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Financial Mathematics

After the considerable expansion of 2001, the department FINANCIAL MATHEMATICS has again been growing during the past year, so that ten scientists are now working together. Considering the global crisis on financial markets, this may be surprising. However, a closer look at the situation reveals that such a development has virtually been inevitable. Particularly in times of increasing risk and decreasing yield prospects, financial mathematics becomes especially important due to a stronger demand for competence with respect to the realistic modeling of the development of interest rates and equity prices, as well as with respect to an efficient calculation of complex derivative prices. It is this competence that makes the decisive difference.

In the last few years, four main subjects of the research and project work have been developed:

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

The main subjects Option Pricing and Credit Risk are leading with respect to funds and orders received, whereas most of the research results have been achieved in the field of portfolio optimization.

Outlook

In 2002, we were able to increase our competence considerably with respect to industrial as well as research projects. Thus, one objective now is the application of this competence within further projects. New projects have already been acquired for the year 2003 in the main subjects of the department. The main subject Portfolio Optimization appears to be the most appropriate in order to reach clients from SMEs, which is why next year, activities will be increased here.

Scientific highlights of 2003 will be the sojourn of our guests Paul Wilmott (London) and Mogens Steffensen (Copenhagen). They will help to join our competence in the field of financial mathematics with competence in the field of insurance mathematics, in order to enable us to appear as a possible project partner also in the insurance sector.

Credit Risk

When a credit has been allocated, there is always a certain risk that the borrower might not be able to pay the credit back completely. A bank usually allocates a large number of credits, thus being subject to a multiple risk of that kind. Therefore, the possibility to estimate the default risk due to a credit transaction respectively due to the entire number of a bank's allocated credits is an urgent necessity.

Most German banks use so-called internal credit rating models: based on a series of quantitative and qualitative features of the borrower, conclusions are drawn with respect to the probability of a credit not being paid back completely ("default probability"). In order to estimate this probability as exactly as possible on the basis of the borrower's available data, a large number of statistical methods is applied in practice, ranging from simple linear regression methods and nonlinear regression to semi-parametric estimation methods and neural networks.

The rating method is then completed by sorting the credits with respect to different rating classes, based on the estimated default probabilities. In 2002, a large project regarding this subject, i. e. the development of a credit rating according to the proposals of the Basle accord ("Basle II"), has been concluded successfully at the ITWM in cooperation with several German regional banks.

If a private investor or a bank wants to hedge the default of a credit (e. g., a Land bond or corporate loan), this can be achieved by the acquisition of a respective credit derivative. The pricing of such derivatives is a further large subsection of the main subject Credit Risk. Here, individual projects have also been started or continued, respectively, in 2002.

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Pricing of convertible bonds

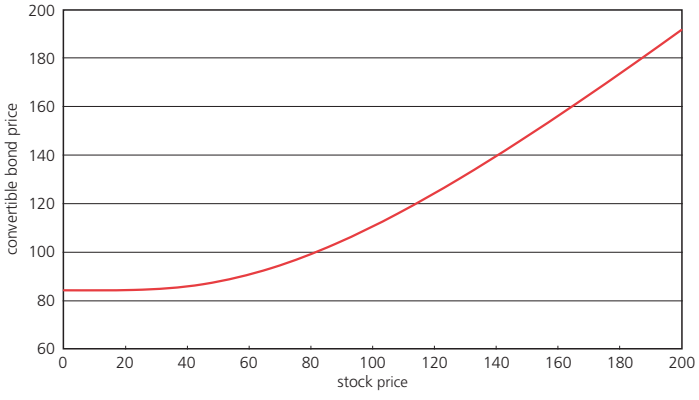
The classical financing possibilities of a joint stock corporation consist in raising loans, resulting in an increase of the enterprise's total liabilities, and the issue of new equities, leading to the increase of equity funds. A mixture of these two possibilities is the issue of convertible bonds.

The buyer receives a corporate bond including the possibility to choose between a repayment of the respective credit sum at the end of the term, and the redemption of the debt by a determined number of equities. Additionally, such a convertible bond can include numerous put and call properties, i. e. times may be agreed upon when the enterprise is allowed to repay the credit prematurely, or when the owner of the convertible bond may demand premature payment of the sum. In both cases, the contract expires, together with further interest rate payments and conversion rights.

On the other hand, this kind of flexibility of the convertible bond represents a real challenge for financial mathematics with respect to modeling and pricing. Three elements must be modeled simultaneously: the enterprise's equity price, the interest rates with respect to the terms of the convertible bonds, as well as the development of the default probability with respect to the enterprise (i. e. the probability that the enterprise may not be able to pay individual interest rates completely). On the one hand, this is very complex with respect to the modeling (especially with respect to the modeling of the default probabilities), and on the other hand, the efficient pricing of a convertible bond is a difficult task because the process on which the price is based can be three-dimensional in the extreme case (and may even be of a higher dimension depending on the model which has been applied for equity prices and interest rates!).

The development of efficient tree algorithms and Monte-Carlo simulation methods has therefore been the subject of two projects of the ITWM in the year 2002, to be continued in 2003.

Development of a convertible bond in the case of rising equities



Option pricing

The main subject Option Pricing is focused on the derivation of pricing formulas and the development of numerical algorithms for the computation of the price of complex 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. The field of option pricing is considered as the most popular field of financial mathematics, which is emphasized by the Nobel Prize for economics, received in 1997 by Robert Merton and Myron Scholes for their respective research. Within 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 efficient numerical methods, as well as realistic models of equity prices where the modeling of the price development is more complex than, e. g., in the simple Black-Scholes model. This is the reason why we have been able to start many industrial cooperation projects during the past year within our main subject Option Pricing, especially within the field of pricing complex derivatives (e. g., Cliquet options) by price models with stochastic volatility (e. g., Heston model), and to solve the respective problems successfully.

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Option pricing by stochastic volatility models

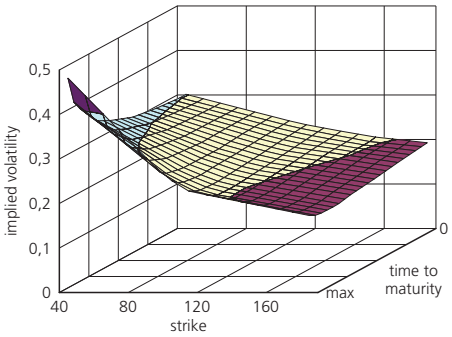
The pricing and risk management of complex derivatives are decisive problems of modern financial mathematics. Especially in the case of structured products, such as Cliquet or forward starting options, whose percentage of traded options is continuously increasing, a more realistic modeling of the basic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

In the framework of several current industrial projects, the stochastic volatility model of Heston has been implemented successfully, as well as its extension by jump diffusion processes for different structured options.

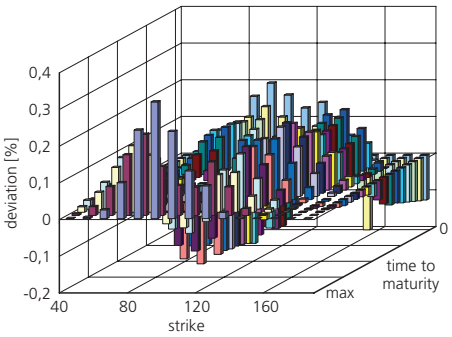
Due to the closed solutions for standard calls, the model provides the possibility of fitting the model parameters in practice to the current market situation (calibration). In contrast to the Black-Scholes model, the Heston model is able to reproduce the volatility smile observed on the stock market. Maximum deviations for ATM call options were less than 0.15 per cent.

Besides, the computation of option prices as well as of option sensitivities (greeks) for different structured options have been implemented and successfully verified by several numerical methods (closed form solutions, Monte Carlo, FDM).

