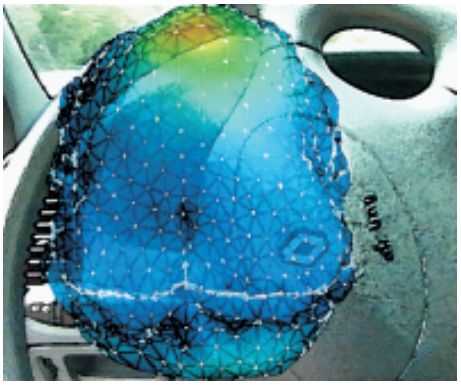
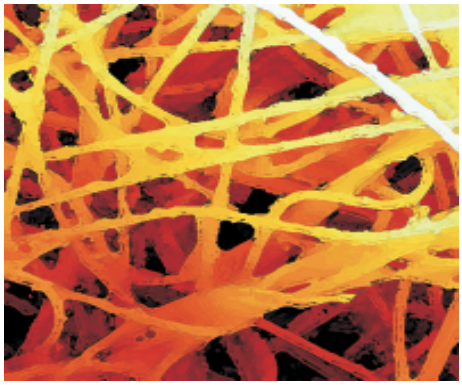
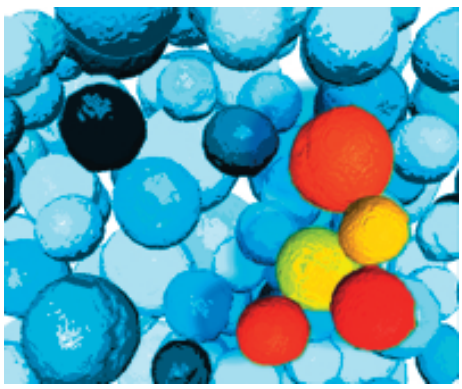
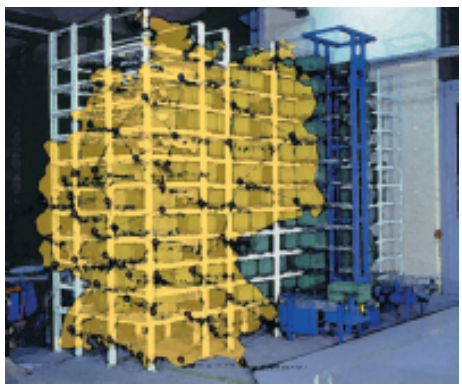
ITWM

Fraunhofer Institut
Techno- und
Wirtschaftsmathematik

Annual Report 2000

Annual Report 2000

Fraunhofer-Institut
für Techno- und
Wirtschaftsmathematik ITWM

Imprint

The editors thank all cooperating partners for placing the corresponding photos at their disposal.

This annual report is also available in german.

Address	Gottlieb-Daimler-Straße, Building 49 D-67663 Kaiserslautern
Telephone	+49 (0) 6 31/2 05-44 41
Fax	+49 (0) 6 31/2 05-41 39
E-Mail	info@itwm.fhg.de
Internet	www.itwm.fhg.de
Editing and layout	Juliette Armbrecht Steffen Grützner Cäcilie Kowald Marion Schulz-Reese
Translation	Dipl.-Übers. Petra Schulz, Berlin
Printing	Rohr Druck GmbH Kaiserslautern

Juliette Armbrecht

Steffen Grützner

Cäcilie Kowald

Marion Schulz-Reese

Contents

Introduction

The year 2000 was the most important year in the still young history of the Institute for Industrial Mathematics. It stands for the conclusion of a dynamical set-up phase, which began on November 9, 1995, with the foundation of the ITWM as a research institute of the Land Rhineland-Palatinate, funded by a non-profit corporation. Meanwhile, five years of intensive research and project work have passed. I think that today, we have the right to claim that we have successfully managed the transition from purely theoretical science to a key technology for economic and technical innovations, and consistently worked according to the Fraunhofer philosophy, i. e. to do practical research with applications in different economic sectors. This was confirmed by the senate of the Fraunhofer Society, who decided that on January 1st, 2001, the ITWM would join the society as its 48th member.

As an institute for applied mathematics, the ITWM is committed to one of the oldest fields of science, which is characterized in a particularly strong way by system immanent tendencies of development, and is also especially attractive as an exciting and phantastic game. At the same time, we stand at the beginning of a new career within the Fraunhofer Society, one of the largest and most successful organizations for applied research in the world. The reason for this divergence is that the importance of mathematics for production, service, information and communication processes in the modern industrial society has increased dramatically. Today, mathematics has become a more indispensable part of science and technology than ever before, with a continuously growing importance for economical, social and life sciences. At the ITWM, mathematics is considered as a key technology on the same level as other technologies, such as nano- or biotechnology. At first sight, this may appear as a bold construction. At least, there is a need for explanation. Of course, for millenniums now scientists have made use of mathematics as a language for the formulation of their theories, and it has been the basis for the calculations of engineers. Thus, it has at least been used as a raw material, the material for models which are then applied for the development of new techniques. However, mathematics has risen to the level of technology due to the computer. In a certain way, the computer is the purest form of mathematics as a technology. Mathematics has materialized in the computer, and is at the same time the spirit of each computer simulation. Simulations require models, algorithms for their evaluation, and the visualization of results. If we take a closer look, we can realize that the basis, i. e. the "source code" of these steps, is always mathematics. Computers have changed our world. With the words of the cultural philosopher Illich, they have become a universal, convivial tool. Today, computer simulations represent the essential tool for the design and optimization of products and working processes. Real models are substituted by virtual models. As the raw material and key technology, mathematics is the foundation for the link between the real and this second world – the virtual world of simulations –, which is already influencing almost all fields of society and economy.

In this context, the main objective of the ITWM is to develop real applications of mathematics by using methods of mathematical modeling and scientific computing, to adapt theorems and algorithms to practical models, and to find practicable solutions instead of theoretically existing optimum solutions. Here, the classical disciplines of applied mathematics, such as numerics, differential equations, stochastics and optimization, represent our basic competence, together with further fields of theory which have turned out to be mostly mathematically oriented domains between mathematics and technology. Since its foundation, the ITWM has carried out more than 200 different projects on the basis of this competence, regarding its central business fields

- virtual material and product design,
- simulation and optimization of technical and logistics processes,
- systems of diagnosis in quality and process control and in medicine.

Cooperation partners are companies from very different branches, ranging from automobile industry, aeronautical industry and classical engineering to electronics and textile producing companies. However, there are also intensive cooperations with service enterprises – such as the German Railway and Lufthansa –, as well as with small and medium-sized enterprises, many located in the region of Kaiserslautern. Here, the consulting competence and the support offered by the ITWM are especially important. The technology transfer of our institute consists in maintaining "in-house" algorithms and software tools for the domain between basic research and applied mathematics, and in the development of new simulation software, partly in cooperation with leading software enterprises.

In 2000, the main subject was the continuous further development of basic competences and the successful handling of projects which had already been started earlier. However, the scientific know-how was also enlarged, e. g., mainly by financial mathematics. Modern financial mathematics is a mathematical research area of large practical importance where at the mo-

ment innumerable research projects are carried out. The mathematics on which the models for stock exchange and risk management are based comprises stochastic processes, differential equations, and integration theory, as well as methods of parametric and non-parametric statistics. The ITWM has a large potential for success in this area and has begun in 2000 to install a research group Financial Mathematics within the department for Adaptive Systems. The objective is the foundation of a special department in this area. On a medium-term range, apart from the cooperation with banks and larger consulting enterprises, the ITWM intends to become the partner for small and medium-sized enterprises from the field of financial services with respect to scientific consulting and software development. The technology transfer to be expected includes the fields of profit and risk control, as well as the application, evaluation and new development of structured derivative financial products.

With respect to the Fraunhofer Society, the year 2000 certainly was characterized by the continuing integration process. Many directors of other institutes met us with great sympathy and benevolence. We received special support from Mr. Encarnação, from the Institute for Graphical Data Processing IGD, Mr. Sommer, from the Institute for Material Mechanics IWM, and Mr. Müller, from the Institute for Silicate Research ISC. However, as the youngest member of the Fraunhofer Society, we were immediately involved in the turbulences due to the merger with the Society for Mathematics and Data Processing GMD. Although we clearly belong to the field of information and communication technology with respect to our methods, our range of offers with respect to software development also shows a strong affinity towards the Fraunhofer institutes in the field of material science and production techniques. The situation is similar with respect to our industrial partners. Apart from large enterprises in the field of information and communication technology, like Infineon or SAP, our cooperation partners are also many small and medium-sized companies, e. g., paper-producing companies, foundries, or fleece producers. Life is full of decisions everywhere, and if one has the freedom to decide, one must make one's choice. The ITWM has decided to join the group of information and communication technology. The decision was made easier by our good relations with several GMD institutes, especially the SCAI and its director, Mr. Trottenberg. However, we will continue our close cooperation with the other institutes of the society, and we will try to maintain our own profile within this conflict area.

The social highlight were the celebrations on November 9, 2000, on the occasion of the integration into the Fraunhofer Society. We were able to welcome many of our business partners, friends and supporters, and to celebrate together the event which was so important for us. A commemorative publication documents very nicely our way into the Fraunhofer Society.

However, the integration into the Fraunhofer Society was also connected with a change of directors of the ITWM. Professor Neunzert has left the management on July 1st, 2000. He has consciously taken this step one year before his retirement. Of course, it would have been a special satisfaction for him to harvest the crops of his preparatory work at least for some months as the director of a Fraunhofer Institute for Mathematics. Nevertheless, he retired in favor of his successor, thus showing his special way of consistently doing what he thinks best for "his" institute. This is a decision which we understand as a special obligation to proceed on the way for which we have decided together. Without his energy, optimism and tireless efforts, there would not be any Fraunhofer Institute for Mathematics today. Prof. Neunzert has persistently pursued his aim to integrate the ITWM into the Fraunhofer Society with expertise, visionary competence and a large talent for negotiations. We would like to thank him and hope that he will support the ITWM in word and deed also in the next few years, particularly with respect to scientific interchange and international cooperation.

We would also like to thank all our friends and business partners who had confidence in us and supported us on our way into the Fraunhofer Society. The Land Rhineland-Palatinate has laid the foundation for the success of the ITWM by the generous funding of our set-up phase and by assuming the financial obligations in the course of the further integration into the Fraunhofer Society. Special thanks also to our Minister for Education, Science and Qualification, Prof. Zöllner and his staff, who supported us in word and deed and provided fast an unbureaucratic solutions for many problems. The Fraunhofer Society has actively helped us in many ways during the integration process. The University of Kaiserslautern, and especially the department for mathematics, have contributed to a tight network of research and lecturing by a wide range of offers for cooperation. The former director of the Fraunhofer Management Society, Dr. Deuster, has cautiously introduced us to the way of thinking of the Fraunhofer Society, and his many precious advice have helped us to avoid unnecessary mistakes. The board of trustees of the ITWM and the evaluation commission had a lasting influence on the development of the ITWM because of their recommend ations. Our special thanks

go to Professor Maaß, who has directed both committees with large commitment and circumspection.

The city of Kaiserslautern has eliminated an essential obstacle for the realization of a new building for our institute by buying a large building site for the Fraunhofer Institutes. We hope that the financial means for the building project will now be swiftly provided by the Land Rhineland-Palatinate and the Fraunhofer Society.

Finally, I would like to declare my respect and express my thanks to our colleagues for their work in favor of the development of our institute. As a mathematical institute without essential laboratory equipment, the ITWM particularly depends on its human capital in the conflict area between research and technology transfer. The ideas and competences of our colleagues are the lifeblood of the institute. Only their efforts and their voluntary obligation to follow our objectives and visions have made possible the real success of the ITWM.

The present report is intended to give a survey of our research and the projects during the year 2000. We continue to look forward to a productive and successful cooperation with our partners and friends in the following years. We are sure that we will also be able in the future to justify the confidence that we enjoy, and to come up to the expectations of the Fraunhofer Society.

Prof. Dr. Dieter Prätzel-Wolters, Director

Profile of Fraunhofer ITWM

Objectives

The creation of images of the real world in the virtual world of models and software, and their application for the solution of problems, is of central importance today and refers to all fields of industry, from space technology to textile industry.

Mathematics is the technology required for the creation of these images and their efficient implementation into software, it is the raw material for the models and the basis of each computer simulation. It is the mission and the task of the ITWM to refine this technology, to provide innovative ideas and to apply them in practice in cooperation with industrial partners.

The intention of the ITWM is not only to forge the link 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 for mathematics of the University of Kaiserslautern is especially important for the ITWM.

Portrait

The Institute for Industrial Mathematics was founded in 1995 by members of the research group Technomathematics of the University of Kaiserlautern. As a research institution of the Land Rhineland-Palatinate, it was managed from the beginning by the Fraunhofer Society, striving for an integration into the society. After a successful evaluation in 1999, the ITWM became a member of the Fraunhofer Society from the beginning of the year 2001 as the first mathematical research institute.

Up to now, three business fields have been established at the ITWM:

- virtual material and product design,
- simulation and optimization of technical and logistics processes,
- systems of diagnosis in quality and process control and in medicine.

80 scientists – mainly mathematicians and physicists – in five departments deal with research and application problems especially focused on medium-sized companies. Here, the ITWM does without the application of its own experimental and measuring equipment in wide areas.

The product range includes software developed on the basis of our know-how, offers of consulting and support, and system solutions. At the ITWM, simulation software is not only used, but also developed, often in cooperation with leading software enterprises.

Our cooperation partners are companies from very different branches, e. g., automobile and aeronautical industry, classical engineering, electronics, and the whole range of textile industry. Other partners are service providers, such as the German Railway and Lufthansa, and research institutes, as well as institutions of the social system.

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

Organizational Chart 2001

Director	Prof. Dr. Dieter Prätzel-Wolters		+49 (0) 6 31/2 05-44 42
Steering Board	Division Director	Prof. Dr. Horst W. Hamacher	+49 (0) 6 31/2 05-44 71
	International matters, Scientific Exchange	Prof. Dr. Helmut Neunzert	+49 (0) 6 31/2 05-27 46
	Division Director	Dr. Franz-Josef Pfreundt	+49 (0) 6 31/2 05-27 44
	Head of Administration	Dr. Marion Schulz-Reese	+49 (0) 6 31/2 05-41 40
	Head of Department	Dr. Raimund Wegener	+49 (0) 6 31/2 05-39 26
Departments	Transport Processes	Dr. Raimund Wegener	+49 (0) 6 31/2 05-39 26
	Flow in Complex Structures	Dr. Konrad Steiner	+49 (0) 6 31/2 05-40 80
	Models and Algorithms in Image Processing	Dr. Ronald Rösch	+49 (0) 6 31/3 66 81-29
	Adaptive Systems and Financial Mathematics	Prof. Dr. Dieter Prätzel-Wolters Dr. Patrick Lang	+49 (0) 6 31/2 05-44 42 +49 (0) 6 31/2 05-28 33
	Optimization	PD Dr. Stefan Nickel	+49 (0) 6 31/2 05-45 58
Central Services	Administration	Dr. Marion Schulz-Reese	+49 (0) 6 31/2 05-41 40
	EDP	Dieter Eubell	+49 (0) 6 31/2 05-44 43
	Public Relations	Dipl.-Math. Steffen Grützner Cäcilie Kowald	+49 (0) 6 31/2 05-32 42 +49 (0) 6 31/2 05-23 37

Competence and main subjects

- Flow dynamics:
  - interaction between flow and flexible structures
  - software extensions for FLUENT®, CFX®
- Particle methods for compressible and incompressible flows:
  - airbag inflation
  - refueling processes
- Radiation transport:
  - cooling of glass
  - radiation transport in biological tissue
- Kinetics:
  - diluted gas flows
  - traffic flow models
- Simulation-based control and optimization:
  - problems from glass and cement industry
  - construction of loudspeakers
- Simulation of porous media:
  - moisture and heat transport
  - filtration and filter design
- Virtual material design:
  - microstructure simulation
  - computation of material properties (flow resistance, acoustic absorption)
- Filling processes:
  - casting simulation
  - injection molding of fiber-rein forced thermoplastics
- Flood and risk management of municipal sewerage systems
- Surface inspection:
  - structured and colored surfaces (e. g., wood, paper, steel)
- 3D image analysis:
  - geometric characterization of 3D structures
  - modeling of microstructures
  - 3D image processing
- Image and video compression by wavelet methods
- Autonomous control systems
- Analogous circuits:
  - symbolic analysis
  - numerical simulation
- Diagnosis and prognosis systems:
  - data mining
  - diagnostics in medicine
- Mechatronic systems:
  - methods of control
  - system identification
- Material models
  - viscoelastic materials with memory
  - homogenization methods for composite materials
- Financial mathematics:
  - portfolio optimization
  - evaluation of options
  - financial time series
- Internal logistics:
  - planning of material flow
  - simulation
  - online optimization
- Inter-company logistics:
  - location planning
  - supply chain management
- Planning of traffic:
  - tariff planning
  - secure connections
- Optimization of resources in the social sector:
  - hospital logistics
  - evacuation planning

Simulation of airbag inflation

In order to protect the passengers of an automobile effectively in the case of an accident, the adequate inflation of existing airbags is of decisive importance. In automobile industry, crash experiments are increasingly accompanied by simulations, therefore these simulations must also account for airbag inflation.

The ESI Group, Paris, offers a tool with a wide range of applications on this market sector, where the airbag inflation now ought to be integrated on the basis of the particle method developed at the ITWM. The special challenge of this project is the handling of the completely changing flow area during the process. Here, the specific advantages of the grid-free particle method (SPH) developed at the ITWM could impressively been proved with respect to the solution of flow dynamical problems with time-dependent geometries.