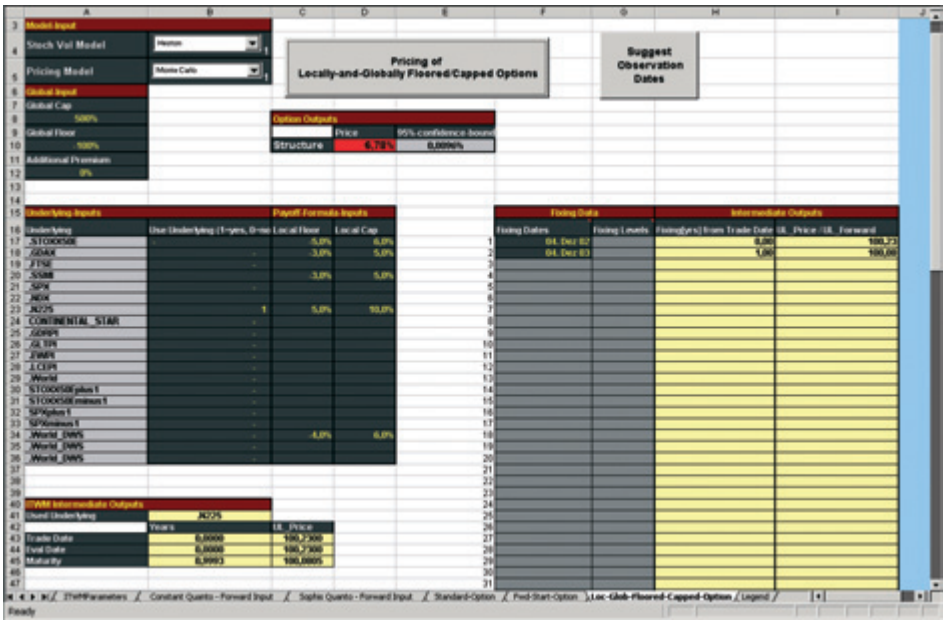
All the routines and the model calibration are available as C++ functions in MS Excel, and can thus be integrated comfortably into the usual Office systems.



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



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



ITWM extensions of standard software allow for the option pricing in state-of-the-art models.

Portfolio Optimization

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 continuous-time 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, continuous-time portfolio optimization has advanced so far that many algorithms are available for practical application and implementation, which has meanwhile also been carried out at the ITWM. The intention for next year is to gain customers from the SME sector (e. g., investment management companies) by the resulting preliminary product, either as users or as partners for the development and merchandizing of a portfolio optimization tool, in order to increase industrial revenues also within this main subject.

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, and the portfolio optimization in the case of given consumption constraints have been examined. A large part of the results which have been achieved are included in the PhD thesis of Holger Kraft, "Optimal Portfolios with Stochastic Interest Rates and Defaultable Assets".

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Interest Rate Models

Although interest rates usually do not fluctuate as strongly as equity prices, they neither show a constant behavior with respect to time. This can especially be said in the case of so-called current interests such as the EURIBOR interest rates (the interest rates at which the banks borrow money from one another) with their different terms. The interest rate market is of enormous importance due to the volume of transactions which are carried out, therefore it is very important to model the development of interest rates as realistically as possible. In contrast to the modeling of equity prices, however, no benchmark model, such as the Black-Scholes model of equity prices, has yet been developed for interest rates.

In theory as well as in practice, there are numerous models for the development of interest rates, all showing their specific advantages and disadvantages. Several models allow for negative interest rates, several are lacking the so-called mean reversion effect (i. e. interest rates always tend to develop towards a long-term value), and other models are unable to explain market prices which can be observed today.

Another special feature of the field of interest rate markets is the unbelievably large number of complex interest rate derivatives, which in parts are hardly understandable with respect to their contract structure and represent a great challenge to financial mathematics also with respect to their pricing. Therefore, the main subject Interest Rate Models is also an ideal domain where the ITWM can be active with respect to basic research as well as with respect to application projects. The main subject is currently being developed, although first projects have already been concluded in 2002.

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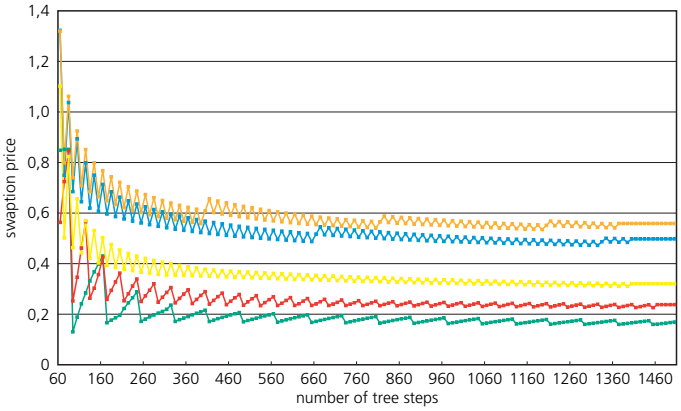
Pricing of swaps and swaptions

Standard products for hedging interest rate risks are swaps respectively options on swaps (swaptions). Two parties to a contract agree by a swap to exchange interest rate payments. In the case of a plain vanilla swap, a previously determined firm interest rate is exchanged by a variable interest rate, the variable interest rate usually being a market interest rate (example: LIBOR).

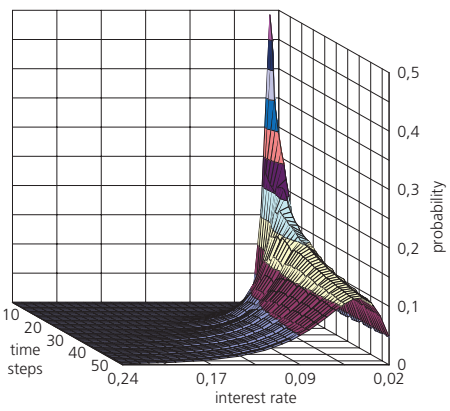
Swaps are agreed on in order to hedge, e. g., interest rate risks of credits: when a bank has allocated a credit, it can hedge the credit by a swap, paying the firm interest rates (corresponding to the credit interest rate payments) and receiving in exchange the current market interest rates. In contrast to a plain vanilla swap, the variable interest rate of exotic swaps does not necessarily correspond to a market interest rate. Instead, it can depend in various ways on one or several market interest rates. In addition to these possible structures, various call rights may be agreed upon for one or both parties. Especially swaps and swaptions including call rights can frequently only be priced by numerical methods.

Besides, various possibilities are available for the stochastic modeling of the interest rate development. Therefore, a model must be selected which allows for an efficient pricing from the numerical point of view, simultaneously yielding economic results that make sense. An example is the low interest rate level in Japan. Obviously, the short-term interest rates on the Japanese market have remained at a level of approximately zero per cent for some time now. Nevertheless, negative interest rates are not to be expected.

Five swaption prices depending on the number of steps of a tree



Development of the interest rate distribution function for the first 50 steps of a trinomial tree



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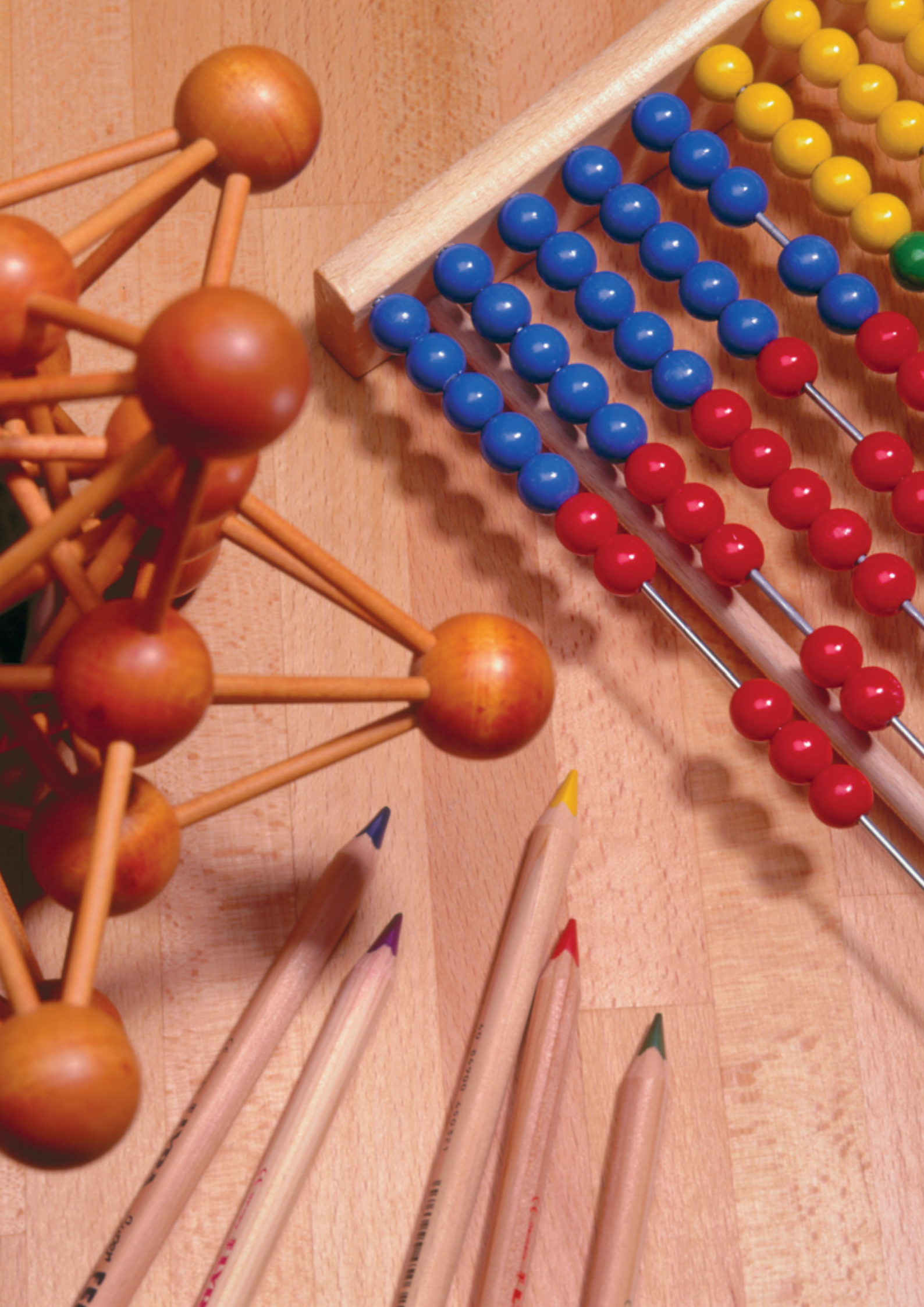
Not in the photograph: M. Sc. Vasile Lasar