Virtual material design by microstructure simulation

The virtual material design by microstructure simulation supports the development of new materials and helps to improve already existing materials, such as foams, fleeces, papers, felts and ceramics.

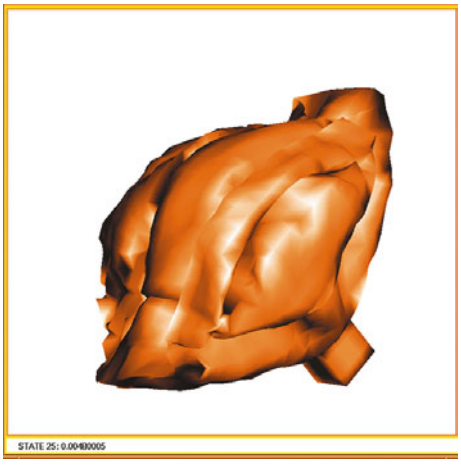
Three-dimensional realizations of material models are generated in the computer. Macroscopic material properties (permeability, capillary pressure, sound absorption) can be computed by special numerical methods, e. g., the Lattice-Boltzmann method, which is particularly appropriate for flows in complex geometries, and by the mathematical tool of homogenization. By variations of the model, the dependence of the material properties on the production parameters can be simulated. Thus, materials can now be designed by the computer.

ABIS: Automatic Body Inspection System

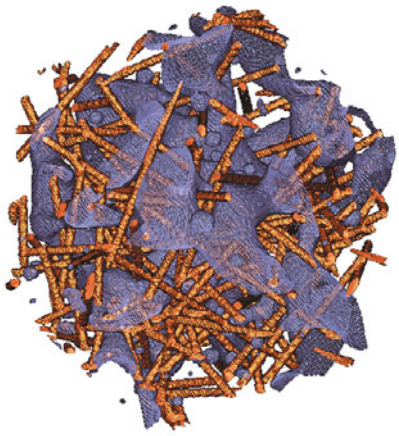
In the project ABIS, a system has been developed which automatically recognizes, classifies and marks almost invisible surface faults of a raw car body.

A transfer of such errors to the painting processes can thus be avoided. For this purpose, an optical measuring system for the visualization of sheet metal faults, e. g., dents or bulges, a software package including the latest software techniques for the realization of surface faults, and the respective system technology for the automatization of the individual functions (measurement, realization, classification, marking etc.) have been developed. The system is adaptive, i. e. it collects the knowledge of experienced controlers, which is then used as a basis for the development of objective evaluation criteria in order to guarantee a constant quality level.

Department "Transport Processes" (cf. p. 24)



Department "Flow in Complex Structures" (cf. p. 40)



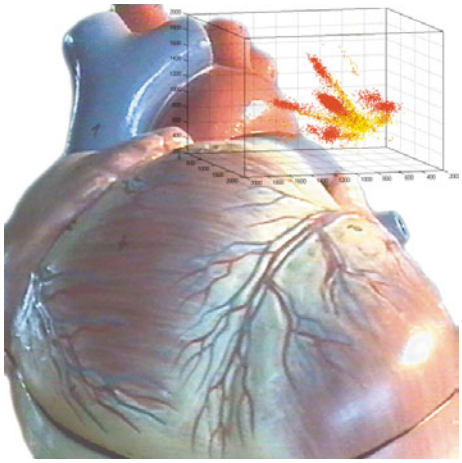
Department "Models and Algorithms in Image Processing" (cf. p. 55)

Risk parameters in the case of arythmic heartbeat

Disturbances of the highly complex control system of the heart lead to arythmic heartbeat, which can be totally harmless, but also deadly, as in the case of sudden cardiac arrest. If risk patients are recognized in time, countermeasures can be taken, e. g., the prescription of medicines with antiarythmic effects or the implementation of a defibrillator.

In the project "Risk parameters in the case of arythmic heartbeat", different nonlinear parameters are developed and examined, which are intended to improve the estimation of a risk by substituting or supporting the already existing parameters. Here, methods of nonlinear time series analysis, cluster methods and neural networks are applied. Generally, the parameter combinations currently used in practice do not yet yield a satisfactory risk estimation, and thus lead to partly unnecessary treatments.

Department "Adaptive Systems and Finance Mathematics" (cf. p. 72)

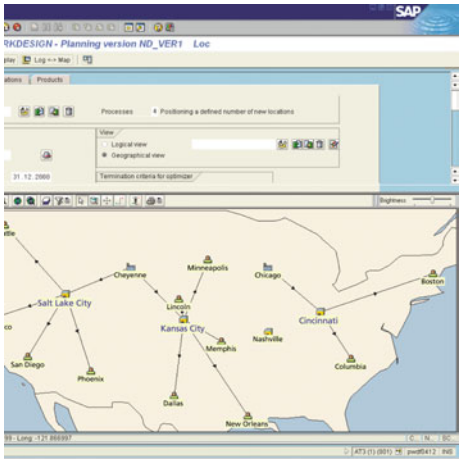


Network Design

In cooperation with SAP Inc., the software tool "Network Design" has been developed which is intended to support decisions with respect to the strategic design of a supply chain. The tool is able to account for preference systems and cost structures with respect to decisions in the fields of supply, production and distribution. Location planning (opening up / closing of warehouses or production facilities) and the determination of an optimum customer assignment are especially supported. The software allows the analysis of an existing supply chain, as well as a redesign.

In Network Design, different models of discrete optimization are available. These are formulated as mixed integer linear problems. Besides, geographically oriented methods are also offered. Network Design is a module of the actual version of the SAP supply chain software APO (Advanced Planner and Optimizer).

Department "Optimization" (cf. p. 86)



Prof. Dr. Helmut Neunzert

Finally, we have reached our objective to become a Fraunhofer institute – this is the last time that I will mention this with a little pride. We have excellent scientists at our institute and a broad expansive market, mainly in Germany. However, science and economics are international, which is the reason why the Fraunhofer Society is also strongly interested in internationalization. A subsidiary in the USA has already been established, and the activities in Europe are systematically extended now.

This corresponds very well to the "visions" of the ITWM. Like informatics and physics, mathematics is a very international science, which holds especially for mathematics at the University of Kaiserslautern. More than fifty per cent of our graduate students come from foreign countries. This is due to the openness of many professors for mathematics in Kaiserslautern, especially of those connected to the ITWM, and to the support by the German Academic Exchange Service (DAAD), the Humboldt Foundation and the German Ministry for Education and Research (BMBF). Therefore, the colleagues and PhD-students of the ITWM already come from all over the world, from Nepal to Bulgaria and Italy, from Indonesia to France and Portugal. The lack of human resources is a strong motive for internationalization; I would also like to mention that we suffer from this lack in the same way as other areas of information technology, and that we also need official promotion for the next generation of scientists.

However, not only the market for our staff is global, the market for our services and products is not restricted to Germany either. Why should the demand for new, especially tailored software anywhere else in Europe be lower than here? There are several countries with a highly developed technology where there is a large demand for mathematical research in industry – although they are not always conscious of it; certainly, Italy and Sweden are among these countries. Therefore, it is not by chance that the managing board of the Fraunhofer Society has selected exactly these two countries for the new European initiative. Of course, the ITWM would like to join this initiative, because it has adequate partners in both countries. In Gothenburg, this is the Chalmers Technical University, where an Institute for Applied Mathematics (ITM) has been established. Already for a long time now, industrial projects in the field of mathematics have been carried out there, even if the dimensions are smaller than at the ITWM. In Florence, there is a group of applied mathematicians at the university who have excellent contacts to industrial enterprises in Tuscany. Both accepted the proposal of a closer cooperation with great enthusiasm.

Thus, the idea of a European Fraunhofer institute for mathematics came to life. Although the concept is scientifically and economically "correct", it can only be realized very slowly and patiently. However, it is worth the effort: together with Gothenburg, a business plan is set up for a Fraunhofer-Chalmers Center, which will hopefully be able to start working in the middle of 2001 as a real "child" of the Fraunhofer Society with approximately ten scientists. With respect to Florence, there is a bilateral cooperation agreement between the ITWM and a local non-profit corporation which is intended to support the first common projects, although they are not very extensive yet.

Please let me add a few ideas with respect to "Fraunhofer in Europe". We have already mentioned the advantages: human resources and an improved access to the market. It is not sufficient to buy expertise anywhere in the world, although this is a popular model especially in Eastern Europe, where there is much knowledge and only very few possibilities for application. "We have phantastic experts for everything – please hand us the problem and keep half of the revenue". If only it were as simple as that! The contact between company and institute, which is extremely important, is lost – and we need the cooperation of the customer, because we offer service instead of complete solutions, at least in most cases. However, "market access through cooperation" is also very difficult. It is not that easy to pass on a beautiful problem, whose solution is also well paid, to a cooperation partner.

No, Europeanization ought to mean more, namely the creation of new "Fraunhofer-like" institutions in Europe. Of course, an adequate local partner is necessary, but the result must (also) belong to us, i. e. it must also be part of the ITWM. In the same way, the ITWM will be part of the new unit. A new and larger institution must be established: a European Fraunhofer institute at different locations, which would have more competence and access to a larger market.

A step in the direction of this vision is our Fraunhofer-Chalmers Center with its connection with the ITWM and the cooperation partner in Florence. As I already said: it is a difficult approximation process requiring much patience.

Let us "only" take a look at the external financing: one half should be provided by Sweden, and the other half by the Fraunhofer Society. The question is inevitable what "we will get back in Germany for German tax payers' money flowing to Sweden". Not everybody is a real European yet! On the other hand, the sceptics are also right to a certain extent: doubtlessly, the money flows mainly in one direction, and in the best case, paid work is coming back. This is not really European either. I would prefer the following solution: half of the external financing should always come from European funds, and the other half from the country where the institute is located. At long last, this should also be the case for the German institutes - or better: for the German locations of European institutes.

I know that I am demanding very much, although in principle, the concept is logical. Since it is a step in a really European direction, it should be prepared by several small steps. Such a small step would be the foundation of the European Fraunhofer institute for mathematics, i. e. a European ITWM, which would still be relatively small (and therefore inexpensive). If they are efficient and successful, maybe such small steps are able to convince the European Union to begin with a Fraunhofer-friendly support policy. This would be very positive for the EU and for Europe. Then, the investments of the Fraunhofer Society in a European ITWM would in any case be worthwhile. Only a dream? When I was talking about a Fraunhofer Institute for Mathematics many years ago, people also took me for a dreamer.

Back from the visions to present time. The market in Sweden is excellent, and our partners, Chalmers and ITM, have many contacts mainly to big enterprises such as Volvo and Saab, Ericsson, ABB etc. Since this small "Institute for Applied Mathematics" ITM will be part of the Fraunhofer-Chalmers Center, starting projects are already certain. The excellent small and medium-sized companies in Sweden represent a large market, which is still unexplored. The ITWM is familiar with this situation and will contribute with its experience. A small and modest start with a subsequent doubling of the personnel after three years, strictly according to the Fraunhofer rules, is the recipe which has already worked for the ITWM. Why should it be different in Gothenburg? At the same time, the third pillar of the European Fraunhofer institute for mathematics carefully develops in Florence, initially with two or three common projects with industrial partners from Tuscany. An institute like that is securely based on three pillars, and it is more convincing for the European Union.

According to my opinion (which is the result of several painful, unsuccessful attempts), a cooperation with countries like India, Indonesia, China etc. makes more sense for the universities. There are not many projects to acquire in these countries, but there are many promising young scientists. Fraunhofer institutes can support post-graduate studies, which are mostly still necessary, by grants. In contrast to the market for projects, the educational market is not concentrated on the European Union; instead, it is focused on Eastern Europe and the Third World. However, the Marie Curie Centers show that excellent scientific personnel can also be found in the EU - the ITWM is such a center.

A European institute with excellent scientists from all over the world, who can all refine their qualification in Germany according to the Fraunhofer philosophy: this is our big and promising objective at the ITWM.

Promotion of young scientists

The promotion of young scientists is very important for the ITWM. Since 2000 ITWM is a training site of the EU program "Marie Curie", thus offering the possibilty for PhD-students from EU countries to stay at the ITWM during a large part of their PhD-studies. Here, they learn how mathematical modeling can be used for the solution of practical problems.

With respect to the promotion of young scientists, there is an intensive cooperation between the ITWM and the department for mathematics of the University of Kaiserslautern. The graduate college Technomathematics (GTM) for PhD-students of business and technomathematics, is funded by the German Research Society DFG and the Land Rhineland-Palatinate. 20 PhD-students are directly supported by the individual departments, most of them receiving grants and being directly associated to the GTM. In general, the PhD-students are financed by grants, so that approximately 3 years are the rule in order to finish a PhD-thesis. Besides, many master's theses are written. The university research groups of the professors connected to the ITWM are responsible for approximately 90% of all the master's students of the department. In addition, many colleagues at the ITWM are lecturers at the department for mathematics.

For all the activities regarding young scientists, internationality is very important. Many students finish their studies within the program "Mathematics International", where at least one semester at a foreign university is obligatory. Lectures for graduate students are almost exclusively held in English.

Clients and Cooperation Partners

The ITWM already for years successfully cooperates with enterprises of all different sizes and various industrial sectors. In the following some partners of 2000, who agreed in being mentioned, are listed.

- alphaCardio GmbH, Grünstadt
- Analog Microelectronics GmbH, Mainz
- Atecs Mannesmann Dematic, Offenbach
- Automazioni Tessili Frigerio, Lurate Caccivio (I)
- Atmel Germany GmbH, Heilbronn
- Audi AG, Ingolstadt
- BGS Systemplanung, Mainz
- Boehringer Ingelheim Pharma KG, Ingelheim am Rhein
- Caparol Farbe Lacke Bautenschutz GmbH & Co Vertriebs KG, Ober-Ramstadt
- DePfa Bank, Wiesbaden
- Deutsche Bahn AG, Regionalbereich Frankfurt/Main
- Deutsche Gesellschaft für Onkologie e. V., Cologne
- Deutscher Wetterdienst, Offenbach/Main
- Deutsches Krebsforschungszentrum, Heidelberg
- ESI-Group, Paris (F)
- Filterwerk Mann + Hummel GmbH, Speyer
- Findeisen GmbH, Ettlingen
- Freudenberg Vliesstoffe KG, Weinheim und Kaiserslautern
- gbo AG, Rimbach
- GE-Harris, Bad Dürkheim
- Glatz Feinpapiere, Neustadt/Wstr.
- HegerGuss GmbH, Enkenbach-Alsenborn
- HILTI AG, Schaan (Liechtenstein)
- ICON Industrie Consulting GmbH, Karlsruhe
- Imtronic, Berlin
- Infineon Technologies AG, Munich
- J. Wagner GmbH, Markdorf
- KS Beschallungstechnik GmbH, Hettenleidelheim
- Landesbank Baden-Württemberg
- m2k Informationsmanagement GmbH, Kaiserslautern
- MAGMA Gießereitechnologie GmbH, Aachen
- Mannesmann-Rexrodt AG, Lohr a. Main
- MVT Maschinen- und Verfahrenstechnik Bernhard Blatton GmbH, Dillingen
- Nahverkehrsservice Sachsen-Anhalt mbH (NASA), Magdeburg
- NEUMAG GmbH & Co., Neumünster
- PHB Stahlguss International, St. Ingbert-Rohrbach
- Pierau Planung, Hamburg
- psb GmbH, Pirmasens
- Regionalbus Saar-Westpfalz GmbH (RSW), Saarbrücken
- SAP AG, Walldorf
- Schott Glas, Mainz
- SIEDA Software GmbH, Kaiserslautern
- Siemens AG (KWU), Mülheim/Ruhr
- Steinbichler Optotechnik GmbH, Neubeuern
- tecmath AG, Kaiserslautern
- Thomas Josef Heimbach GmbH & Co., Düren
- University of Kaiserslautern
- Verein Deutscher Gießereifachleute (VDG), Düsseldorf
- Verkehrsverbund Rhein-Neckar GmbH (VRN), Mannheim
- Verkehrsverbundgesellschaft Saar mbH (VGS), Saarbrücken
- Westpfalz Verkehrsverbund GmbH (WVV), Kaiserslautern

Board of Trustees

The board of trustees consists of representatives from science, economy and politics. It advises the ITWM in scientific and organizational matters. The board of trustees of the society previously maintaining the ITWM had the following members:

Prof. Dr. Dieter Maaß
(Director)

Dr. Gunter Frank
Dresdner Bank AG, Frankfurt

Prof. Dr. Albert Gilg
Siemens AG, Munich

MR Wolfgang Habelitz
Ministry for Education, Science and Higher Education, Mainz

Dr. Wilhelm Krüger
tecmath AG, Kaiserslautern

Dr. Martin Kühn
SAP AG, Walldorf

Dr. Horst Loch
Schott Glaswerke, Mainz

Dr. Ulrich Müller
Ministry for Economics, Traffic, Agriculture and Wine Growing, Mainz

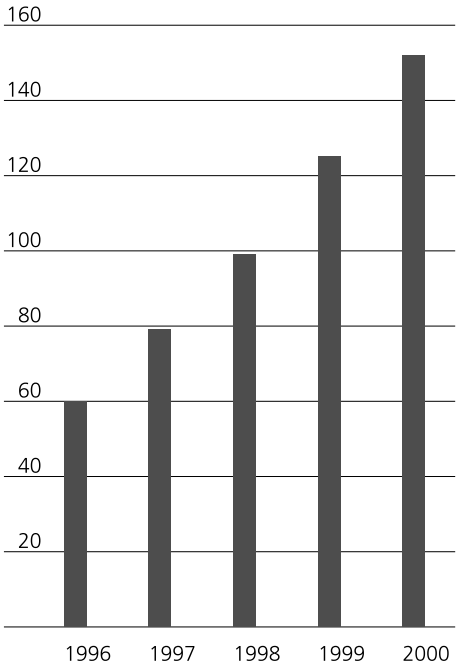
Dr. Werner Sack
Hilti AG, Schaan, Liechtenstein

Prof. Dr. Günter Warnecke
President, University of Kaiserslautern

Development of personnel

Since its foundation, the number of colleagues has continually increased at the ITWM. In the year 2000, the personnel of the ITWM comprised 81 colleagues (54 scientists, 19 PhD-students and 8 colleagues in central departments), as well as 60 graduate and undergraduate assistants and trainees.

Overall development of personnel



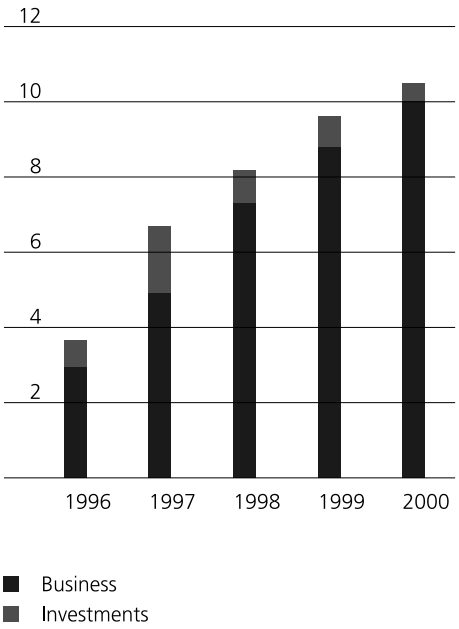
	1996	1997	1998	1999	2000
Scientists	26	32	43	45	54
Ph. D. students	5	6	13	17	19
Central Services	3	5	6	7	8
Part time employees	22	26	29	48	60
Other employees	4	10	8	8	11

Budget

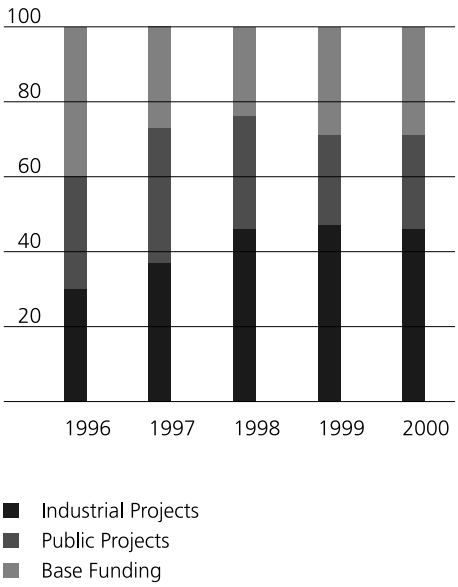
The development of the institute's operating budget is represented in the graphic scheme on this page. Since the final close of accounts for the year 2000 takes place after the deadline for this report, the numbers for 2000 are only preliminary. However, experience shows that they do not essentially differ from the final numbers.

For the year 2000, the operating budget will probably reach 10 million DM. Approximately 7 million DM stem from the institute's own profits. Compared to the previous year, the operating budget has increased by 10 per cent.

Development of Budget
Mio DM



Distribution of Yield
in %



Central Services

Administration

Dr. Marion Schulz-Reese

Dipl.-Betriebswirt (VWA) Brigitte Williard

Manuela Hoffmann

Katharina Parusel

Martina Deghmouche

EDP

Dieter Eubell

Dipl.-Phys. Christian Peter

Public Relations

Dipl.-Math. Steffen Grützner

Cäcilie Kowald

Mathematik-Allianz

Dipl.-Biol. Claudia Meißner

The Fraunhofer-Gesellschaft at a Glance

The Fraunhofer-Gesellschaft is the leading organization for institutes of applied research in Germany, undertaking contract research on behalf of industry, the service sector and the government. Commissioned by customers in industry, it provides rapid, economical and immediately applicable solutions to technical and organizational problems.

Within the framework of the European Union's technology programs, the Fraunhofer-Gesellschaft is actively involved in industrial consortiums which seek technical solutions to improve the competitiveness of European industry. The Fraunhofer-Gesellschaft also assumes a major role in strategic research: Commissioned and funded by Federal and *Länder* ministries and governments, the organization undertakes future-oriented research projects which contribute to the development of innovations in key technologies and spheres of major public concern, such as energy, transport and the environment.

The global alignment of industry and research has made international collaboration imperative. Furthermore, affiliate Fraunhofer institutes in Europe, in the USA and Asia ensure contact to the most important current and future economic markets.

At present, the organization maintains 48 research establishments at locations throughout Germany. A staff of some 9 600, the majority of whom are qualified scientists and engineers, generate the annual research volume of around € 760 million. Of this amount, € 650 million is derived from contract research. Research contracts on behalf of industry and publicly financed research projects generate approximately two thirds of the Fraunhofer's contract revenue.

Fraunhofer scientists specialize in complex research tasks involving a broad spectrum of research fields. When required, several institutes pool their interdisciplinary expertise to develop system solutions.

The Fraunhofer-Gesellschaft was founded in 1949 and is a recognized non-profit organization. Its members include well-known companies and private patrons who contribute to the promotion of its application-oriented policy.

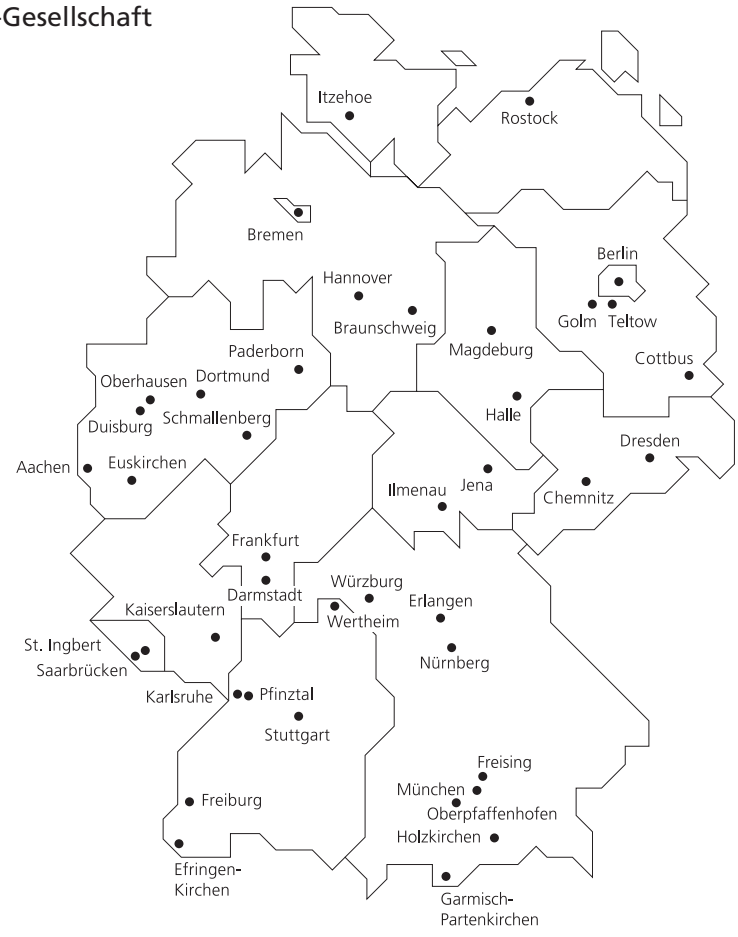
The organization takes its name from Joseph von Fraunhofer (1787-1826), the successful Munich researcher, inventor and entrepreneur.

Address

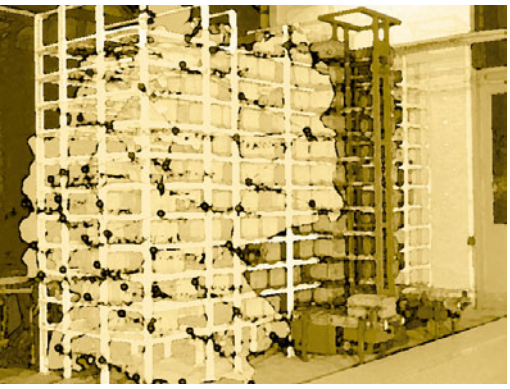
Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V.
Leonrodstraße 54
D-80636 Munich

Telephone: +49 (0) 89/12 05-01
Fax: +49 (0) 89/12 05-3 17
Internet: www.fhg.de

The Fraunhofer-Gesellschaft in Germany



Department of Optimization



The objective of the department is the research and development of mathematical optimization models and methods for the industry, service and public sector. Here, the development of the respective software according to the customer's needs is of main importance.

The main subjects of the department are:

- in-house logistics,
- inter-company logistics,
- traffic planning,
- optimization of resources in the public sector.

In the fields of logistics, an extraordinary growth could be registered. In the field of traffic planning, a very promising research project could be started.

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

In-house logistics

In many companies, there is a considerable potential for improvements by a better organization of working processes. However, this potential often cannot be exploited by a selective improvement of single working steps. Instead, an analysis and optimization of the entire working processes are necessary. By simulation, such potentials can be registered, so that the customer becomes aware of possible problems. Then, using methods from business mathematics, the registered problem areas can be analyzed in cooperation, and the results can be verified by simulation, if necessary. Here, an important tool is online optimization.

Inter-company logistics

Due to the globalization of markets and the growing together of Europe, an efficient design (e. g., facility location planning) and management (e. g., production planning) of a supply chain becomes increasingly essential for economic success. The objective is the modeling of the respective decision processes by methods of location theory and combinatorial optimization, and the offering of possible solutions. Moreover, the introduction of modern e-business concepts is also supported.

Prof. Dr. Horst W. Hamacher

PD Dr. Stefan Nickel

Dipl.-Math. Patricia Domínguez-Marín

Dr. Michael Eley

Dr. Thomas Hanne

Dipl.-Math. Jörg Kalcsics

Optimization

Traffic planning

The continuous growth of individual traffic requires that public transport ought to become increasingly attractive without increasing costs, resulting in a better coordination of the different means of transport. Here, methods of graph theory, location planning and combinatorial optimization are applied. Special subjects of our research include delay management in traffic systems and tariff organization for the local public transport, the design of efficient intermodal traffic systems for passenger and freight transport, as well as combined regular and user-oriented traffic systems.

Optimization of resources in the public sector

One of the main problems in the public sector are the limited resources available. Therefore, it is the objective of this research area to maintain or even improve the level of performance under the given conditions by mathematical modeling. Here, it is essential to focus on the human "resources".

Examples include decision and planning systems for hospitals (especially with respect to the transport of patients, elevator control and layout). Another project is the cooperation with the German Center for Cancer Research (DKFZ) in Heidelberg that involves optimization methods for the radiotherapy of cancer patients.

In addition, further topics are the evacuation of buildings, sports stadiums and entire regions.

Contact:

Prof. Dr. Horst W. Hamacher
Division Director
Phone: +49 (0) 6 31/2 05-44 71
E-mail: hamacher@itwm.fhg.de

PD Dr. Stefan Nickel
Head of Department
Phone: +49 (0) 6 31/2 05-45 58
E-mail: nickel@itwm.fhg.de

PD Dr.
Karl-Heinz Küfer

Dr.-Ing.
Alexander Lavrov

Dr. Teresa Melo

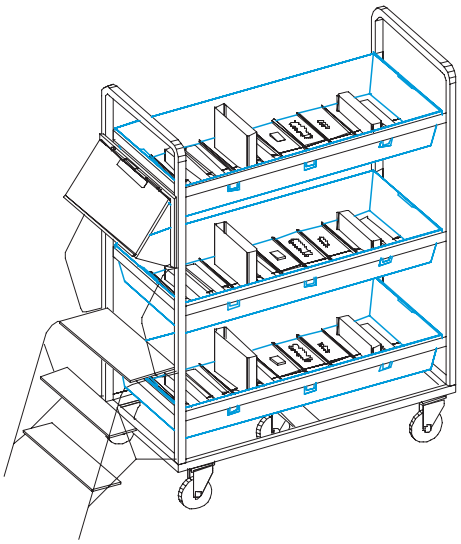
Dipl.-Math.
Martin C. Müller

Dr. Anita Schöbel

Dipl.-Math.
Tim Sonneborn

M. Sc.
Stevanus Tjandra

Dipl.-Math.
Hans Trinkaus



Commissioners´ trolley.

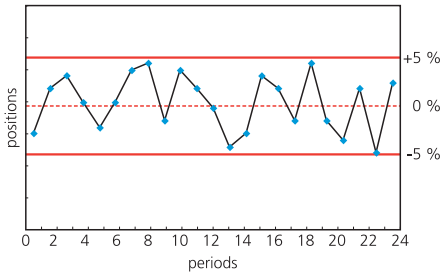


Fig. 1: Order lines per period within feasible corridor.

Keeping the balance - a more effective order picking using combinatorial optimization

Order picking is the central component of a mail order company's logistics center with a product range of approximately 100 000 articles. Merchandise does not only have to be delivered to a large number of private customers, but also to local branches and business customers. The handling of the individual customers' orders is extremely demanding and requires a flexible and high performance system. Similarities to mass production include throughput and added value. However, exclusively customer-specific products such as deliveries are handled. In contrast to the next project, the focus here is on the optimization of production planning instead of pure simulation.

We have a modular system of manually operated order-picking places which are interconnected by a material flow network. At several points, parallel systems increase the throughput. The strict obedience to sequence conditions is supported by sorting buffers. The central task of production planning is the determination of the optimal sequence of working steps for the whole system.

Modeling

The main objective of the optimization of such entire systems is an undisturbed and steady working process even in the case of varying loads. The maximization of individual performances is less important. This is particularly the case for an average load, where average and maximum performance do not have to be identical - in contrast to a maximum load.

The load of the entire system is determined by nearly as many different criteria as there are components. For a manual order picking process, the number of order lines per time unit is decisive. At another point, however, the geometric exterior dimensions are limited by an automatic buffer, or the number of deliveries per time unit is limited by the length of a transport belt. In order to guarantee an undisturbed working process, the sequence of process steps must now be controlled in such a way that all the loads for short intervals vary as little as possible. Therefore, a multi-period multi-knapsack model has been developed which guarantees an appropriate corridor for each individual criterion (cf. Fig. 1):

$$\left|\sum c_{ij} x_i\right| \leq \varepsilon_j \quad \forall\, i, j.$$

If parallel systems are used, the amount of orders is divided into independent sets by a set partitioning approach. At the same time, the robustness of the system can be increased because the effects of temporary failures are limited locally. In addition, there are local optimizations, e. g., with respect to route length and driving time, and the assignment of work places to the employees according to ergonomic aspects. For the numerical solution, we apply commercial solvers (XPRESS®, CPLEX®) as well as known graph theoretical algorithms and heuristics developed at the ITWM.

Application

Apart from a material flow simulation, a completely functioning prototype of the production planning software has been developed at the ITWM. This prototype will represent the core of the production software which will control the real system.

Partner:

Pierau-Planung, Hamburg

Contact:

Dipl.-Math. Martin C. Müller
Phone: +49 (0) 6 31/2 05-44 72
E-mail: mueller@itwm.fhg.de

Dipl.-Math. Jörg Kalcsics
Phone: +49 (0) 6 31/2 05-44 79
E-mail: kalcsics@itwm.fhg.de

Optimization

Simulation for the planning and realization of a distribution center

Modern logistics enables companies to supply geographically large, and in some cases worldwide markets from one or only a few locations at reasonable costs. The research project "location planning and supply chain management" deals with the convenient location of such distribution centers for external logistics (cf. following page). Here, the logistics at the location, i. e. within and between the buildings, is optimized, because the systems must be able to meet extreme demands with respect to each of the following aspects:

- high storage capacities,
- high throughput,
- maximum range of products,
- flexibility with respect to customers' desires.

The owner and the construction engineer, i. e. the system provider, are both confronted with the problem of an appropriate planning. The complexity of the technical and organizational realization requires the consideration of the system as a whole. Simulation is applied in the sense of an organizational modeling which represents the individual processes.

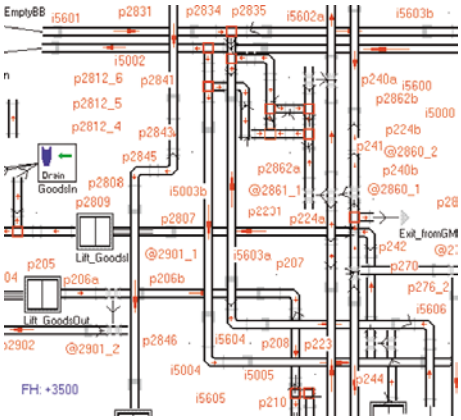
The transport of part load units is based on a wide range of mechanical systems. In this case, there are roller conveyors, belt conveyors, belt transfers, pushers, S-conveyors, elevators, paternosters, stacker cranes, palette handling systems, flow racks, gantry robots, and Rotastores. The control is divided into an underlying control system which directly controls the mechanical actuators and sensors, and a computer for the material flow, which generates the transport orders for the underlying control system and receives orders from the warehouse management system. The strategies which have been developed refer to all three levels.