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. Today, the commercial use of parallel systems has also become possible due to initiatives of the European Union and the growing importance of simulation in industry. The increasing computing power 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 ITWM were already delivered to our customers in 1995. Today, the ITWM maintains a coupled system of three 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 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. Thus, industry now has a competent partner who can answer all the central questions of cluster computing.

The software packages developed at the ITWM today are principally prepared for parallel computer systems. Besides, existing commercial software packages are parallelized by customer order. The research is mainly focused on

- parallel algorithms
- dynamic load balancing
- object-oriented software structures for parallel software
- performance analysis, benchmarking
- special aspects of cluster and grid computing

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 (FhRG, *www.fhrg.fhg.de*) were presented very successfully during the international fair Supercomputer SC2002 in Baltimore.

Parallel computers are mainly used in the case of simulation methods from the field of molecular dynamics, which meanwhile have advanced so far that an industrial application becomes possible. This subject will be further extended in 2003, apart from a reinforced development of cluster computing. The establishment of the Fraunhofer Re-

Grid Computing

Up to now, the internet has mostly been providing information. In the future, it is also supposed to provide computing power. Therefore, the ITWM and four other institutes are developing the Fraunhofer Resource Grid especially for application in industry. First applications have been presented during the SC2002 in Baltimore, the globally most important fair for supercomputers.

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. The system will select an appropriate free computer or, if necessary, the cheapest one for a job to be carried out.

The FhRG is intended 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.

As a first example, the leading casting simulation software MAGMASOFT has been integrated into a grid environment at the ITWM. On a laptop located in Baltimore, computations were started within the FhRG, the results being visualized on the laptop.

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.

FhRG
Fraunhofer Resource Grid

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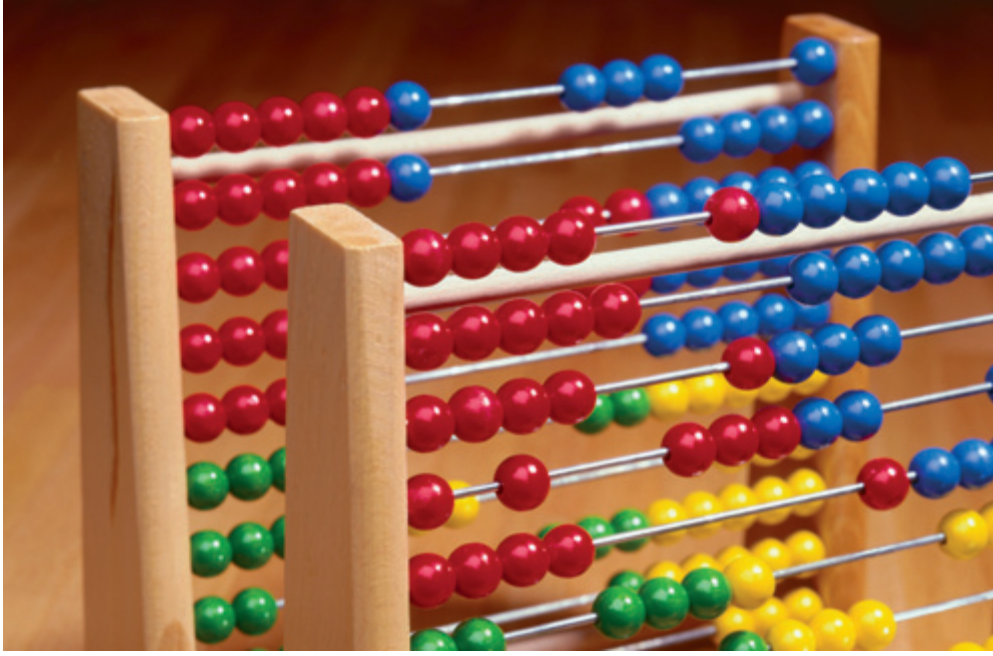

Parallelization and Performance Analysis

Today, the performance analysis is of central importance for the operation of modern high-performance parallel computers. 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 evaluation of the performance of these systems. Simultaneously, the development of optimized software for these computers also is also getting more and more complicated. Here, the communication between nodes, memory accesses, and I/O strategies must especially be accounted for.

In cooperation with our partners within the IPACS project (Integrated Performance Analysis of Computer Systems), which is funded by the BMBF, we have the objective of developing an extensive benchmarking environment which allows for the analysis of all aspects of modern parallel computers. On the basis of the fluid dynamical code ParPac, which has been developed at the ITWM, and a structure mechanical software developed by us, application benchmarks are generated which are typical for the programs applied in industry and science. These benchmarks are completed by adequate problems which are solved by commercial software. Thus, the run-time behavior of commercial codes on parallel computers can also be determined. We will develop methods of performance prediction in connection with low level benchmarks. All the benchmarks used within IPACS are scalable and portable, a feature intended to guarantee their long-term and wide-scale application.

Performance is an evaluation criterion for hardware systems; however, still more important are the selection of the best algorithm, the correct design of data structures, efficient parallelization, and, finally, the details of code optimization, which also includes the computer architecture. Within several projects, existing MPI codes have been made considerably faster. Besides, important non-parallel applications of our customers have also become faster due to

IPACS Benchmark

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Visualization

Many applications from the fields of simulation technology, medicine, fluid dynamics, material science, or seismology produce volume data which no visualization system is able to represent interactively today due to their size. This restriction of the interactive analysis of multi-dimensional data records has induced 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 resolution of this pure software solution with respect to space and time exceeds the performance of other hardware and software systems by far.

The 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.

The PV-4D kernel is based on the vector shift algorithm developed at the ITWM, which allows for the mapping of decisive 3d data structures onto the vector units (SSE-I, SSE-II) of the processors. Several units of the rendering kernel thus partly reach the peak performance of the current Intel/AMD processors. The scaling of the performance on the SMP level is guaranteed by a user level spinlock synchronization. A parallel PV-4D kernel is available for the visualization of extremely large amounts of data. This kernel works on the basis of a mixed hardware topology (shared memory/distributed memory) and is currently optimized for Myrinet networks.

PV-4D (release 1) is available for Windows/Linux, as well as for Linux PC clusters (4-256 SMP nodes). In cooperation with our partner Linux NetworX, complete visualization solutions can be provided as well. We also offer the integration of PV-4D into already existing production environments if required.

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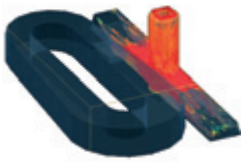
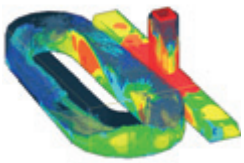
Application of PV-4D with respect to casting simulation and medicine

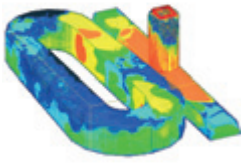
As a first application, the software package ParPac, developed at the ITWM, and the parallel version of MAGMASOFT, the leading casting simulation package, have been supported by PV-4D. Thus, it has now become possible for the first time to really visualize interactively as moving films the large amounts of data resulting from parallel simulation. The representation in the Virtual Reality Lab of the ITWM, 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 space by high-resolution images.