Modeling

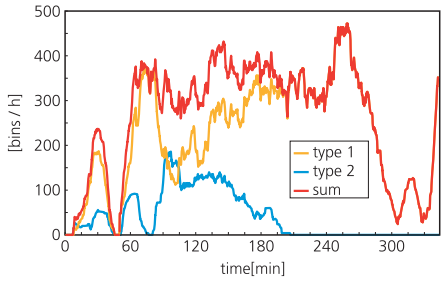
The considered model mainly refers to queue networks of a complexity, that cannot be handled by explicit mathematical methods. Besides, in the present case a purely stochastic method would not be adequate because the control strategies applied in the simulation will also be applied in the real system. Therefore, the system was mostly represented deterministically by an event-oriented, time discrete model. Stochastic influences are due to the human worker and the modeling of the unknown future development of orders.

Application

In the year 1999, the planning was finished using simulation to verify its effectiveness, and the customer placed the order to realize the system. Consequently, the emphasis moved from the support of the planning to consulting and incremental improvements. In order to design details of the technical components, dynamic load profiles, which support the engineer's decision with respect to the variant to be realized, were developed for all components of the material flow. Because of the previously realized work, the software conception made a jump start during strategy planning. Finally, the real system will undergo an acceptance test according to the simulation; that is, an actual end-to-end control will take place.



Material flow network.



Performance chart for an individual network component.

Partner:

psb GmbH, Pirmasens

Contact:

Dipl.-Math. Martin C. Müller
Phone: +49 (0) 6 31/2 05-44 72
E-mail: mueller@itwm.fhg.de

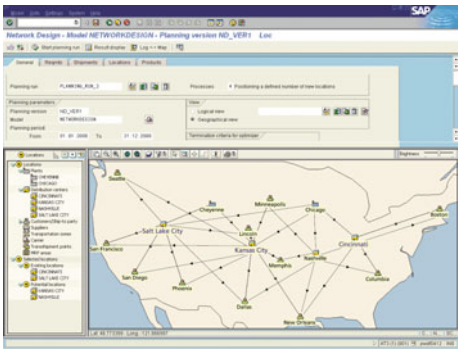


Fig. 2: Structure of a supply chain in network design: Starting configuration.

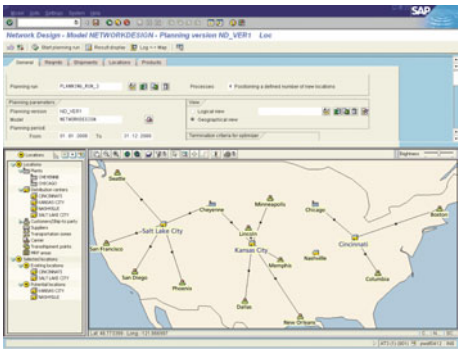


Fig. 3: Optimized supply chain.

Optimization of facility location decisions in supply chain design

Strategic decisions that involve the location of, e. g., production plants, distribution centers and warehouses, are very important for the profitability of supply chains. A thorough facility location planning results in a more efficient material flow and lower costs, as well as a better customer service.

Together with our project partner, SAP AG, we developed the software tool Network Design that assists decision-makers in the strategic design of a supply chain. Taking demand and cost data into account, the tool supports decisions with respect to the following questions:

- *supply:* Which amounts of materials should be purchased and from which suppliers?
- *production:* Where and how much should be produced?
- *distribution:* Which transport routes should be used?
- *location planning:* How many new facilities should be opened, and where should they be located? Which of the existing facilities (e. g., warehouses) should be closed?
- *assignment of customers:* Which customers should be served by each facility?

Figure 2 shows a supply chain in the Network Design module, consisting of eleven customers and two production plants in the USA. The objective is to determine the optimal number of new warehouses out of four potential sites. The possible transport routes between the locations of the supply chain are also illustrated.

Modeling

For the planning of the supply chain, Network Design provides different discrete optimization models. These are formulated as mixed integer linear problems and solved with the optimization software CPLEX®. Figure 3 shows the optimal configuration of the supply chain illustrated in Figure 2. From the four potential locations for new warehouses, three have been selected. Figure 3 also shows the optimal assignment of customers to warehouses and of warehouses to production plants. These assignments are made with respect to costs.

In addition, Network Design supports a regular evaluation of an existing supply chain using planar models, in order to detect weaknesses. For example, an existing supply chain is examined with respect to the assignment of customer demands to service facilities. This problem corresponds to determining the catchment or trade area of each service facility.

System environment

Network Design is a module of APO (Advanced Planner and Optimizer), the supply chain software developed by SAP, and is linked to other applications of APO, e. g., the demand planning module which generates demand forecasts.

Partner:

SAP AG, Walldorf

Contact:

Dipl.-Math. Jörg Kalcsics
Phone: +49 (0) 6 31/2 05-44 79
E-mail: kalcsics@itwm.fhg.de

Dr. Teresa Melo
Phone: +49 (0) 6 31/2 05-44 26
E-mail: melo@itwm.fhg.de

Multistage production planning

In a supply chain, intermediate and end products are produced, transported or stored. Figure 4 shows a supply chain as a network of nodes and arcs. Each node represents a product at a certain location, and the arcs describe precedence relations between items.

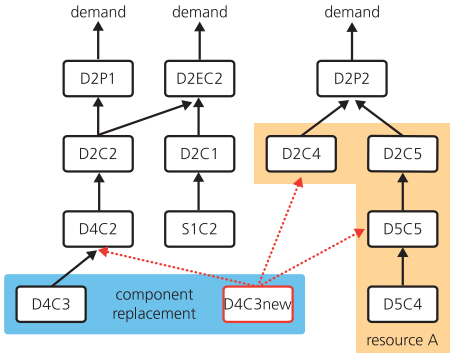


Fig. 4: General structure of a supply chain.

The aim is to determine a production plan for each end product and its components, e. g. the amount and time period in which each item should be produced, delivered or ordered. During the planning, several aspects are accounted for, e. g.:

- Resources have limited capacities and can be required by different products.
- Desired lot sizes, minimum inventory targets and minimum batch sizes and orders should be accounted for.
- Due to continuous technological and product changes, the structure of products is dynamic, i. e., individual components are replaced by new components during the planning horizon.
- Products can be manufactured using alternative components and resources with different consumption rates.

Usually, customers' orders exceed available production capacities so that late deliveries are often unavoidable.

Solution approach

Real-life problems with more than 100 000 orders, for which daily production schedules need to be determined over a planning horizon of one year, are not uncommon. Lists of parts or Bills of Materials (BOM) with more than 50 000 items and a complex product structure are relatively normal. Since such large problems are too hard to solve optimally in reasonable computing time, one is compelled to use heuristic solution methods.

Figure 5 illustrates the basic structure of the construction heuristic that was developed for solving the problem described above. First, a production plan is generated which neglects the capacity constraints. It starts by planning the production of the end items. Since lot sizes on a given BOM level determine the demand for components on lower levels, the procedure evolves iteratively by generating lot sizes level by level until the last BOM level has been reached. In the second step of the heuristic procedure, strategies for reducing overloaded resources are applied. Finally, in a third step, local optimization strategies are used in order to improve the quality of the production plan.

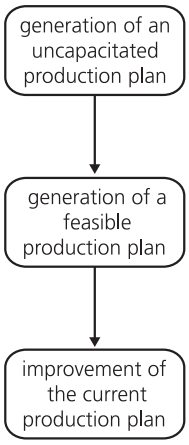


Fig. 5: Basic structure of the solution procedure.

Partner:
ICON Industrie Consulting GmbH, Karlsruhe

Contact:
Dr. Thomas Hanne
Phone: +49 (0) 6 31/2 05-44 70
E-mail: hanne@itwm.fhg.de

Intelligent catalogues - integration of content and product data

Most industrial production companies use 3D product data only in connection with the process of innovation. Although data visualization which goes beyond these limits would be desirable for an integrated product data and content management – e. g., for internal communication, in-house training, and an efficient design of marketing media –, it often fails due to a lack of knowledge management at the company.

Problem

Tehalit Ltd., Heltersberg, is the leader in the German market for electric installation systems. Accompanying the substitution of an essential part of the established product range, a new marketing tool had to be developed which should be able to draw the attention of different user groups to the products, to provide detailed product information, and to realize secure ordering processes. All graphic information had to be derived from the existing CAD construction drawings.

NP-COM – new paths in e-business

In the first part of the project, an integrated information and ordering software was developed and is based graphically on virtual data.

Animated image sequences present new products to production planners, detailed installation sequences inform technicians, and an interactive ordering tool enables the customer to place orders comfortably and error-free.

Figure 6 shows an essential aspect of the ordering process, where the user is led from the survey of the system to the individual product, at the same time acquiring knowledge about the system.

In future project phases, the integration of product data and content management will be intensified, in order to optimize the internal workflow and thus to accelerate the entire product innovation process decisively.

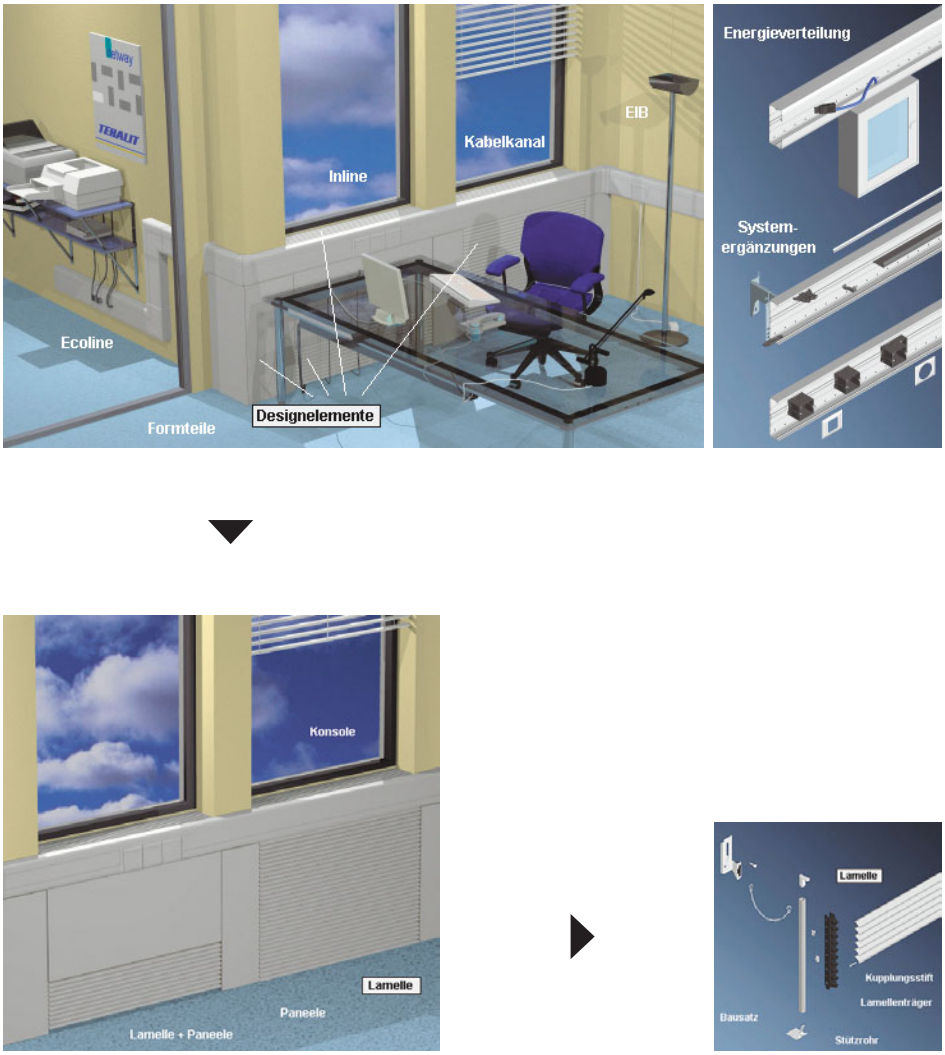


Fig. 6: Top-down approach for ordering.

Partner:
Tehalit GmbH, Heltersberg

Contact:
Dipl.-Math. Hans Trinkaus
Phone: +49 (0) 6 31/3 66 81-11
E-mail: trinkaus@itwm.fhg.de

Optimization

Delay Management in multi-modal public transport systems

It is the main objective in the current planning of traffic to strengthen local public transport in cities and surroundings. As many people as possible should be encouraged to use public transportation, like busses and trains, instead of automobiles.

However, there is no direct connection for each desired destination, therefore a changing of lines cannot be avoided. An absolute must for these line changing processes are so-called secure connections, i. e. the passenger must be able to change the bus or train within a reasonable time after having arrived at the stop, in order to continue his/her journey. On the one hand, this time interval must not be too short, so that necessary transfers by foot or short delays can still be managed. On the other hand, scheduled waiting times should not be too long.

Practical problems of Delay Management

Many public transport companies have structured their schedules with respect to secure connections only to a very low degree. Often, scheduled changing times are too short because a longer transfer by foot or a possible delay are not accounted for sufficiently, so that already due to very short delays, the connection is missed. Especially with respect to the changing of different means of transport (e. g., from train to bus) in multimodal public transport systems (see Fig. 7), often there is no coordination at all.

Mathematical optimization of Delay Management

In order to examine the complex area of a transport association and to simulate the effects of possible changes of schedules, a mathematical model was formulated for the Delay Management Problem (DMP). The DMP was described in the form of appropriate quantitative relations, equations and inequalities, which allow the application of algorithmic methods using discrete mathematics. Here, several (possibly contradictory) objective functions can be integrated into the evaluation. The resulting optimization tools are intended to support the planning in the case of all types of schedule changes. On the one hand, they should help to estimate and compensate their effects on secure connections. Schedule changes are necessary in the case of new schedules or the introduction of a new line, or they can result from road repair or detours. On the other hand, possible reactions to unexpected events like breakdowns or delays should also be accounted for. Furthermore, the mathematical model can determine weaknesses of the transport network and offer methods for their elimination.

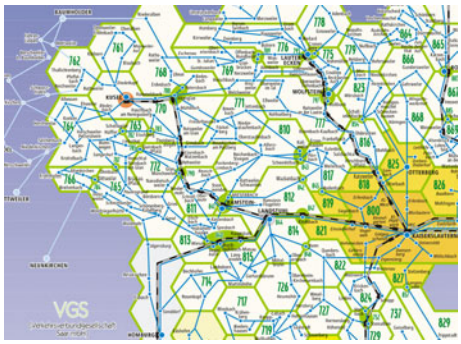


Fig. 7: Reference area "Lautertal" near Kaiserslautern.

Impact of delays in the reference area "Lautertal: source delay in Wolfstein. The subsequent delays are marked in red.

Funding:

Foundation Rhineland-Palatinate for Innovation

Partner:

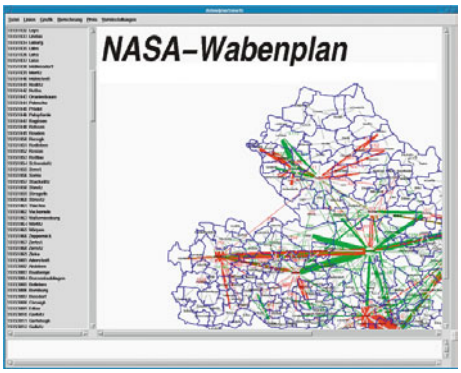
Verkehrsverbund Rhein-Neckar GmbH (VRN), Mannheim

Verkehrsverbundgesellschaft Saar mbH (VGS), Saarbrücken

Deutsche Bahn AG, Regionalbereich Frankfurt

Contact:

Dipl.-Math. Tim Sonneborn
Phone: +49 (0) 6 31/2 05-44 73
E-mail: sonneborn@itwm.fhg.de



NASA zone planning.

Evaluation of tariff zones for local public transport

An essential problem of local public transport is the development of common tariff systems. These should be fair and easy to manage, and at the same time transparent for passengers. Therefore, most of the large transport associations already use "tariff zones", or plan their introduction. Here, the entire region where the associations operate is divided into tariff zones. The fare then results from the number of tariff zones through which the passenger has travelled. By using a graphic theoretical model, for each pair of stops the new fare within the tariff zone system can be determined on the basis of these data, and then compared to the former fare.

Evaluation of tariff zone systems

An important criterion for the evaluation of a new tariff system is the expected income through fares, because the original income usually should not decrease. However, another important objective is to design the tariff zones in such a way that as few passengers as possible are annoyed by increasing fares. The following evaluation criteria are interesting:

- average absolute change of the fare for the customers after the introduction of the tariff zones,
- harmonization result (with respect to the different companies involved),
- result of the tariff rate fixing.

In order to compute these data, it is necessary to know the number of passengers for each pair of stops. Here, relation-exact customer data are required. However, these are usually not available, and an approximation becomes necessary. Excellent results can be achieved if the (mostly incomplete) relation-exact data are combined with the existing sales statistics. In the individual case, different evaluation and combination methods are necessary, which is very time-consuming.

If customer data are available, a detailed evaluation and the design of new tariff zone systems can be carried out with the software WabPlan (developed by G. Schöbel). The applications which will be described in the following were carried out in cooperation with the consulting firm G. Schöbel.

Applications

- Planning of tariff zones in Saarland: development of a common tariff system for all public and private transport companies in Saarland.
- Transition area between Saarland and Western Palatinate: evaluation of special tariffs for passengers crossing the border between both regions and using both transport associations, VGS and WVV.
- Tariff for passengers crossing borders within the region Anhalt-Bitterfeld-Wittenberg:

Development of a tariff system for owners of time-varying tickets that can be used for more than one transport company.

Partner:
Verkehrsverbundgesellschaft Saar mbH (VGS)
Westpfalz-Verkehrsverbund GmbH (WVV)
Nahverkehrsservice Sachsen-Anhalt (NASA) GmbH
Beratungsbüro G. Schöbel, Kaiserslautern

Contact:
Dr. Anita Schöbel
Phone: +49 (0) 6 31/2 05-45 90
E-mail: schoebel@itwm.fhg.de

Optimization of Ressources in the Public Sector

Optimization

Planning of patient transports in hospitals

Within the framework of hospital logistics, the transport service has the duty of transporting patients between wards (departments) and examining rooms. In large hospitals, often there are hundreds of patient transports per day, and a large percentage of the transports is required during the peak periods in the morning. The efficient organization of these transports is a precondition for possible planning in many hospital departments (e. g., surgery planning).

Transports are usually planned manually by a central department. Orders are collected in a simple list (cf. Fig. 8) and handled according to the FIFO method (First In First Out), i. e. an order is passed on to the next free colleague of the transport service. Emergencies are handled separately. However, without an electronic processing of orders, there is no data basis for optimization. Consequently, the FIFO strategy often leads to delays resulting in undesired waits and standstills of the departments waiting for patients.

Solution approach

Due to its high complexity, the problem must be solved by applying modern mathematical methods from the fields of integer and online optimization. Therefore OptiTrans, the software for the optimization of patient transports, includes an intelligent planning component which guarantees that given appointments are kept, and minimizes waits and empty transports. Additionally, further criteria are accounted for during the assignment of orders, e. g., necessary transport aids, special qualification of the personnel, or different priorities of the orders. Thus, the department requesting a transport and the department responsible for the coordination of transports can be informed online anytime about the status of the orders (cf. Fig. 9). A system of reports deals with the statistical evaluation of the transports which have been carried out. These evaluations are used for the information of colleagues, the quality assurance and the support of cost accounting (e. g., distribution of costs between different departments, utilization of the transport service's entire capacity). A homogeneous implementation into the already existing software infrastructure, i. e. hospital information systems (KIS), avoids multiple processing and facilitates the use of data for other software products and vice versa. Here, an example are the necessary patient data which should be taken directly from the KIS if a transport is required.

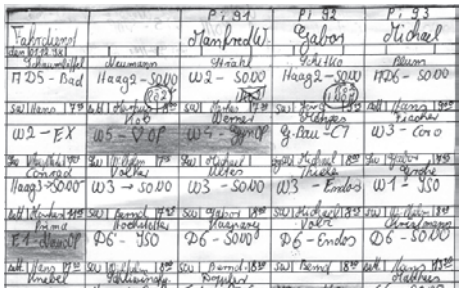


Fig. 8: Form for manual order scheduling.

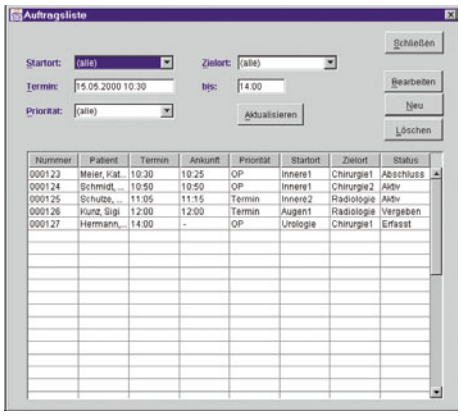


Fig. 9: Overview of orders in OptiTrans.

Partner:

GWI SIEDA GmbH, Kaiserslautern

Contact:

Dr. Michael Eley
Phone: +49 (0) 6 31/2 05-44 70
E-mail: eley@itwm.fhg.de

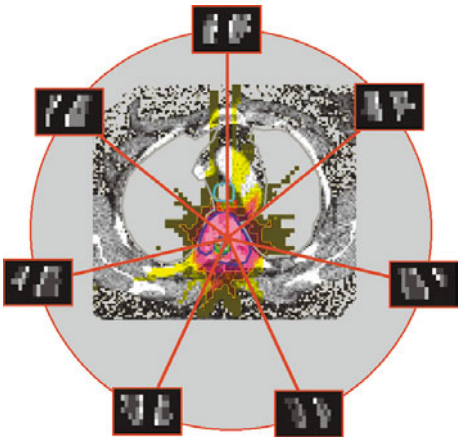


Fig. 10: Irradiation geometry and intensity profiles.

Planning of radiation therapy - new models for EUD

The planning of clinical radiation therapy is always a tightrope walk between a dose which is too low for the tumor respectively the target volume which endangers a successful therapy, and a dose which is too high and thus dangerous for the surrounding tissue, especially for risk organs. The planning is based on ideal lower bounds for the target volume and upper bounds for the risks. These bounds result from clinical statistics and models of radiation biology.

Problem

There is hardly any case where these "ideal" dose bounds can be applied, because in general the respective mathematical model has no solution. Therefore, an acceptable compromise must be found between a dose which is too low for the tumor tissue and a dose which is too high for risk organs. Naturally, the problem of planning radiation therapy can be modeled as a multicriteria optimization problem (cf. ITWM report 1999, p. 68).

The objective of the project is the development of an integrated real time planning system for the generation of the complete therapy setup, i. e. irradiation geometry and intensity profiles of the radiation fields (cf. Fig. 10).

Evaluation of the dose distribution

A central problem of the decision between different possible therapies is the evaluation of the dose distribution within the target volume and the risk organs. Here, an adequate model of radiation biology is EUD (Equivalent Uniform Dose), where comparable homogeneous doses with respect to effectiveness are assigned to the generally inhomogeneous dose distributions of the entities. The effectiveness of radiation is estimated according to statistical observations and estimations, where probabilities with respect to a positive therapy or to side effects are assigned to the homogeneous doses.

The observation of occurring phenomena reveals a relation between the effectiveness of radiation and the structure of the organs. We distinguish between serially structured organs, like spinal cord or gullet, and parallel structured organs such as the lung. In contrast to serial organs, parallel organs still function almost free of side effects even if parts of the tissue have been destroyed or removed. In the year 2000, a new modeling for the definition of the EUD has been developed. Depending on an index with respect to the serial/parallel structure of an organ between 0 (an organ of almost completely parallel structure) and 1 (completely serial organ), the EUD can be fitted by a max-and-mean family of norms

$$\mathrm{EUD}(D) = (1-\alpha)\, D_{mean} + \alpha\, D_{max}$$

The following table shows several α-values for the evaluation of the dose distribution.

Organ	α-value
heart	0.53
lung	0.09
liver	0.49
esophagus	0.90
brainstem	0.75

Partner:

Deutsches Krebsforschungszentrum (DKFZ), Heidelberg

Contact:

PD Dr. habil. Karl-Heinz Küfer
Phone: +49 (0) 6 31/3 66 81-13
E-mail: kuefer@itwm.fhg.de

Department of Adaptive Systems and Financial Mathematics

The department develops mathematical models for technical and medical systems, materials, financial products and process simulations in industry and economy. Financial mathematics was included in the name of the department only in the year 1999, in order to demonstrate explicitly the particular importance of this field by the development perspectives of a special department. The main compentence is concentrated in the following areas.

Computer-based design of analogs circuits

This research group develops algorithms supporting the systematic design of analogous circuits. Our main competence in dealing with these problems is the combination of symbolic and numerical methods for the automatic set-up of equations, the model simplification and the solution of circuit equations. The software development was focused on the further improvement of the software tool "Analog Insydes", where symbolic and numerical methods for the computation, analysis and evaluation of linear and nonlinear circuits are integrated. Since the end of 2000, the beta version "Analog Insydes 2" is available.

Diagnosis and prognosis systems

At the moment, the main field of application for the results of this research group is computer-based diagnostics in medicine. Through systematic data mining and the development of expert systems, already existing medical data can be evaluated, hypotheses generated, and already existing hypotheses can be examined and validated statistically. New adaptive methods from the fields of neural networks, cluster analysis and Fuzzy Logic combine data analysis and expert knowledge, resulting in computer software for the support of diagnosis and therapy. Actual projects are concentrated on risk stratification of long-term electrocardiograms, support of the diagnosis in regulation thermography and development of nutrition expert systems.

Model-based monitoring and control of mechatronic systems

This research group especially deals with the development and implementation of methods for the system identification and model adaptation of mechatronic systems. At the moment, main fields of application are electrical


Prof. Dr. Dieter Prätzel-Wolters


Dr. Patrick Lang


Dr. Günter Gramlich


Dipl.-Ing. Thomas Halfmann


Dipl.-Math. Harriet Holzberger


Dr. Hagen Knaf

machines, particularly turbo sets. The parameter identification of electrical machines is part of a DFG-project (German Research Society). The resulting models of mechatronic systems often are the basis of our methods for the design of observers and controllers. In this context, two projects funded by the Federal Department for Education and Research (BMBF) have already been carried out successfully: "Design of dynamical observers for torsional vibrations" and "Sensitivity and robustness analysis for the construction and observation of turbo sets". The results of these projects have been accounted for in the development of the software tool TorAn.

Material models

Here, mainly viscoelastic materials with a memory are examined, i. e. the respective stress and strain fields at a certain time depend on the entire deformation and loading history of the material. A further subject is the development of averaging methods for composites. Here, different projects have provided the mathematical foundations for the computation of the average viscoelastic material properties by finite element methods.

Financial mathematics

Modern financial mathematics is a mathematical research area of large practical importance where at the moment innumerable research projects are carried out. The mathematics on which the models for stock exchange and risk management are based comprises the fields of stochastic processes, stochastic calculus, stochastic and partial differential equations, as well as parametric and non-parametric statistics. These methods are increasingly accepted in practice, i. e. smaller and medium-size consulting enterprises and financial service providers also feel increasingly obliged to collect the respective know-how or to ask for support from external research institutes. The ITWM has a large potential for success in this area and has begun in 1999 to install a research group for financial mathematics within the department. The objective is the foundation of a special department in this area within the next three years. The technology transfer to be expected refers to the fields of "modern methods for profit and risk control", "use, evaluation and new development of structured derivative products", "efficient simulation methods", as well as "risk management, measurement and modeling of risks on the financial sector".

Contact:

Prof. Dr. Dieter Prätzel-Wolters
Phone: +49 (0) 6 31/2 05-44 42
E-mail: praetzel_wolters@itwm.fhg.de

Dr. Patrick Lang
Phone: +49 (0) 6 31/2 05-28 33
E-mail: lang@itwm.fhg.de


Prof. Dr.
Ralf Korn


Dipl.-Math.
Martin Krekel


Dr. Gerald
Kroisandt


Dr. Julia Orlik


Dr. Wilfred Pohl


Dipl.-Ing.
Jutta Praetorius


Dipl.-Math.
Tim Wichmann


Dipl.-Math.
Andreas Wirsen


Dipl.-Math.
Stefan E. Zeiser

Analog Insydes: Computer Based Methods for Analog Circuit Design

In order to improve design security and to shorten the time required for development, in the field of industrial production of analogs integrated circuits there is a high demand for computer-based methods. Up to now, apart from numerical simulation methods, for the design only very few tools have been available in order to get a more detailed insight into the behavior of a circuit. In order to close this gap, at the ITWM the software tool Analog Insydes is developed, where symbolic and numerical methods for the modeling, analysis and sizing of linear and nonlinear analogs circuits are integrated. The research objective is the development of algorithms and methods to support the systematic design of analogs circuits and their implementation in Analog Insydes. Some of these algorithms resulted from the project "SADE", funded by the BMBF. Especially in the following fields, the software can be applied profitably:

Modeling

- modeling of electronic components for symbolic analysis and numerical behavioral circuit simulation,
- generation of analytical models for linear and nonlinear circuit blocks (also on different hierarchy levels),
- symbolic simplification of nonlinear system descriptions.

Analysis

- symbolic analysis of electronic and control systems,
- numerical simulation of behavioral models of nonlinear dynamical systems (solution of DAE systems),
- extraction of dominating circuit behavior in analytical form by special simplification techniques for the circuit interpretation, sizing and fast system simulation,
- algorithms for the symbolic approximation of poles and zeroes of linear systems.

Sizing

- determination of sizing equations for circuit parameters as a function of global circuit specifications,
- numerical synthesis of element characteristics, e. g., for the solution of compensation problems.

Optimization

- symbolic preprocessing of systems of equations for a more efficient numerical optimization,
- topology optimization by symbolic analysis.

Analog Insydes, Version 2

In the period accounted for by this report, efforts were concentrated on finishing the new Version 2 of Analog Insydes. Since December 2000, a beta version is available. A fully functioning free demo-version can be downloaded for a limited period of 30 days from the following address: *www.analog-insydes.de.*

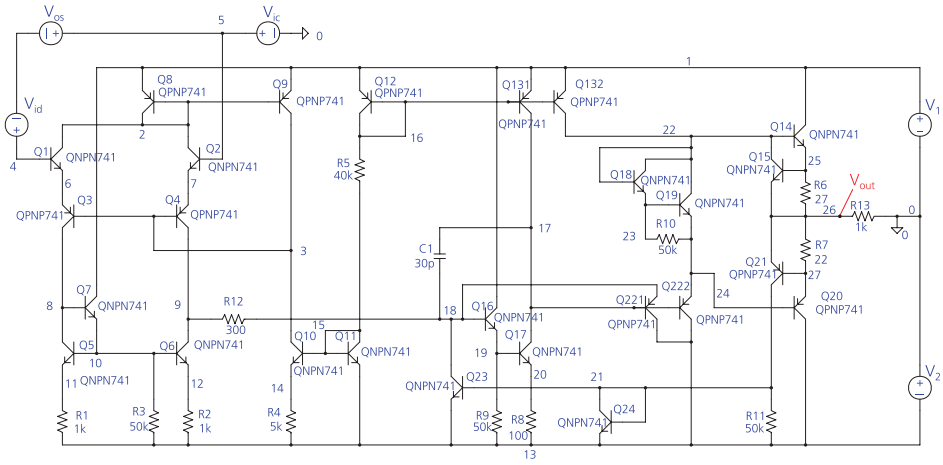
Based on a hierarchic netlist format and a flexible modeling language, Analog Insydes can be applied to the design of analogs circuits and control systems. An extensive model library is available (R, L, C, Diode, BJT, JFET, MOS). Numerical as well as symbolic methods for DC-, AC- and transient analysis and the analysis of temperature, noise, poles/zeroes and parametic analysis can be carried out by Analog Insydes. Especially important are the automatic equation setup (symbolic and numerical) and the symbolic approximation methods for linear and nonlinear circuits. The results can be visualized by a large number of graphic functions, e. g., by Bode and pole/zero diagrams, transient and root locus plots. Analog Insydes is completed by interfaces for the circuit simulators "PSpice", "Eldo", "Saber" and "Titan", so that, e. g., the input of schematics, netlists and simulation data is possible or MAST behavioral models can be generated.

Applications

Already for several years now, Analog Insydes has been successfully applied in industry. Due to the numerous improvements of the new version, the application has been simplified essentially. Particularly the new interfaces for different circuit simulators, such as Eldo and Titan, allow for the integration of Analog Insydes into the environment with which a circuit designer is familiar. Thus, Analog Insydes has been integrated into the analogs design flow of Atmel Wireless & Microcontrollers and of Infineon Technologies corporation.

User seminars

For professional users, the ITWM organizes seminars of several days where theoretical and practical knowledge with respect to the application of Analog Insydes for the circuit design is offered.

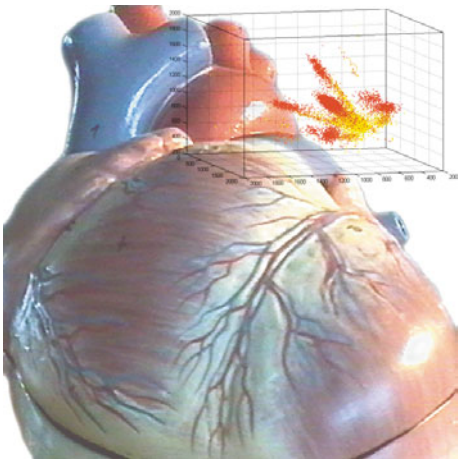


Schematic of the μA741 operatinal amplifier.

Partner:
Infineon Technologies AG, Munich
Atmel Wireless & Microcontrollers, Heilbronn
Analog Microelectronics, Mainz

Contact:
Dipl.-Ing. Thomas Halfmann
Dipl.-Ing. Jutta Praetorius
Dipl.-Math. Tim Wichmann
Phone: +49 (0) 6 31/2 05-44 75
E-mail: halfmann@itwm.fhg.de
praetorius@itwm.fhg.de
wichmann@itwm.fhg.de

Adaptive Systems in Medical Diagnosis and Prognosis



The diagnosis of diseases and the prognosis of the course which they will take require a lot of experience. In general, the effect of a disease on the human organism is complex, therefore it is usually necessary to evaluate large amounts of data in order to give a good diagnosis or prognosis for each single case. Thus, there are innumerable "rules" which the physician must follow. Here, expert systems – i. e. computer programs which imitate expert knowledge and conclusions – can be of multiple use. A well-functioning expert system can help the physician with his diagnosis by offering a "diagnosis proposal", and it can support the learning by experience. Furthermore, a whole group of physicians can participate in the development of an expert system - in this case, knowledge is integrated and objectified.