In cooperation with the Medical University Hospital Hanover, a beating heart of a living person has been rendered for the first time as a high-resolution moving object in space in such a way that the user can immerse himself/herself interactively in 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. Therefore, PV-4D will also be further developed with respect to this field. In practice, a double processor computer without special requirements with respect to the graphics card (Dual-P4, FireGL) is sufficient. With the new 64-bit systems of AMD, which will be available in 2003, we will succeed in entering a new performance class.

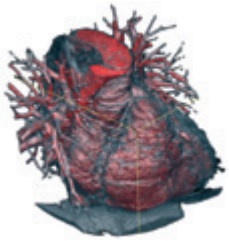
Filling and temperature simulation of a molded part:
data record: 565 × 354 × 196 × 195

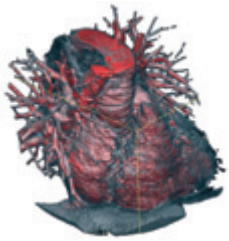


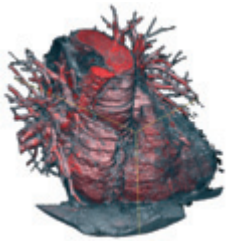




Beating heart:
data record: 512 × 512 × 384 × 10







Linux NetworX Research Lab (LNRL)

The LNRL was founded in October 2002 as a common research lab of the ITWM and the company Linux NetworX. Linux NetworX is one of the leading suppliers of PC cluster solutions in the USA. The PC cluster at the Lawrence Livermore National Laboratory, e. g., which is currently the fastest PC cluster, has been developed by Linux NetworX.

Apart from a careful configuration of the hardware, the management of the system is the key for the productivity of PC clusters. This is where the ITWM and Linux NetworX are working in especially close cooperation. Besides, the activities of the ITWM are focused on the development of new applications for PC clusters and the consulting of industry with respect to the introduction of PC cluster technology and the code conversion of applications in order to be compatible with these systems.

This cooperation is supposed to represent a nucleus of further industrial activities in this field due to the proximity of the European Headquarter of Linux NetworX in the PRE-Park Kaiserslautern. As a first step, additional companies also located in the PRE-Park Kaiserslautern will cooperate within a Distributed Computing Lab, where Linux NetworX will also be participating.

Linux NetworX

From atoms to devices: Multiscale Modeling of Materials

Service offers of the Competence Center

- development and code conversion 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 large data sets
- HPC system consulting
- software design for parallel applications

Technical equipment of the ITWM

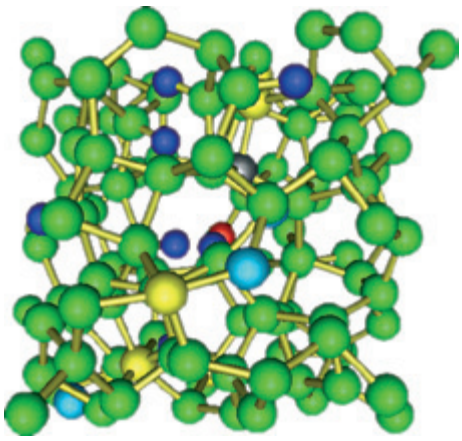
- Top500 PC cluster with 128 P4-CPUs (linpack performance: 400 Gflop)
- high-performance storage and backup systems
- VR laboratory for the visualization of large data sets (> 10 Gvoxel per second)
- PC cluster for the testing of new technical concepts

The properties of many materials result from processes operating on a variety of space and time scales, ranging respectively from nanometers to meters and from femtoseconds to years. Therefore, the mapping of the intrinsic multiscale character of materials science into successful computer models represents a big challenge for scientists and engineers.

However, the production, processing, and application of many materials occur far away from the thermodynamic equilibrium. As a consequence, material properties become "history" dependent and even highly non-linear. Currently, the only method known for studying such highly non-equilibrium processes are atomistic simulations (Molecular Dynamics and Monte Carlo). These simulations give insight into complex material behavior on atomistic time and length scales. However, the scales relevant for many of the properties to be controlled by engineers are much larger than the atomistic ones. For numerical simulations in materials science, the challenge therefore consists in bridging the gaps of space and time scales that separate atomic and macroscopic material properties.

Example Project: Surface Coating

In this project, we want to study the formation of thin films on wafers in a PVD chamber. The PVD process itself operates far away from thermodynamic equilibrium, and experimentally, it is well known that the "process window" is very small for the production of high quality coatings. Moreover, the process window depends on the coatings, wafers, and even the geometry of the PVD chamber used in a fashion not understood theoretically. Therefore, engineers are forced to use time consuming trial-and-error methods in order to adjust the appropriate process parameters. The multiscale simulation methodology currently under development at ITWM is supposed to provide engineers a software tool which correlate the experimentally controllable parameters with the resulting properties of the coated films.



Atomic simulation of amorphous silicon modifications

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Fraunhofer Chalmers Research Centre for Industrial Mathematics FCC

The Fraunhofer Chalmers Research Centre for Industrial Mathematics was founded in September 2001. It is closely cooperating with the Fraunhofer ITWM and the Department of Mathematics of Chalmers University, thus occupying a special position among the Swedish and European industrial research institutes.

According to the business plan of March 2001, the FCC is supposed to increase the turnover of 1.7 million € for the first budgetary period to 2 million € for 2004. The preliminary profits for the first budgetary period are 1.73 million €, distributed in the following way: 46 per cent basic funding, 32 per cent industrial projects, and 22 per cent public funded projects.

In September 2001, the FCC has started with six employees. This number is supposed to increase to 15 till 20 until the end of 2004. At the end of 2002, 14 employees are working at the Swedish institute, including one scientist from the ITWM. Thus, the FCC now has approximately the size of a department of the ITWM.

ITWM and FCC are trying to establish a larger European network of similar institutions. The basic idea of such a network is that projects can be worked on at the location which is the most appropriate one. After the development of the basic structure of the FCC in the years 2001 and 2002, working on common projects of ITWM and Chalmers now is the most important objective.

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

- material fatigue and load analysis
- quality engineering
- finite element technology
- bioinformatics

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Material Fatigue and Load Analysis

Within this main subject, statistical methods are used in order to make statements about the reliability in mechanical constructions with respect to material fatigue. The service life depends on the material strength and the load to which the material is subject. The strength is determined by material tests, whereas the load is measured during operation. The relation between strength, load, and material fatigue is represented by simple physical models. Inexact measurements and models yield final results that are subject to a certain amount of uncertainties. A statistical consideration allows for a combination of all the uncertainties and variations, resulting in a reliability analysis. The damages determined during operation can be used in order to improve the models. Four subdomains can especially be identified:

- Planning and evaluation of fatigue tests

Established statistical methods, such as statistical planning of experiments, regression, confidence and prediction intervals are preferred.

- Studies of the actual load

The theory of stochastic processes and the rain flow count analysis are applied here. Problems of the relations between laboratory experiments and actual load are accounted for.

- Uncertainty of empirical models

A statistical approach towards the problem allows for a comparison of model uncertainties and random variations with respect to load and material, in order to find an optimal complexity of the modeling.

- Accounting for determined damages

The application of the Bayes update method allows for distinguishing between random and systematic sources of uncertainties, and for the improvement of future models.

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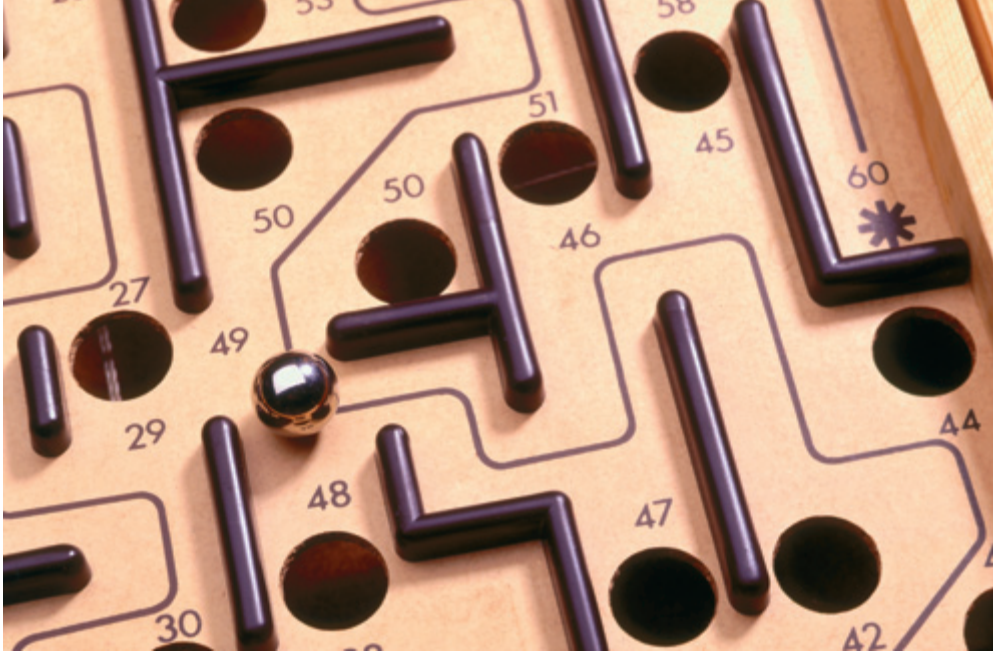

Quality Engineering

The demand on quality engineering has increased considerably within the last few years due to the challenge of producing high-quality products at low costs with short lead-times.

Geometry-related quality problems are frequently detected during assembly, if components to be joined do not fit exactly as expected. The reason often is that a geometrically sensitive product or production concept has not been verified sufficiently due to a lack of powerful analysis tools. A change of design or production at this point is very costly, leading to a belated introduction on the market, and entailing in lost revenues. The cooperation with the Wingquist Laboratory of Chalmers University enables the FCC to solve these geometry-related problems.

- Robust design and variation simulations

Statistical Monte Carlo simulations as well as sensitivity analysis and contribution analysis of the FCC partner RC&D Technology are applied in order to render the product insensitive with respect to manufacturing tolerances of the individual components during assembly. Thus, the demand for expensive prototypes and test series is reduced.

- Inspection preparation

The FCC develops methods and tools for an intelligent inspection preparation. The motive is to receive a maximum on information about the product and the process with a minimum number of inspection points. This area also includes the partner IVF Industrial Research and Development Corporation.

- SPC and root cause analysis

Statistical methods for the root cause analysis on the product are developed in order to detect and correct problems in the manufacturing and assembly process. The motive is a fast identification and correction of problems and an increased knowledge about the product-process correlation.

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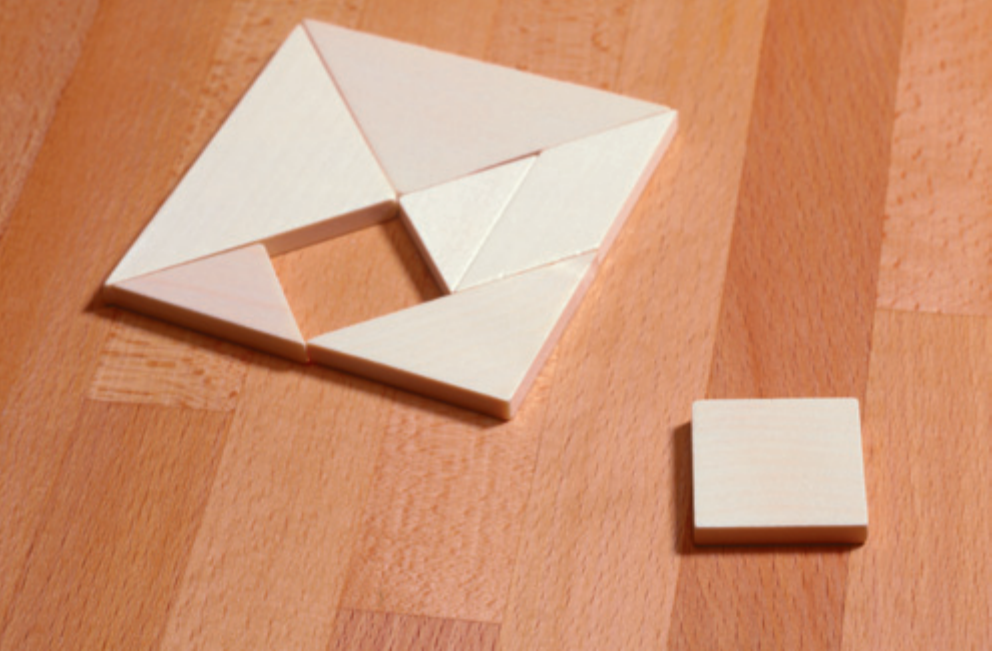

Finite Element Technology

The finite element method is a general method for the numerical solution of differential and integral equations, by which a large number of physical phenomena can be modeled. The FCC closely cooperates with the Chalmers Finite Element Center, a leading group on this field.

Many industrial computations are based on the generation of a grid with desired properties and a desired quality, which is often difficult due to incorrect CAD data, a lack of robust grid generators, or the demand for special grids. Computer simulations allow for a fast product design and optimization by the application of fast solvers and efficient algorithms.

Modern finite element techniques are based on multi-resolution approximations where the local resolution results from an adaptive method. In order to achieve the required exactnesses, newly developed error estimation methods are applied. Current projects include the development of automatic error estimation for industrial problems. An adaptive method generates a series of grids for the solution of discrete systems of equations by the multigrid method. Another technique in order to reach a high quality of exactnesses is the application of higher order polynomials.

Inverse problems typically include the determination of parameters or objects on the basis of measured data. Usually, a forward solution is determined for the problem, deviations are computed, the initial design is adapted, and the process is repeated. The integration of an optimization loop and the adaptive strategy mentioned above allow for the possibility of an efficient optimization on a rougher scale, followed by a local optimization on a finer scale.

A current project in cooperation with Chalmers is the EU project **ViSiCADE**. The objective of the project is the development of an intuitive simulation tool based on virtual reality. The FCC is developing a fast FEM solver in order to be able to carry out real time simulations.

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Bioinformatics

Bioinformatics is a new discipline combining genetics, mathematics, and computer science. It can be very helpful on the path from the DNA sequence to the development of new medicines and treatments. It comprises research, development, and application of computer-based tools, and starts to extend the application of the data by their preparation, analysis, and visualization.

The decoding of the DNA is the foundation of genetics and bioinformatics. However, it is still very difficult to understand cellular biochemistry and disease mechanisms. A first step is the organization, classification, and determination of the immense amount of DNA sequence data.

Although the most reliable method for determining the function of a gene are direct experiments, this is often very difficult. It would be easier if the gene function could be inferred directly from the DNA sequence. Functional genomics is characterized by experimental methods, combined with statistical and computer-based analysis, and involves assessing structural information from the primary sequence structure of the genes.

In order to develop medicines against a disease, a drug target must be identified first. Therefore, we need to know the possible forms a protein can take, and what interactions and metabolic pathways it may be involved in. Proteomics and functional genomics include the identification, characterization, and quantification of proteins and will be the main components of the future development of clinical diagnosis methods and pharmaceutical therapies. At this point, bioinformatics enters the field of biostatistics, on the path from the drug target of a medicine to specimens, clinical experiments, and the ready product.

In September 2002, the main subject bioinformatics was initiated, its focus being directed towards the pharmaceutical industry, where contacts to a certain number of biotech companies already exist. We expect a strong demand from the biotech industry for direct help with the evaluation of analysis data, as well as with respect to software product development.

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Looking Back at the Year 2002

March 4	Move of another ITWM department to the PRE-Park
June 13	Foundation of the Fraunhofer joint project "Numerical Simulation" (office located at the ITWM)
August 17/18	Presentation of the ITWM during the Open Day of the Federal Chancellery
September 4	Official inauguration of the Fraunhofer Chalmers Research Centre for Industrial Mathematics (FCC) in Gothenburg (Sweden)
September 14	Presentation of the Hansjörg Wacker Memorial Prize to Nicole Marheineke (Department of Transport Processes) during the conference ECMI in Latvia
November 4	Kaiserslautern bus line no. 15 extended to the PRE-Park
November 21/22	Organization of the ECMI Glass Days in Wattens (Austria) by the ITWM
December 5	Official inauguration of the Linux NetworX Research Lab

During the last year, the Fraunhofer ITWM again did not have sufficient space on the university campus, which, in the month of March, resulted in a further department moving to the PRE-Park, where a branch of the ITWM had already been established at the end of 1998.

In the new building of the company tecmath on Europaallee, 40 colleagues and several research assistants have found a new home. Thus, the ITWM location in the PRE-Park is scarcely smaller than the location at the university campus. The Fraunhofer ITWM with its currently six departments will remain divided between these two locations until the new Fraunhofer Center will be completed, which is supposed to be at the end of 2005.

In September, the Hansjörg Wacker Memorial Prize was presented to Nicole Marheineke, PhD student at the ITWM, for her diploma thesis. After 1993 and 1998, it is already the third time that this award goes to Kaiserslautern. In addition to the prize money, Nicole Marheineke received an invitation to present her work during this year's ECMI Conference in Jurmala (Latvia). ECMI is the European Consortium for Mathematics in Industry, which was founded in 1986 by mathematicians from Kaiserslautern around Prof. Helmut Neunzert and other colleagues, with the intention of strengthening the cooperation between scientists at universities and scientists in industry.