In hospitals and doctor's practices, naturally large amounts of medical data are collected. After they have been used for the respective objective, there is often no further application of these data. Here is a considerable potential for the increase, improvement and theoretical foundation of the existing medical knowledge. By the application of systematic data mining, already existing hypotheses can be examined and validated statistically. Software systems for the automatic recognition of data structures can provide new ideas and the motivation for research in a concrete, new direction.

Expert systems and data mining are based on mathematical concepts such as time series analysis, Fuzzy Logic, neural networks and cluster analysis: fields of competence of the department "Adaptive Systems and Financial Mathematics".

Apart from the risk analysis for long-term electrocardiograms, a project which will be described in detail below, at the moment the research is concentrated on projects in the fields of nutrition optimization and support of the diagnosis in regulation thermography.

Nutrition optimization

During the period covered by this report, the development of a concept for a modular nutrition expert system has been started together with the German Society for Oncology.

In the center of the system is the modeling of the need for different nutrients of one special person. This modeling is strongly dependent on the health state and the living conditions of the respective person.

The computation of the nutrient balances should also especially account for the latest results with respect to the mutual dependence of the different nutrients. For example, for several combinations of nutrients significant compensation effects are known if they are taken simultaneously during meals.

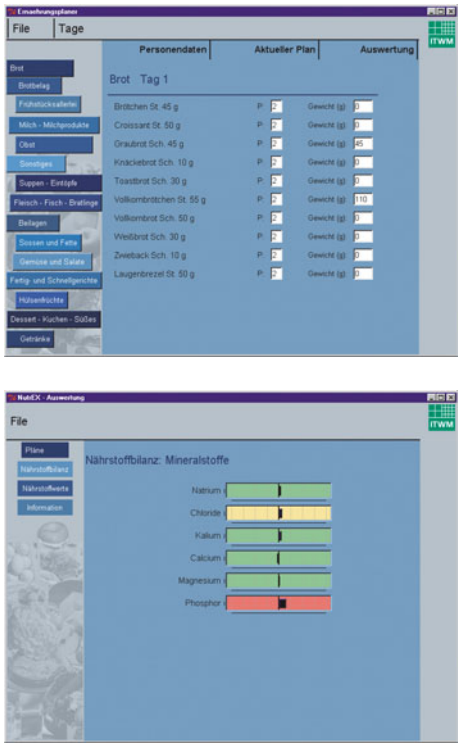
The evaluation and optimization of the nutrition behavior by the expert system are based on the diet plans of the users, which should be available for a period of approximately one week. The expert system will then carry out a step by step improvement with respect to the nutrient situation. A central problem is the intended acceptance of the modified diet plans by the user, therefore the new plans should not differ too much from his/her original diet.

Diverse realizations of the concept of the expert system are intended in totally different contexts, such as healthy food, special diets, sports, oncology and other disease-specific modifications. Potential marketing possibilities are internet portals with respect to healthcare or PC versions.

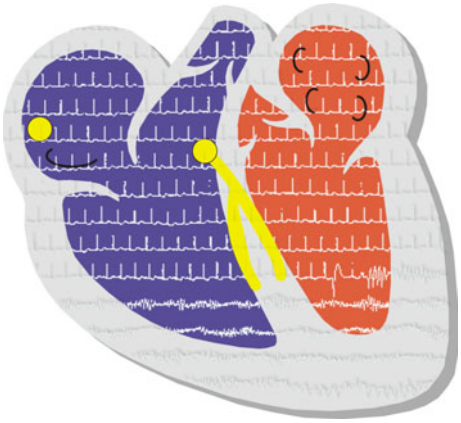
Regulation thermography

Besides, starting in February of 2001, the department for Adaptive Systems will concentrate on the support of the diagnosis in regulation thermography, a research project funded by the BMBF. The evaluation of the temperature structures measured with this method will especially be focused on nonlinear discriminant analytical methods, at the same time accounting for medical constraints, and on the automatic generation of diagnosis rules. Furthermore, the medical expert knowledge existing with respect to regulation thermography shall be validated and enlarged in this way.

A first concrete application of the project will be the diagnosis and therapy control in the case of breast cancer. In principle, however, the method can also be applied in the context of other entities of cancer, which will be the subject of subsequent research projects.



User-interface of the nutrition expert system.



Risk parameters in the case of arythmic heartbeat

The rythm of the heartbeat is controlled by a complex combination of an internal electrophysiological system with external nerval and hormonal components. Disturbances of the internal system lead to arythmic heartbeat, which can be totally harmless, but also deadly, as in the case of the Sudden Cardiac Arrest (SCD): the contraction sequence of the cardiac muscle is disturbed so badly that the amount of blood pumped into the circulation becomes insufficient.

According to medical hypothesis and experience, the risk of dying due to SCD can be estimated by a combination of physiological and statistical parameters. Countermeasures in the case of a high risk are the prescription of medicines with anti-arythmic effects or the implantation of a defibrillator.

In general, the parameter combinations applied at the moment do not yet provide a satisfying estimation of the SCD-risk. An improvement of this situation will help persons with a high SCD-risk, and on the other hand will prevent wrong and possibly expensive treatments of persons with a low risk.

Since 1998, different nonlinear parameters have been examined at the ITWM which are intended to improve the risk estimation by substituting or completing the already existing parameters. The research is based on the electrocardiogram respectively on the extracted time series of the intervals between successive heartbeats (RR-intervals). A classification of heartbeats with respect to the responsible trigger mechanism is also important. Both pieces of information are computed from the electrocardiogram by commercial software.

Mathematical modeling

The time series of the RR-intervals $(t_i)_{i=1,\dots,N}$ of an electrocardiogram can be examined mathematically in different ways. Already the computation of simple statistical values such as the standard deviation of the intervals yields the parameter SDNN, which is of good medical use. Of course, it contains only very few dynamical information. Additionally, the heart rythm has been proved to be nonlinear, i. e. methods from nonlinear dynamics are required. The time series $(t_i)_{i=1,\dots,N}$ is considered as a scalar measurement of the state of a dynamical system. A method for the geometric representation of this state is the so-called Lorenz plot: natural numbers m and t are selected, and the m-tuples $((t_i, t_{i+t}, t_{i+2t}, \dots, t_{i+(m-1)t})$ are considered as points in the m-dimensional space R^m. The series of RR-intervals appears as a structured point cloud $L \subset R^m$, whose morphology reflects the dynamics of the heartbeat rythm in different ways, depending on the selection of the embedding dimension m and the delay τ. For obvious reasons, in medicine the embedding dimensions 2 or 3 are preferred. However, the mathematical foundation of the method described above are the embedding theorems of Takens and Sauer, according to which the coordinates provide a complete description of the state of the dynamical system on which the heartbeat is based only if m is sufficiently large.

By two different approaches, the point clouds L are classified according to their morphological properties, and then related to the SCD-risk. On the one hand, for each point $x \in L$ three local dimension numbers are computed which describe certain aspects of the point distribution in the neighborhood of x. The distribution of the values of these dimension numbers throughout the entire cloud L is evaluated accord-

Funding:
Foundation Rhineland-Palatinate for Innovation

Partner:
alphaCardio GmbH, Grünstadt

Contact:
Dr. Hagen Knaf
Phone: +49 (0) 6 31/2 05-44 74
E-mail: knaf@itwm.fhg.de
Dr. Patrick Lang
Phone: +49 (0) 6 31/2 05-28 33
E-mail: lang@itwm.fhg.de

ing to a geometrically motivated, heuristic method, and finally yields a combination of three candidates of numerical risk parameters. In order to examine their medical relevance, the values of the parameters are analyzed on the basis of a sufficiently large amount of medically classified electrocardiograms. Here, methods of non-parametric statistics are applied.

The second evaluation method for a point cloud L is based on neural networks. In a first data reduction step, the morphologically most dominating point clusters in the Lorenz plot are detected. Appropriate methods are unmonitored cluster methods, such as the neural gas or the maximum entropy algorithm. Usually, less than 20 neurons are enough in order to guarantee a sufficiently good representation of the original structure. Based on the clustered Lorenz plots and several statistical parameters, e. g., different fractiles of the RR-interval distribution, in a second step monitored adaptive methods are applied in order to recognize the relations between the neural clusters and the SCD-risk.

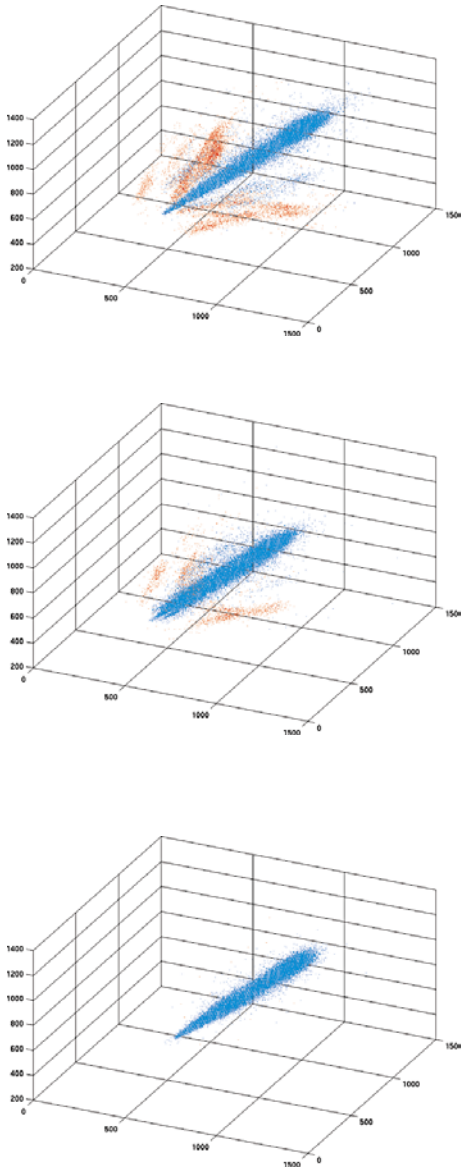
Results and perspectives

In cooperation with the medical service provider alphaCardio, a combination of three morphological parameters of the three-dimensional Lorenz plot has been examined as a potential parameter for arythmic heartbeat. In a first step, a data record consisting of 553 medically classified electrocardiograms was used in order to determine on the one hand the critical parameter domain for a high SCD-risk, and on the other hand to test the quality of the parameters, so that necessary modifications could be recognized. As a consequence, the quality of the parameters is examined during a study carried out currently at a French hospital. Here, the emphasis lies on the combination of the parameters with physiological values like the left-hand side ventricular ejection fraction (LVEF) and frequency parameters resulting from the Fourier analysis of the electrocardiogram. The results which have been found up to now are very promising.

A univariate comparison has shown that the classification approach based on neural networks is superior to the approach presented first. The required computation time is also evidently shorter.

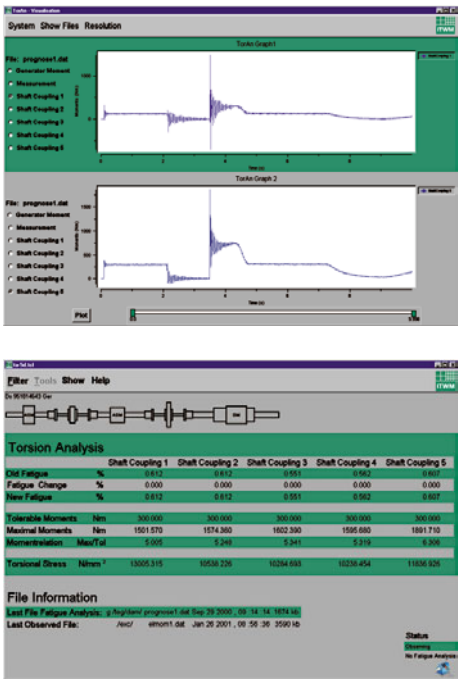
A further application of the Lorenz plot with respect to electrocardiogram analysis is the identification of patients with atrial fibrillation from short-term electrocardiograms, which is a research subject since May, 2000. A detection software developed at the ITWM will be tested in practice in the first months of 2001.

Apart from these projects which are strongly orientated towards possible applications in medicine and marketing aspects, the research activities also included Master's theses with respect to the electrocardiogram analysis by neural networks and to methods of Symbolic Dynamics. Together with the research group Statistics of the Department for Mathematics, problems of the splitting of electrocardiogram time series into approximately stationary parts by linear time series models have been examined. These are questions which repeatedly arise in practice. A research project for the analysis of stress electrocardiograms has been started.



Lorenz plot of a person treated with an anti-arrhythmic drug (blue: normal beat, red: extra-systolic beats).
above: before treatment.
middle: short period after starting the treatment.
below: ongoing treatment after longer period.

Model Based Steering and Control of Mechatronical Systems



TorAn - User interface.

TorAn: Online Monitoring of torsional oscillations of rotating machines

In the context of online monitoring of torsional oscillation of rotating machines, the software tool TorAn (Torsion Analyst) has been developed. In particular, the application of TorAn is supposed to minimize the number of expensive sensors required for measuring the torsional moments. The idea of TorAn is that, based on only a few torsional measurements, the behavior of the moments at the critical system components where no measurements are made can be estimated by an online-capable observer. In the case of a disturbance a lifetime analysis for these components can be carried out. Thus, in particular a lifetime analysis for those critical system components is possible where, due to technical restrictions, no sensor placement is possible.

Technical realization

The robust observer, which has been developed during a BMBF-project, is computed by the ITWM for each rotating system with a software especially developed for this purpose. In a first step, a FE-modeling of the system is carried out. Important information about the influence of parameter disturbances is provided by a sensitivity analysis. Model updating and reduction methods especially developed for elastomechanical systems are used in order to improve the model quality for an appropriate dimension. These improved models are the basis for the robust observer design. The observer computed in such a way is then brought to a format readable for TorAn, so that it is finally available for the user.

In addition to the observer, as a further input TorAn requires measurements of the torsional moments at the sensor positions defined during the design of the observer. These are provided via a measuring card by the remote torque sensor developed by order of the ITWM. Based on the measurements, TorAn gives an online estimation of the torsional moments at the remaining critical system components. TorAn recognizes disturbances and, in tabular form, provides data for the resulting fatigue and those data of the disturbance which are most important for the observed components. A graphic visualization of the time-series of the disturbances is also possible with TorAn.

In the laboratory of Prof. Kulig – our partner at the University of Dortmund –, TorAn has already been successfully applied in practice.

The remote torque sensor and the software tool will be presented at Sensor-2001, which takes place in Nürnberg from May 8 to 10, 2001.

Test rig – University of Dortmund.

Partner:

University of Dortmund

Contact:

Dipl.-Math. Andreas Wirsen
Phone: +49 (0) 6 31/2 05-44 68
E-mail: wirsen@itwm.fhg.de

Description of electrical machines with nonlinear equivalent circuits

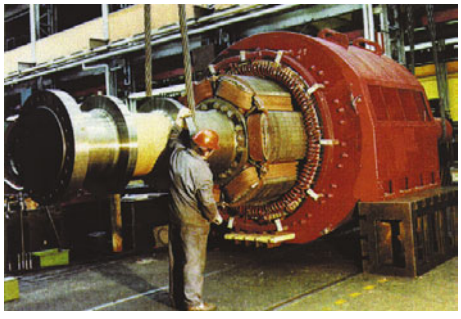
Electrical machines are complex electrical systems. For a description of such a machine, today there are two different methods, where the machine is modeled most exactly via the electrical and magnetic fields. However, this representation is very complex. The field equations can only be solved by means of complicated field computation software. This requires an extremely large amount of computing power and is very time-consuming even on powerful computers. Therefore, electrical machines are usually represented by equivalent circuits. In these equivalent circuits, the physical parameters are represented by the derived parameters for current and voltage, which are related among each other by concentrated elements like resistance, inductance and capacity. The equivalent circuits are understandable models for the behavior of the system, because thinking in the model parameters current and voltage is more easy than in the physical field parameters. The equivalent circuits can also be applied for the computation of complex electrotechnical systems, e. g., energy distribution networks. In Germany, approximately 1000 synchronous machines are working in the electrical power plants in order to manage the power supply.

Modeling and methods

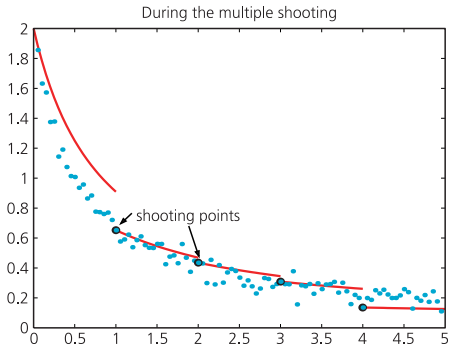
Electrical machines can be divided into two classes: synchronous machines (SM) and asynchron machines (ASM). The names stem from the interaction of rotor and rotary field: in the first case, the rotor is rotating synchronously to the field, i. e. the frequence of the electric supply of the stator defines the number of revolutions of the machine. In the case of the asynchron machine, the number of revolutions is not only defined by the stator frequence, but also by the load moment. If the load moment increases, the number of revolutions decreases.

The usual mathematical models for these machines can be represented by systems of differential equations, where all the parameters, i. e. resistance, inductance etc., are constant. In the case of linear equivalent circuits, inductances are assumed to be constant, therefore, strictly speaking, the model only holds for one set point. Usually, this is the nominal point of the machine. Often, however, one is interested in the behavior of the machine during other working states, e. g., in the case of disturbances.

Here, a model is required which accounts for the saturation as well as for the effects of eddy currents in asynchron machines. A particular feature of



Salient pole generator with that rotor assemblies.



The multiple shooting method.

the respective equivalent circuit is that the parameters subject to the nonlinear effects are considered as variable elements. Their dependence on the current intensity and the frequence is identified by functions of the equivalent resistance of the rotor. A similar model approach for synchronous machines is developed. The parameters of the equivalent circuit which are subject to saturation are regarded as a function of the current. They will be identified by the evaluation of the three-pole short circuit.

First, the asynchron machine (ASM) is described in the real three-phase system with its equations for voltage and flow and the mechanical relations, to be subsequently transformed into a two-axis system by the Park transformation. A further transformation to the reference coordinate system yields the fundamental differential equations for the equivalent scheme. The nonlinear inverse problem is the determination of physical parameters p (inductances) which cannot be measured. Measuring data b (current intensities) are available. A mathematical model describes the relation of p and b: $F(p) = b$, where F: $X \mapsto Y$ is a nonlinear operator between appropriate function spaces which describes the relation parameter / solution of the differential equation for dynamical systems. The inverse problem is the detemination of p from b.

For a numerical realization of this nonlinear inverse problem, optimization method and ODE-solver must be combined. The applied integration method, its exactness and its stability is essentially important for the solution of the ODE-system. However, it is very difficult to determine this importance theoretically, which is the reason for the special emphasis on this problem during the project. Frequently, the application of complex, derivative-based mathematical methods for the numerical solution of optimization problems is not very popular, although there are already efficient implementations. Often, methods are preferred which are easier to understand on an intuitive basis, or ad-hoc methods are applied, such as trial-and-error, genetic algorithms or simulated annealing. If there are only a few variables in the optimization problem, these approaches may work, although they mostly require more time and power by several orders of magnitude than the solution of a simulation problem. Therefore, in any case it is more efficient to apply derivative-based methods for the solution of optimization problems (e. g., quasi-Newton methods). Here, the derivatives of the state variables are determined according to the parameters. If multi-shooting or collocation methods are applied for the discretization of the ODE initial value problem, additional equity and inequity constraints must be accounted for within the optimization problem of a special block structure at the shooting points. In order to avoid the instabilities of nonlinear inverse problems, regularization strategies are included in the optimization methods.

Funding:

Deutsche Forschungsgemeinschaft (DFG)

Partner:

University of Dortmund

Contact:

Dr. Günter Gramlich
Phone: +49 (0) 6 31/2 05-27 42
E-mail: gramlich@itwm.fhg.de

In nature and industry, there are many examples of viscoelastic composites: wood composites, concrete, asphalt, bones and different kinds of polymers. A material is called viscoelastic if the stress and strain fields at certain moments not only depend on the stress or strain at these moments, but also on the whole deformation or loading history of the material. This property is called memory of the material.

The department develops mathematical models and homogenization algorithms which allow for the computation of the average viscoelastic properties or the strength of composites on the basis of known properties of their components.

A project funded by the EU for the improvement of dental composites on the basis of polymers periodically reinforced by glass particles has already been carried out successfully.

Clinical use of cementless hip prostheses

The treatment of hip ostheoarthritis is focused on pain relief and the improvement of joint movement. If conservative methods of treatment fail, it is necessary to exchange the affected joint by an artificial replacement, i. e. a joint prosthesis. Every year, more than 500 000 patients worldwide undergo hip replacement surgery in order to diminish pain and stiffness of the joint and to restore mobility. There are two types of hip prostheses: cemented and cementless. The more recent type, the cementless prosthesis, today represents 35 percent of the European market. The current trend is an increase of this market share due to a lower failure rate than that of the cemented prosthesis. A failure is frequently related to an imperfect design of the implant and in particular to the lack of methodologies and tools in order to validate the design prior to clinical tests. This validation should refer to the primary stability immediately after the surgery, as well as to the secondary stability after a first bone ingrowth.

Mathematical modeling

It is known that immediately after the implantation, a prosthesis is kept stable against the bone only by press-fit and friction. A mature and stable bone is not in direct contact with the surface of the implant. Instead, both are separated by a thin zone of pits (see Fig. 1) or of reduced mechanical stiffness and strength. According to the data provided by the project partner IOR, the thickness of the fibrous tissue around the implant is approximately 100 - 200 microns.

Within this CRAFT-project, a method will be developed which allows the computation of the macro-stresses at the interface between bone and prosthesis, at the time accounting for the micro-geometry of the E-interface layer (the bone-penetration into the pits) and the stiffness of titanium, and the inhomogeneous stiffness of the bones. The formal asymptotic expansions for different relations between the thickness of the interfacial layer and the period of pits will yield different contact conditions, which should be found in the project. The derived macro-contact

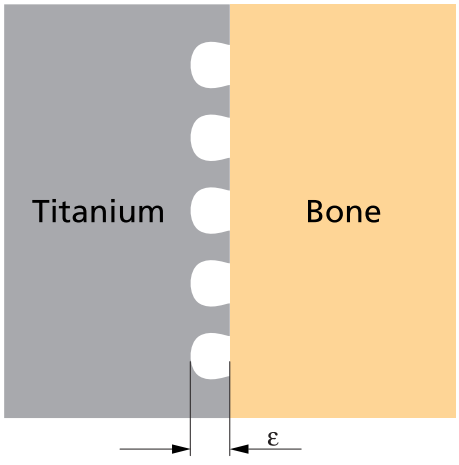


Fig. 1: Bone-implant initial contact (with empty pits).

FE-simulation for loading a bone with a hip prosthesis.

condition will then be implemented into the FEM-model developed by the project partner in Wales. However, only the macro-shape of the prosthesis as well as the stiffness and strength of the bone and the titanium will be accounted for. The average contact conditions derived at the ITWM will replace the E-layer in this macro-FEM-model, i. e. this layer with its micro-geometry will be skipped.

Another subject of the project is the definition of the micro-strength of composites on the basis of their known macro-stresses and micro-geometry, and of the elastic properties of their components. Therefore, the method of asymptotic homogenization will first be applied to the computation of the homogenized macro-stresses, and then to the approximation of the micro-stresses. The zero-order approximation to the micro-stresses can be written as a tensor product of the homogenized stress tensor and a so-called stress-concentration tensor. The homogenized stress tensor is only a function of the slow (macro-)variable, while the stress-concentration tensor is a function of the fast (micro-structure) variable leaving on the periodicity cell. The stress-concentration tensor can be determined in terms of auxiliary cell-problem-solution and the homogenized stiffness tensor. Further, the macro-strength of the composite can be estimated by using this approximation to the micro-stress field, and then be represented in terms of the only macro-stresses. The convergence with respect to the actual strength conditions remains to be investigated in the course of the projects.

The project is carried out in cooperation with different European companies and research institutes. The first six months were supported by an Exploratory Award of the European Union. Since February, 2001, the project is part of the CRAFT-program of the European Commission.

Another project, "Nanostrength", has been submitted to the EU, dealing with problems of interface strength and crack initiation for composites.

Funding:

Europeen Commission (program "CRAFT")

Partner:

Dept. of Basic Dental Science, College of Medicine, University of Wales (GB)

Instituti Ortopedici Rizzoli (IOR), Bologna (I)

Hit Medica, Rimini (I)

Coating Industries, Vaulx-en-Velin (F)

Techn. Beratung Dr. Becker, Ensdorf

Contact:

Dr. Julia Orlik
Phone: +49 (0) 6 31/2 05-27 42
E-mail: orlik@itwm.fhg.de

Financial Mathematics

Adaptive Systems and Financial Mathematics

Background and development

Modern financial mathematics is one of the mathematical research areas where at the moment innumerable research projects are carried out. The mathematics on which the models for stock exchange are based is very complex modern mathematics (i. e., mathematics which has been developed only in the last few decades). In parts, very special knowledge from the fields of stochastic processes, stochastic calculus, stochastic and partial differential equations, as well as parametric and non-parametric statistics is required. At the same time, the main results of financial mathematics find thousands of applications daily, and the trend with respect to their practical influence on financial markets is further increasing.

The ITWM has set up a research group "Financial Mathematics" within the department "Adaptive Systems" in order to meet these challenges. In addition to the colleagues already working in the field of financial mathematics of the department, two further positions have been established, funded by the Ministry for Education, Science and Qualification of Rhineland-Palatinate. The long-term intention is the establishment of an additional department on the basis of this research group. The head of the group is Prof. Korn, who is a consultant of the ITWM together with Prof. Franke.

Competence

The ITWM shows excellent competence in all essential fields of modern financial mathematics, e. g., in the fields of:

- portfolio optimization,
- derivatives (especially exotic options),
- investment in case of a crash risk,
- bootstrap and neural networks,
- measurement, modeling and management of risks,
- credit rating, credit risk, credit derivatives.

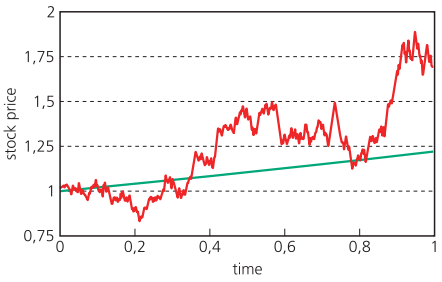
Among others, the following projects have been carried out in the past year:

- examination and implementation of modern methods of portfolio optimization,
- numerical methods for the price calculation of exotic derivatives,
- transformation of credit ratings.

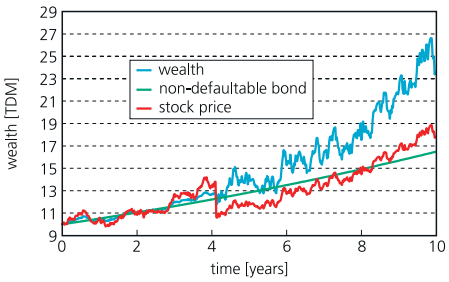
The last two projects were the basis for industrial cooperations with the Landesbank of Baden-Württemberg and the DePfa Bank in Wiesbaden. The latter was supervised by Dr. G. Kroisandt and will not be further described in the following. Besides, Dipl.-Math. Harriet Holzberger finished her PhD-thesis on the subject "Nonparametric Estimation of Nonlinear ARMA and GARCH Processes" in the period covered by this report.

Visions

As already mentioned above, the present year will completely be devoted to the growth of the research group. Apart from further industrial cooperations, special independent research projects will be carried out in order to collect more know-how, e. g., in the fields of credit risk, energy and weather derivatives. It is the objective of the ITWM to become *the* partner for financial service providers and consulting enterprises if research problems in the field on financial mathematics are concerned.



Simulated stock price.



Evolution of the wealth process of the crash-optimized strategy in the presence of a stock price crash of 24 percent after four days.

Modern methods of portfolio optimization

The problem of optimum investment of capital in different assets is one of the central problems of financial mathematics. In contrast to the evaluation of options, where, for decades now, continuous-time models of financial mathematics have been applied in practice, the basis of investment decisions of portfolio managers today still is the single-period model of Markowitz with several variants, which is more than forty years old.

Modern methods

In the meantime, the development of continuous-time portfolio optimization has advanced so far that many algorithms for practical application and implementation are available, e. g., algorithms for a continuous-time portfolio optimization for corporate stocks, bonds and derivatives, developed at the department for mathematics of the University of Kaiserslautern. The examination and implementation of further methods which, e. g., explicitly account for crash risks, proves that the know-how existing at the ITWM in this field reaches far beyond the standard methods in the practice of financial mathematics.

Implementation and practical adaptation of theory

Several assumptions on which the modern methods mentioned above are based, seem to prevent their practical application at first sight. These are, e. g., the assumption of continuous action, the neglect of transaction costs, the concentration on stock investment, as well as ignoring the crash risks on the market.

In the course of the project, the effects of the practical adaptation of these assumptions were examined. It has been realized that the missing continuous action has hardly any consequences. If, e. g., the portfolio is rebalanced only once a month according to the optimum strategy of the continuous-time model, in comparison to the idealized model this yields almost identical values for the expected profit and the assets at the end of the planning period.

Furthermore, it has become clear that derivatives in the investment portfolio can contribute to risk reduction. The explicit accounting for a possible stock market crash has also been examined more closely.

The available algorithms have been implemented within a "one-dimensional" program together with many state-of-the-art functions of portfolio optimization, such as

- selection of action frequency,
- modeling in case of a crash risk,
- accounting for transaction costs,
- selection of derivatives as an alternative for stock market investment,
- output of different risk measures (CaR, VaR, standard deviation).

Additionally, they have also been implemented within a "multi-dimensional" program together with several state-of-the-art functions.

Contact:
Prof. Dr. Ralf Korn
Dipl.-Math. Elke Korn
Phone: +49 (0) 6 31/2 05-27 47
E-mail: korn@itwm.fhg.de

Numerical methods for the price calculation of exotic derivatives

Due to the large success in derivatives trading in the last few decades, which was documented not only by the establishment of the German Options Exchange (DTB) in Frankfurt in 1990, and to the growing globalization of markets on the other hand, more and more new types of derivatives are offered on the financial market, which are generally summarized as exotic options. In order to calculate the prices of these options, the Black-Scholes model is used, which is very popular in spite of punctual criticism and is market standard today. This is probably one of the reasons why Merton and Scholes received the Nobel prize in 1997.

Within their model, the stock price is is assumed to follow a geometric Brownian motion.

$$dS = S(\mu\, dt + \sigma\, dW_t).$$

The fair price of an option is defined as the value of the cheapest portfolio with which the payoff of the respective option can be duplicated. This price is the average value of the payoff with respect to the risk-neutral probability measure.

Within the Black-Scholes model, there are closed price equations for many types of options. Probably the most well-known equation is the so-called "Black-Scholes formula", which provides the price of a call or a put option, respectively. However, since the payoff of an exotic option does not only depend on the stock price at the expiration date, but also on the entire price behavior, in most cases no closed solutions are available.

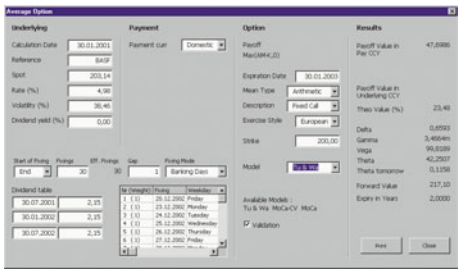
Method

Depending on the type of option, appropriate numerical methods are developed from the fields of tree models, simulation, Quasi-Monte-Carlo methods and discretization methods for partial differential equations. Furthermore, analytical approximations are also implemented which are mostly based on the approximation of the random variables occurring during computation by variables which yield a closed equation.

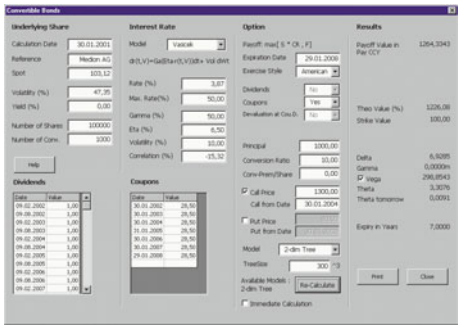
The objective is the selection of efficient methods for the computation of option values, and the adaptation and further development of existing numerical methods for new types of options. Simultaneously, for a certain type of derivatives algorithms for a concrete price calculation will be implemented.

Implementation

In order to guarantee a broad application of the evaluation modules, they have been implemented in C++. The modules are integrated into a Dynamic Link Library (DLL) and thus also integrated in EXCEL. In EXCEL, a comfortable user interface has been developed with Visual Basic for Applications (VBA), where the user can call the evaluation routines. Additionally, the modules can be applied as user-defined functions on the spread sheets.



Pricing tool for an average option.



Pricing tool for a convertible bond.

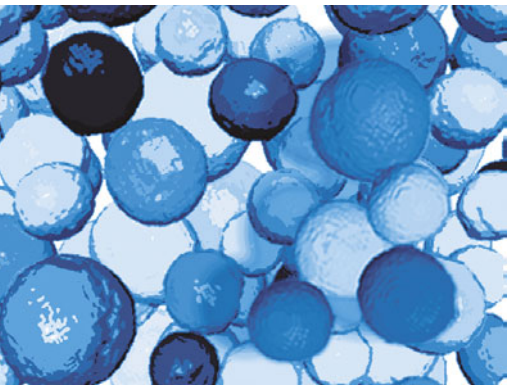
Partner:

Landesbank Baden-Württemberg, Stuttgart

Contact:

Dipl.-Math. Martin Krekel
Phone: +49 (0) 6 31/2 05-44 68
E-mail: krekel@itwm.fhg.de

Department of Models and Algorithms in Image Processing



The department "Models and Algorithms in Image Processing" offers complete and partial solutions for different application areas of image processing. Its main competence is the development of algorithms and their efficient implementation on standard PC hardware (e. g., by using MMX). Online capability, which is in parts necessary, is given through the use of PC clusters. The software development is based on a modular concept, so that individual solutions can also be implemented efficiently according to the customer's needs.

Research and development activities of the department are concentrated on the following areas:

- automatic surface inspection,
- three-dimensional image analysis and modeling of microstructures,
- data compression by wavelet methods,
- signal analysis concerning railways,
- cryptography.

Dr. Franz-Josef Pfreundt

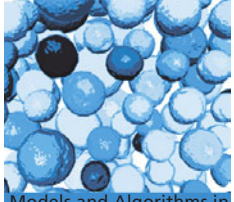
Dr. Ronald Rösch

Dr. Axel Becker

Dipl.-Phys. Martin Braun

Dipl.-Math. Norbert Göb

Dipl.-Phys. Andreas Jablonski



Models and Algorithms in Image Processing

Particularly in the areas of surface inspection and 3D-image analysis, there is a wide range of experience, with the main focus on the development of algorithms and systems for the control and evaluation of textured surfaces (e. g., textiles, fleece, wood), including also information provided by colors. The developments in 3D-image analysis are concentrated on the determination of geometric properties of the microstructure of certain materials from three-dimensional (e. g., tomographic) images by using methods of stochastic geometry. On this basis, 3D-models of these materials are developed which represent the geometric structures very well, so that computations and simulations are simplified or even possible for the first time.