The extension of bus line no. 15 in November connects more closely the two technology locations of Kaiserslautern, university and PRE-Park. The initiative for the new routing came from the Fraunhofer ITWM, whose different locations are now directly connected.

The new "ITWM bus" accounts for this fact by showing the four basic pillars of the ITWM: I like Innovation, T like Technology, W like Wissen (knowledge), and M like Menschen (human beings).

In September, The Fraunhofer Chalmers Research Centre for Industrial Mathematics (FCC), which had already been founded a year before, was officially inaugurated in Gothenburg by Jürgen Zöllner, Minister for Science of Rhineland-Palatinate, and Leif Pagrotsky, the Swedish Minister of Commerce.

F. l. t. r.: Secretary of State Agnetha Blad (Ministry of Education, Sweden), Prof. Jürgen Zöllner (Minister of Science, Education, Research, and Culture, Rhineland-Palatinate), Leif Pagrotsky (Minister of Commerce, Sweden), Prof. Dieter Prätzel-Wolters (Fraunhofer ITWM), Dr. Uno Nävert (FCC), Prof. Peter Jagers (Chalmers University, Gothenburg)

The Swedish partner institute of the Fraunhofer ITWM is based on the former "Institut för Tillämpad Matematik (ITM)", i. e. the Institute of Applied Mathematics at the Department of Mathematics of Chalmers University in Gothenburg. The head of the former ITM, Uno Nävert, is now also Director of the Fraunhofer ICC.

In August, the Fraunhofer ITWM presented "Mathematics from Kaiserslautern" in the garden of the Federal Chancellery in Berlin. During the Open Day of the Federal ministries, more than 100,000 citizens accepted the "invitation to a state visit", 20,000 people alone came to the Federal Chancellery. The motto of the event, which took place for the fourth time, was "sustainment", a subject where mathematics can contribute quite a few things.

The technology location PRE-Park in Kaiserslautern is now counting one more company: Linux NetworX, a US specialist in the field of PC clusters based on Linux computers, opened up its European branch here. Simultaneously, the Linux NetworX Research Lab at the Fraunhofer ITWM was inaugurated. The cooperation of Linux NetworX and ITWM will also enable European customers to gain access to the latest developments in the field of cluster technology.

The Linux NetworX Research Lab has access to the new cluster system of the ITWM, which comprises 128 P4 PCUs and belongs to the 500 fastest computer systems in the world.

Appendix

Lectures

Andrä, H. (mit Rutka, V. und Wiegmann, A.):
Mikrostruktursimulation zur Berechnung makroskopischer mechanischer Eigenschaften poröser Materialien
Südwestdeutsches Mechanik-Kolloquium, Kaiserslautern, November 2002

Andrä, H.:
An Alternating Iterative BEM Algorithm For The Reconstruction Of Internal Cracks
BMBF Workshop «Boundary Element Methods – Modern Algorithms and Industrial Applications«, Saarbrücken, September / October 2002

Andrä, H.:
Contact Mechanics
University of Kaiserslautern, winter term 2002/03

Andrä, H.:
Einführung in die Boundary-Element-Methode
University of Kaiserslautern, summer term 2002

N. Ettrich:, Nieschulz, K.-P.,
Fließverhalten von Iller- und Ellerbach
Umweltausschuss, Kaiserslautern, September 2002

Feßler, R., Würz, W.:
Flugerprobung eines Funk-Umschlagsensors
DLR Segelflugsymposium, University of Stuttgart, November 2002

Günther, M.:
Parameter estimation in power networks
Kontaktdag Hokskola Industri, Chalmers University Gothenburg, May 2002

Hanne, T.:
A Multiobjective Evolutionary Algorithm for Approximating the Efficient Set
SIGOPT - International Conference on Optimization, Lambrecht, February 2002, und 16th Triennial Conference of the International Federation of Operational Research Societies, Edinburgh, July 2002,

Hensel, H., Mohring, J.:
Coupled simulation of a glass tank heated by a nonlinear electric network
Glass Days, Wattens, Austria, November 2002

Iliev, O. (mit Chernogorova, T., Ewing, R., Lazarov, R.):
On Finite Volume Discretizations of Elliptic Problems with Discontinuous Coefficients
International Conference on Finite Volumes for Complex Applications, Porquerolles, France, June 2002

Iliev, O. (mit Laptev, V.):
On Simulation of Coupled Flow in Plain and Porous Media
TU Darmstadt, November 2002

Iliev, O. (mit Laptev, V., Rief, S., Steiner, K., Stoyanov, D. und Wiegmann, A.):
On The Simulation Of Flow In Porous Media
Kick-off Meeting der MACSI-Net-Arbeitsgruppe »Filtration and Paper Manufacturing«, Gothenburg, Sweden, May 2002

Iliev, O. (mit Tiwari, S.):
A Generalized (Gridfree) Finite Difference Discretization For Elliptic Interface Problems
International Conference on Numerical Methods and Applications, Borovetz, Bulgaria, August 2002

Iliev, O.:
Finite Volume Discretization for Interface Problems
University of Kaiserslautern, July 2002

Kalcsics, J.:
Planning Sales Territories - A Facility Location Approach
ISOLDE IX, Fredericton, Canada, June 2002

Kehrwald, D.:
LBGK Interface Tracking
DFG-Workshop «Lattice Boltzmann Methods«, Kaiserslautern, April 2002

Korn, R.:
Mathematische Modelle für optimales Investment
Mathematisches Kolloquium, University of Linz, May 2002

Korn, R.:
Zinsmodellierung
Workshop bei der LRP Mainz, July 2002

Korn, R.:
Optimal Investment under the treat of a crash
Math-Finance-Kolloquium, Johann Wolfgang Goethe-University, Frankfurt, July 2002

Korn, R.:
Credit Risk Models
HypoVereinsbank Munich, September 2002

Korn, R.:
Anwendung des Marginaloptimalitätsprinzinps in der Finanzmathematik
Finanzmathematik-Kolloquium, Maximilian Ludwigs-University of Munich, October 2002

Kraft, H.:
Optimal Portfolios with Defaultable Securities
Finance Day 2002, Center of Finance and Risk-management, Johannes Gutenberg-University of Mainz, November 2002

Kraft, H.:
Optimal Portfolio with Defaultable Securities – A Firm Value Approach
9. Jahrestagung der Deutschen Gesellschaft für Finanzwirtschaft (DGF), Cologne, October 2002

Kraft, H.:
Optimal portfolios subject to credit risk – a firm value approach
Jahrestagung der GAMM, Augsburg, March 2002

Kraft, H.:
Optimal Portfolios with Stochastic Interest Rates and Default Risk
Laboratory of Actuarial Mathematics, University of Copenhagen, October 2002

Krekel, M., (mit Korn, R.):
Optimal portfolios with fixed income or consumption streams
DGF-Tagung, Cologne, October 2002

Küfer, K.-H. (mit Hamacher, H. W.):
Optimization II
University of Kaiserslautern, winter term 2001/2002

Küfer, K.-H. (Trinkaus, H.):
Radiation Therapy Planning – a Multicriteria Problem
Harvard Medical School (MGH), Boston (USA); University of Iowa, Medical Faculty and Engeneering Department, Iowa City (USA), March 2002

Küfer, K.-H.:
Praktische Mathematik: Methoden der Analysis
University of Kaiserslautern, summer term 2002

Kuhnert, J.:
A meshfree method in continuum mechanics
AnumE- Workshop, Freiburg, February 2002

Kuhnert, J.:
Umweltgerechtes Betanken: Aufgabenstellung und Modellierung
BMBF-Statusseminar, Ludwigshafen, December 2002

Laptev, V.:
On Numerical Simulation Of Flow Through Oil Filters
AMIF 2002, Lissabon, Portugal, April 2002

Latz, A.:
Ausgewählte Kapitel aus der Hydrodynamik
University of Mainz, winter term 2002/03

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A Complete, Frame-Invariant Description of the Phase-Space of the Folgar-Tucker Equation
ECMI 2002, Jurmala, Lettland, September 2002

Melo, T.:
Facility Location Planning in Supply Chain Management
IX International Symposium on Locational Decisions, Fredericton, Canada, June 2002

Melo, T.:
Mathematical Models in Supply Chain Management
University of Kaiserslautern, winter term 2002/03

Melo, T.:
Mathematische Modelle für die strategische Supply Chain-Planung
8. Magdeburger Logistiktagung: Logistikplanung und -management, Magdeburg, November 2002

Mohring, J.:
Simulating bass loudspeakers requires non-linear acoustics
ECMI 2002, Jurmala, Riga, September 2002

Monz, M.:
Radiation Therapy Planning – a Multicriteria Problem
GAMM-Jahrestagung, Augsburg, April 2002

Neunzert, H.:
Die Rolle der Mathematik bei der Gestaltung des 21. Jahrhunderts
Technotag der University of Kaiserslautern, May 2002

Neunzert, H.:
Mathematics of water waves
Madras, India, November 2002

Neunzert, H.:
Mathematics: A really useful science, even a technology
International Conference on Numerical Methods and Applications, Borovetz, Bulgaria, August 2002; Madras and Bombay, India, November 2002

Neunzert, H.:
Mathematische Herausforderungen der Praxis - Erfahrungen aus dem Fraunhofer ITWM
Freie Universität Berlin, May 2002

Neunzert, H.:
MINT-Professionals: Mangelware bei stark steigendem Bedarf
TU Ilmenau, January 2002

Neunzert, H.:
Modellierung in der Schule
Adam-Ries-Vorlesung, Erfurt, August 2002

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Möglichkeiten mathematischer Modellierung in der Schule
Lehrplankonferenz Mathematik, Rheinland-pfälzisches Ministerium für Bildung, Frauen und Jugend, Mainz, November 2002

Neunzert, H.:
Research Cooperation of Industry and Academia: An Interdisciplinary and International Task
Conference »Industry and Research«, Bologna, Italy, May 2002

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What did we »Europeans« learn from Alan Tayler?
Alan Tayler Lecture, St. Catherine's College, Oxford, Great Britain, November 2002

Neunzert, H.:
Why is it a good idea to study mathematics?
Madras, India, November 2002

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Discrete Location Theory
University of Kaiserslautern, Wintersemester 2002/03

Nickel, S.:
New results for discrete Ordered Median Problems
ISOLDE IX, Fredericton, Canada, June 2002

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Simulation und Optimierung zur Planung und Steuerung von Kommissioniersystemen
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Solution techniques for discrete Ordered Median Problems
ECCO 2002, Lugano, Switzerland, May 2002

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Lehrauftrag »Mathematik«
FH Wiesbaden, winter term 2002/03

Nieschulz, K.-P.:
Lehrauftrag »Werkstoff- und Prozesssimulation«
Fachbereich Maschinenbau und Verfahrenstechnik, University of Kaiserslautern, Institut für Verbundwerkstoffe GmbH, Kaiserslautern, summer term 2002

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Option pricing using stochastic volatility models
ECMI Conference, Jurmala, Latvia, September 2002,

Ohser, J.:
Image Analysis and Mathematical Morphology I und II
University of Kaiserslautern, summer term 2002

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The Euler number of discretized sets – an appropriate choice of adjacency in homogeneous lattices
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Mathematics as a key technology
FCC Opening, Gothenburg, September 2002

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Modeling and Simulation of Infiltration and Paper Manufacturing
MACSI-Net Workshop »Filtration Problems in Porous Media and Paper Manufacturing«, Kaiserslautern, October 2002

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A Fast Finite Difference Method for Elliptic PDEs in DoMayns with Non-Grid-Aligned Boundaries with Application to 3D Linear Elasticity
ECMI 2002, Jurmala, Latvia, September 2002

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Strahlentherapieplanung – ein neuartiges Planungswerkzeug
Jahrestagung OR im Gesundheitswesen, Nuremberg, March 2002

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Estimation of the pair correlation function via inverse space
Workshop of Stochastic Geometry, Spatial Statistics and Statistical Physics, Oberwolfach, February 2002

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Covering population areas by railway stops
International Conference on Operations Research, Klagenfurt, September 2002

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Heuristische Ansätze zur Lösung von Standortfragen und deren Implementierung
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International Symposium on Combinatorial Optimization, Paris, April 2002

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Shape optimization of pipe flanges
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ECMI 2002, Jurmala, Latvia, September 2002

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Kolloquiumsvortrag am IWS der Universität Stuttgart, November 2002

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Neunzert, H.:
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Nögel, U.:
Option pricing using stochastic volatility models
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Ohser, J., Nagel, W., Schladitz, K.:
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Orlik, J.:
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Orlik, J.; Zhurov, A., Middleton J.:
Homogenised macrocontact condition between cementless hip implant and bone
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Pick, R. M., Franosh, T., Latz, A., Dreyfus, C.:
Light-Scattering by Longitudinal phonons in Molecular Supercooled Liquids I: Phenomenological Approach
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Rauhut, M.:
Papier ist nicht geduldig – Schnelle Inspektion von Papieroberflächen
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Schmitt, T. G., Schilling, W., Saegrov, S., Nieschulz, K.-P.:
Flood Risk Management for Urban Drainage Systems by Simulation and Optimisation
9th International Conference on Urban Storm Drainage ICUD, Proceedings, September 2002, Portland, USA

Schöbel, A., Schröder, M.:
Covering population areas by railway stops
Erscheint in: »Operations Research Proceedings 2002«, Springer

Siedow, N., Brinkmann, M.:
Inverse temperature reconstruction of hot glass
Proceedings of the 2nd International Colloquium MGFT, Valenciennes, France, 173-177, 2002

Siedow, N., Loch, H., Manservisi, S.:
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In: Krause, D., Loch, H. (Eds.): Mathematical Simulation in Glass Technology, Schott Series on Glass and Glass Ceramics, Springer, 209-237, 2002

Siedow, N., Manservisi, S.:
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in: Anile, A.M., Capasso, V., Greco, A. (Eds.); Progress in Industrial Mathematics at ECMI 2000, Springer, 225-229, 2002

Siedow, N.:
Direct and inverse problems of radiative heat transfer
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Theenhaus, T., Allen, M. P., Letz, M., Latz, A., Schilling, R.:
Dynamical precursor of nematic order in a dense fluid of hard ellipsoids of revolution
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Tiwari, S., Kuhnert, J.:
A meshfree method for incompressible fluid flows with incorporated surface tension
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Tiwari, S., Kuhnert, J.:
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Will appear in: Proceedings HYP 2002, Springer

Tiwari, S. Kuhnert, J.:
Finite Pointset Method based on the projection method for simulations of the incompressible Navier-Stokes equations
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Wichmann, T.:
Transient Ranking Methods for the Simplification of Nonlinear DAE Systems in Analog Circuit Design
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Wichmann, T.; Halfmann, T.:
Transiente Rankingverfahren und nichtlineare Verhaltensmodellgenerierung
GMM Fachbericht 38: Proceedings 6. GMM/ITG-Diskussionssitzung (Analog 2002), Bremen, May 2002

Zemitis, A., Velten, K., Iliev, O.:
Analysis of Transport processes for layered porous materials used in industrial applications
In: W. Jäger, H.-J. Krebs (Eds.): Mathematics – Key Technology for the Future, Springer, 243-251, 2002

Scientific Theses for Grading

This section also contains scientific theses in which ITWM employees were in charge for.

Abdi, T.:
Approximation of electron-photon transport in radiation therapy planing
Master thesis, University of Kaiserslautern, Mathematics Department

Magotsch, S.-H.:
A General Dynamic, Multicommodity, Capacitated Facility Location Model for Strategic Supply Chain Planning
Diploma thesis, University of Kaiserslautern, Mathematics Department

Bach, H.:
Risikoparameter für schwere Herzerkrankungen mittels Auswertung von Langzeit-EKGs durch Methoden der nichtlinearen Zeitreihenanalyse
Diploma thesis, FH Zwickau, Department of Computer Science

Garth, C.:
Boundary control in glass cooling including radiation
Diploma thesis, University of Kaiserslautern, Mathematics Department

Godehardt, M.:
Strategien zur Reduzierung der Übersegmentierung beim Wasserscheidenalgorithmus
Diploma thesis, FH Zwickau, Department of Computer Science

Goesmann, C.:
Optimal workload distribution problems in logistics
Diploma thesis, University of Kaiserslautern, Mathematics Department

Hotman, E.:
Combination of Helmholtz Equation and Statistical Energy Analysis
Master thesis, University of Kaiserslautern, Mathematics Department

Iliev, O.:
Finite Volume Discretizations for Elliptic Problems with Discontinuous Coefficients
Postdoctoral Lecture Qualification, University of Kaiserslautern, Mathematics Department

Justen, L.:
An inverse heat conduction problem with unknown initial conditions
Diploma thesis, University of Kaiserslautern, Mathematics Department

Keck, R.:
The Finite Volume Particle Method: A meshless projection method for incompressible flow
Dissertation, University of Kaiserslautern, Mathematics Department

Kehrwald, D.:
Numerical Analysis of Immiscible Lattice BGK
Dissertation, University of Kaiserslautern, Mathematics Department

Knecht, T.:
Grundlagen, Techniken und Anwendungen der Automatischen Differentation und Vergleich verschiedener Ableitungsverfahren
State Examination thesis, University of Kaiserslautern, Mathematics Department

Koch, K.:
Spektralanalyse zufälliger abgeschlossener Mengen
Diploma thesis, Universität Marburg, Mathematics Department

Lozano, M. L.:
Benders' Decomposition for Generalized Capacitated Location Problems
Master thesis, Marie Curie Stipendium, zusammen mit Universität Sevilla, Spanien

Otto, A.:
Finite Volume methods for convection dominated problems
Master thesis, University of Kaiserslautern, Mathematics Department

Panda, S.:
Dynamics of fluid drops and films on a surface
Master thesis, University of Kaiserslautern, Mathematics Department

Santosa, J.:
Associative Memory and Oscillatory Neural Networks
Master thesis, University of Kaiserslautern, Mathematics Department

Sarishvili, A.:
Neural Network Based Lag Selection, for Multivariate Time Series
Dissertation, University of Kaiserslautern, Mathematics Department

Van der Veen, J.:
Time series analysis on 24-hour-ECGs
Bachelor of Science, Hanzehogeschool Groningen

Wirsen, A.:
Sensitivitätsanalyse und modaldatenbasierte Modelladaption bei elastomechanischen Systemen
Dissertation, University of Kaiserslautern, Mathematics Department

Wolf, M.:
Product Aggregation in Supply Chain Management: An Application of Clustering and Error Analysis Techniques
Diploma thesis, University of Kaiserslautern, Mathematics Department

Zemitis, A.:
A Systematic Study of the Euler Number of Discrete 3D-Sets
Diploma thesis, University of Kaiserslautern, Mathematics Department

Participation on Fairs and Conferences

BAIKA-Kooperationsforum »Textilien im Automobilbau«
Hof, October 2002, Exhibitor

CeBIT 2002
Hannover, April 2002, Exhibitor

Control 2002
Sinsheim, April 2002, Exhibitor

DFG-Workshop »Lattice Boltzmann Methods«
Kaiserslautern, April 2002, Organization

ECMI 2002
Jurmala, Lettland, September 2002, Vorträge

edaForum02
Hannover, December 5/6, Participation

Entwurfsplattformen komplexer angewandter Systeme und Schaltungen (EkompaSS), 1. Workshop
Bonn, April 2002, software presentation Analog Insydes

Geografische Informationssysteme in der Wasserwirtschaft
Hannover, November 2002, Participation

Glass Days 2002
Wattens (A), November 2002, Organization and lectures

Hannover Messe Industrie
Hannover, April 2002, Exhibitor

Heidelberger Bildverarbeitungsforum
Aschaffenburg, July 2002, Participation
Fürth, November 2002, Participation

Industrietag: Schaumkeramik – ein Multitalent
Dresden, March 2002, Participation

INTERGEO, Messe der Geodäsie und Geoinformation
Frankfurt, October 2002, Exhibitor

MACSI-Net-Workshop »Filtration Problems in Porous Media and Paper Manufacturing«,
Kaiserslautern, November 2002, Organization

MAGMASOFT User Meeting
Faals, Netherlands, October 2002, Participation

Medica 2002
Düsseldorf, November 2002, Exhibitor

Seminar »Explicit Algebraic Number Theory«
Oberwolfach, November 2002, Participation

Seminar für technische Bildverarbeitung in verteilten Systemen
Iserlohn, June 2002, Participation

Supercomputing 2002
Baltimore, November 2002, Exhibitor

Workshop Graphitklassifikation
Kaiserslautern, March 2002, Organization

Workshop of Stochastic Geometry, Spatial Statistics and Statistical Physics
Oberwolfach, February 2002, Participation

Workshop on Elliptic Curve Cryptography (ECC)
Essen, September 2002, Participation

3. Internationaler Workshop »Risk Management in Urban Drainage Systems – Simulation and Optimization«
Kaiserslautern, October 2002, Organization (along with the city of Kaiserslautern)

6. Symposium »Textile Filter« des Sächsischen Textilforschungsinstituts
Chemnitz, March 2002, Participation

6. GMM/ITG-Diskussionssitzung Analog ‚02: Entwicklung von Analogschaltungen mit CAE-Methoden
Bremen, May 2002, software presentation Analog Insydes

41. Internationale Chemiefasertagung und –messe Dornbirn
Dornbirn, Austria, September 2002, Exhibitor

46. Östereichische Gießereitagung
Leoben, April 2002, Poster and Participation

Guests

Bordignon, G.:
Decision trees for the classification of tumor cell activity
August 2002 – July 2003

Cleary, P. (CSIRO, Australien):
Partikelmethoden
May 2002

d'Humières, D. (ENS Paris, Directeur de Recherche):
Lattice-Boltzmann-Methoden
September 2001 bis May 2002

Lazarov, R. (Texas A&M University, USA):
Entwicklung von Algorithmen für Strömung in gesättigten porösen Medien sowie die Kopplung der Strömungen innerhalb und außerhalb poröser Medien
June 2002

Luo, L.-S. (ICASE, Hampton, VA, USA):
Lattice-Boltzmann-Methoden;
Vorträge: Construction of LBE model for binary mixture, LBE simulations of non-spherical suspensions in 2D and 3D
April 2002

Sandau, K. (FH Darmstadt):
3D-Bildanalyse
February - July 2002

Starikovicius, V., (Universität Wilna, Litauen):
Entwicklung und Implementierung numerischer Algorithmen für Mehrphasenströmung in porösen Medien
May to October 2002

Vasileva, D. (Universität Sofia, Bulgarien):
Entwickling eines lokal adaptiven nichtlinearen Mehrgitterlösers für nicht-Newtonsche Strömung in saturierten porösen Medien
September 2002 to May 2003

Verter, V. (McGill Universität, Montreal, Kanada):
Strategic Management of Logistics Systems
Oktober 2002

Collaboration in Boards, Editorships

Dr. Thomas Hanne

- Member of the program committee at EMO 2003, Second International Conference on Evolutionary Multi-Criteria Optimization, April 8-11, 2003, Faro, Portugal

PD Dr. Karl-Heinz Küfer

- »Operations Research im Gesundheitswesen« team of the GOR (chair)
- Mathematics of Operations Research (expert)
- Medical Physics (expert)
- ORSpektrum (guest editor)
- Zentralblatt für Mathematik (Reviewer)
- Mathematical Programming (expert)

Dr. Hagen Knaf, Dr. Patrick Lang

- Moderators of the working group »16 Cardiac and Cardiovascular Models«

Prof. Dr. Helmut Neunzert

- MACSI-net, chair of strategy board
- Mathematical Methods in the Applied Sciences (advisory editor)
- Surveys on Mathematics for Industry (editorial board)
- European Journal of Applied Mathematics (editor)
- Monte Carlo Methods and Applications (editorial board)
- Mathematical Models and Methods in the Applied Sciences (editorial board)
- Springer Series on Industrial Mathematics (editor)
- Transport Theory and Statistical Physics (editorial board)

Prof. Dr. Stefan Nickel

- European Journal of Operational Research (expert)
- Mathematical Methods of Operations Research (expert)
- Mathematical Programming (expert)
- Operations Research Letters (expert)
- Multi-Criteria Decision Analysis (expert)
- Transportation Science (expert)
- Location Science (expert)
- OR Spektrum (expert)
- Zentralblatt für Mathematik (expert)
- Mathematical Reviews (expert)
- Operations Research (expert)
- Member of the editorial board of »Computers & Operations Research«
- Member od the VDI committees of experts »Simulation und Optimierung« and »Modellbildung«

PD Dr. Joachim Ohser

- Head of the »Digitale Bildanalyse« team in the DGM committee of experts »Metallographie«

Prof. Dr. Dieter Prätzel-Wolters

- ECMI – Council
- GAMM committee of experts »Dynamik und Regelungstheorie«
- MACSI-net – Executive Committee
- Speaker of the graduate school »Technomathematik« at the University of Kaiserslautern
- International Program Committee MTNS 2002

Dr. Franz-Josef Pfreundt

- Production Grid RG im Global Grid Forum
- Europar 2002 program commitee

Dr. Ronald Rösch

- Fraunhofer-Allianz Vision

Dr. Norbert Siedow

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

Dr. Raimund Wegener

- MACSI-net Newsletter (Editor)

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