In the field of data compression, the development of a wavelet-based compression method has been successful by which a high compression of image and video data can be reached, preserving an excellent image quality.

Contact:

Dr. Franz-Josef Pfreundt
Division Director
Phone: +49 (0) 6 31/2 05-27 44
E-mail: pfreundt@itwm.fhg.de

Dr. Ronald Rösch
Head of Department
Phone: +49 (0) 6 31/3 66 81-29
E-mail: roesch@itwm.fhg.de

Dipl.-Math.
Kai Krüger

Dipl.-Math.
Georg Kux

Dipl.-Math. Mark
Maasland MTD

Dr. Martin Nippe

PD Dr.-Ing.
Joachim Ohser

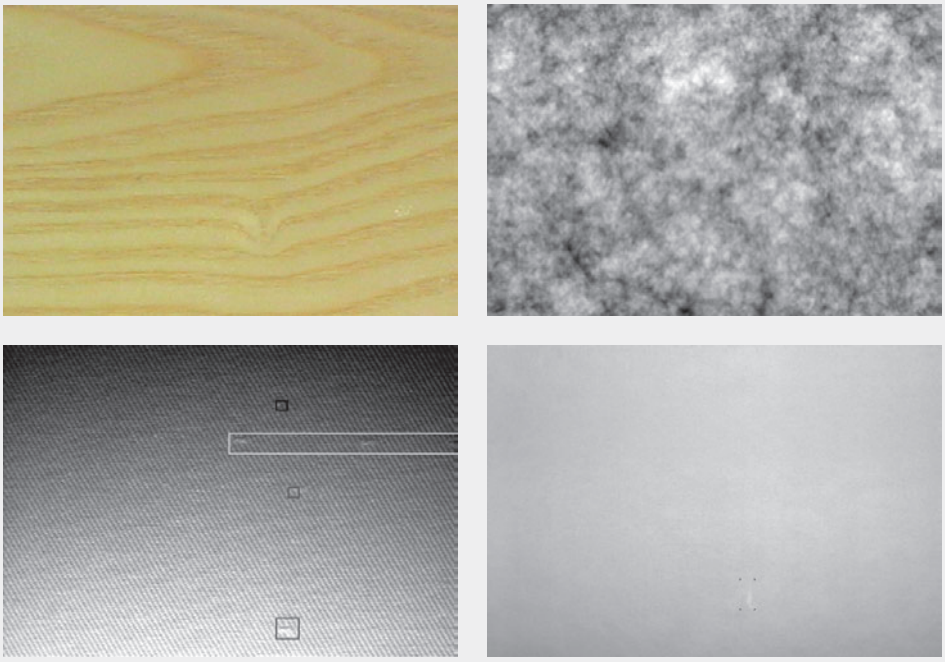
Dr. Katja Schladitz

Surface Inspection

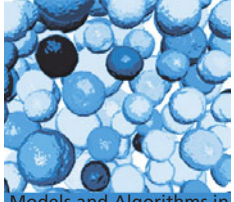
In the last few years, various experiences have been collected at the ITWM through projects concerning surface inspection. The main focus is the analysis of textured materials, also including information provided by colors. For the sorting of wood surfaces according to color and structure, the CCD camera-based system "FOQUS" has been developed for laboratory use. The system is structured in such a way that an application to online inspection problems is also possible without any difficulties. Besides, FOQUS has already proved to be successful in other areas, e. g., concerning the control of color constancy of carpets.

Accidental structures are important in many areas. For the quality evaluation of nonwovens, "VQC" has been developed. The main feature of this software is a scale analyis of free configurability which evaluates the homogeneity of the material within these scales. Thus, it is possible to weight larger or smaller structures more strongly, depending on the application. Potential further applications are, e. g., the analysis of paper, chip boards or other materials which are inhomogeneous due to production.

In the following, the online inspection systems for paper and woven textiles (or other grid-like materials) developed at the ITWM will be presented in detail. Particularly important is the project "ABIS", where complete raw automobile bodies are examined with respect to very small irregularities. Within a project team, the ITWM has developed and implemented the analysis algorithms. ABIS is expected to be fully integrated into the production process in the middle of the year 2001.



Surface inspection of textured materials (veneer, nonwoven, woven textile, paper)



ABIS: Automatic Body Inspection System

An optimum preparation of the raw body is the condition for a perfect quality of the painted car body. In order to reduce refinishing in the painting processes and to guarantee a constant quality level, it is necessary to detect and correct surface defects already during the finishing process of body construction. In the project "ABIS", a system is developed which automatically detects, classifies and marks invisible surface defects of the raw body. Thus, a transfer of such defects to the painting processes can be avoided. The following components are developed:

- an optical measurement system for the visualization of body defects, such as dents or bulges,
- a software package using the latest software technology for the detection of surface defects, and
- the respective system technology for the automization of the individual component (measurement, detection, classification, marking etc.).

The system is adaptive, i. e. it collects the knowledge of experienced controllers, which is then used as a basis for the development of objective evaluation criteria in order to guarantee a constant quality level.

Realization

Figure 1 shows how the system works. As a first step, the car coming into view is recognized automatically. Depending on the type of car, the video sensors move to given positions for the image acquisition while the car is passing them. Via demodulation, depth data is computed from the image data, where each pixel describes the distance between the respective point at the surface and the sensor. Then, as a first detection step, those images are sorted out for which it is guaranteed that they do not show any defects. The remaining images (so-called "defect candidates") are then analyzed in detail, and the areas containing defects, if there are any, are classified by means of a CBR-system (Case-Based Reasoning). Finally, the relevant points where defects are detected are marked on the body, so that a refinishing can take place.

Within the project, the part of the ITWM consists in the detailed analysis of the depth images with respect to possible defects. This is problematic due to the extremely high resolution of the depth images (irregularities from 40 mm onwards should be detected), which leads to a strong disturbance of the depth data. In addition, the time available for the processing of one image is relatively short.

Mathematical methods

Based on the information resulting from the depth images, by means of a linear filter the deviation from a defect-free surface is estimated first. In contrast to noise, defect areas such as dents or bulges correspond to relatively large values in this deviation image. In a second step, local extreme values are determined via adaptive threshold values. The resulting defect candidates are then smoothed by morphological methods. Finally, the characteristic features of these defect candidates are determined for the classification.

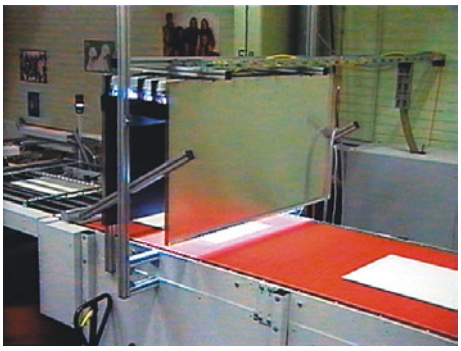
Fig. 1: ABIS-measuring-system at AUDI

Results

In order to carry out first online tests, the application of the prototype of the system described above has been started during the production process in May, 2000. Based on the test results, this prototype is further optimized at the moment. At the end of March, 2001, the system will first be subject to continuous testing.

Partner:
Audi AG, Ingolstadt
Steinbichler Optictechnik GmbH, Neubeuern
University of Erlangen/Nürnberg
tecmath AG, Kaiserslautern

Contact:
Dipl.-Math. Mark Maasland MTD
Phone: +49 (0) 6 31/3 66 81-23
E-mail: maasland@itwm.fhg.de



Online paper surface inspection.

SPOT: System for the inspection of paper surfaces

In the SPOT project, an image processing system for paper processing companies has been developed in order to automize and objectify the quality control of coated sheets of paper. The development included the entire hardware, the interfaces for the paper transporter, and the mathematical basis, the analysis and the classification software. A prototype ready for series production has been developed which is fully integrated into the production process since the beginning of 2000.

Image processing

The main challenge of this project consisted in the development of fast and high quality image processing algorithms in order to meet the requirements with respect to runtime and the conditions of quality. The detection process works in several stages:

- recognition of the boundaries of the paper sheets and reduction of the image to the region showing the paper surface.
- detection of gradient differences in the image by means of a morphological filter on two different scales. Thus, it is possible to recognize point-like defects or larger defects which nevertheless cannot be realized clearly. The realization of longish types of faults, e. g., scratches in the coating, is done by a smoothed second derivative in horizontal and vertical direction.
- computation of RoIs (Regions of Interest) and of features for each of these regions.
- classification of these RoIs according to the previously computed features into different defect categories.
- transmission of these results to the main server.

Description of the system

A SPOT-system consists of the main SPOT-server and the image processing clients SPOT1,..., SPOT<N>, each connected to a camera. The image processing results are transferred via RPC to the SPOT-server, which summarizes the results and gives the command "good" or "bad" to the sorting machine. The SPOT-server is also responsible for the visualization of the production process and for the protocol.

The system is implemented for a sheet width up to 1000 mm and for transport velocities up to 150 m/min. A resolution of less than 0.3 mm per pixel even allows an exact detection of defects smaller than 1 mm.

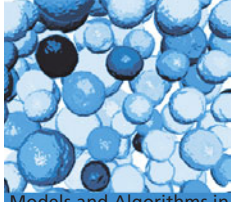
Partner:

Hofmann & Engelmann, Glatz Feinpapiere, Neustadt a. d. Weinstraße

Franz Gremser KG, Neusäß

Contact:

Dr. Martin Nippe
Phone: +49 (0) 6 31/3 66 81-27
E-mail: nippe@itwm.fhg.de



TASQ: Textile Analysis System for Quality control

Even in modern production facilities, weaving faults in textiles cannot be completely avoided today. Examples are knots, double or missing filaments. The quality control of a roll of fabric and the direct marking of defects on the fabric is a work done mainly by production workers up to now. An automatic system is clearly faster in detecting defects already during production, and the quality can be evaluated more objectively at the same time. A particularly high quality of textiles is required in the production of garments and furniture, but there are also other possible markets for such a system.

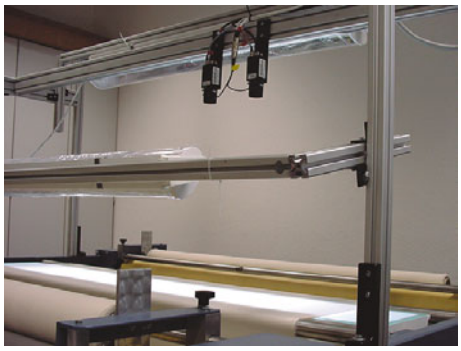
In the project TASQ, an inspection system has been developed mainly for the inspection of continuous materials, such as rolls of textiles. This development is a cooperation with the Italian machine construction company ATF, which produces copping, inspection and packaging machines for textiles.

The inspection system automatically provides a quality protocol, where the number of defects of the same type and their position are indicated. They can also be shown graphically.

The concept is strongly modular. With respect to the hardware, this means that as many cameras as necessary are used. Depending on the complexity of the image processing algorithms and the runtime requirements, one or more cameras are connected to one computer.

For the software, the modular concept has the following consequences: the user interface and the hardware control are implemented in different programs. An inspection taking place does not require the user interface. The algorithms are implemented in the form of modules, so that they can be exchanged and modified arbitrarily. Among others, the algorithms developed for the inspection of structured materials are integrated here. Further, a fast algorithm for the previous detection of defects in textiles has been developed. The algorithms from the paper surface inspection "SPOT" are also available in the same way, so that the system can easily be adapted to different inspection problems.

For the system calibration, the defects can be logged to a protocol file for a new material. The parameters are then fitted automatically. Thus, a surface inspection system is now available which can easily be adapted to the customers' needs.



Facility for automatical inspection of textiles.

Partner:

Automazioni Tessili Frigerio, Lurate Caccivio (I)

Contact:

Dr. Ronald Rösch
Phone: +49 (0) 6 31/3 66 81-29
E-mail: roesch@itwm.fhg.de

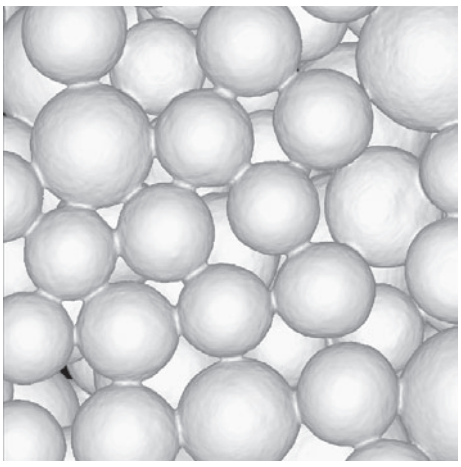
Dr. Martin Nippe
Phone: +49 (0) 6 31/3 66 81-27
E-mail: nippe@itwm.fhg.de

3D-Image Analysis and Modeling of Microstructures

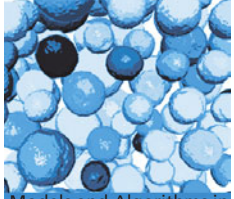
The application of modern physical imaging methods like computer tomography produces a growing number of 3D-images of the microstructure of biological and medical tissues and materials. The main focus of the project group is directed towards the analysis of these three-dimensional images of microstructures. Based on the know-how from the fields of stochastic geometry, statistics and image processing, efficient methods can be developed for these applications. The combination of the three special areas allows not only for the application-specific statistical analysis of various random 3D-structures, but also for the development and fitting of geometric models. For the department "Flow in Complex Structures", these geometric models of microstructures are the basis for fluid dynamical simulation computations for the determination of macroscopic material parameters.

3D-image analysis

The core of the analysis of 3D-images is the determination of basic geometric parameters: the Minkowski functionals (volume, surface, integrals of the mean and total curvature) and their densities. From the Minkowski functionals, further application-specific parameters can be derived. Direction-dependent counterparts of the surface and integral of the mean curvature provide information about preferred directions and the strength of occurring anisotropies. Additionally, 3D-objects (particles) can be isolated and object properties can be determined. Efficient algorithms for the determination of the Minkowski functionals have been developed through the combination of methods from integral geometry and stochastic geometry on the one hand and digital image processing on the other hand.



Reconstructed X-ray tomographic image of sintered copper.



Analysis of sintered copper

Sintered copper is a porous material used as a filter or catalyst in many technical processes. In order to reach a high porosity as well as good mechanical properties, the sintering process must be better understood and controled more effectively. A feature of the quality of a sintered filter is the number of sinter necks per sinter particle.

With our 3D-image analysis methods, the number of sinter particles and the average number of sineter necks per particle can be determined, so that conclusions are possible with respect to the mechanical properties of the material and the production process.

Open foams

Similar methods can be applied for the analysis and modeling of open foams. The mathematical analysis of the image data provides such important parameters as the average edge length per volume unit or the average cell size, which are necessary for the quality control during the production of foams. Software for the practical application in quality control is developed at the moment.

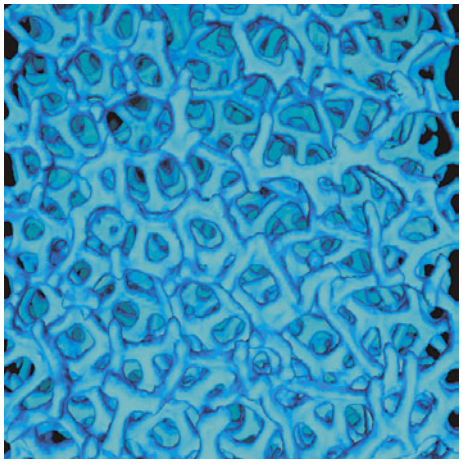
Modeling of microstructures

Many materials found in modern products, such as foams, ceramics, and fleece, are homogeneous on a macroscopic scale. From a microscopic point of view, however, they are heterogeneous. Macroscopic material parameters like relative permeability or sound absorption depend on the microstructure of the material. In order to determine such material parameters by the simulation of dynamic flow and to optimize the material virtually (cf. p. 40 "Flow simulation in microstructures"), a geometric model of the microstructure must be developed on the basis of 3D-image data.

From these images, the Minkowski functionals and information with respect to direction can be derived. By means of these data, an appropriate model is fitted. If there are no 3D-images available, model parameters must be determined from projections or planar sections.

Geometric model of a fleece.

Filter made of sintered copper.



X-ray tomographic image of an open nickel foam.

In order to describe the microstructure of materials which are homogeneous on a macroscopic scale, models from stochastic geometry are useful, such as Boolean models, line processes, or tessellations. The macroscopic homogeneity is taken into account in so far as only stationary models are used, i. e. the "average" microstructure is identical at each point in space.

Analysis and modeling of Berea sandstone

In the following, the path from a three-dimensional image to a geometric model will be illustrated by a sample of sandstone.

Figure 2 shows that a spherical Boolean model is appropriate for the modeling of the structure. The simplest model uses spheres with a constant radius, i. e. two parameters must be determined: the intensity of the center of the spheres and the radius.

The methods developed for image analysis can be used in order to fit the model to reality in a mathematically correct way, i. e. by the computation of the model parameters from the geometric properties. Miles' equations for the Boolean model provide the relation between the volume and surface density and the model parameters. The densities of the curvature integrals can be used in order to test the quality of the fitted model. Alternatively, a more complex model could be applied with a radius distribution of two or three parameters.

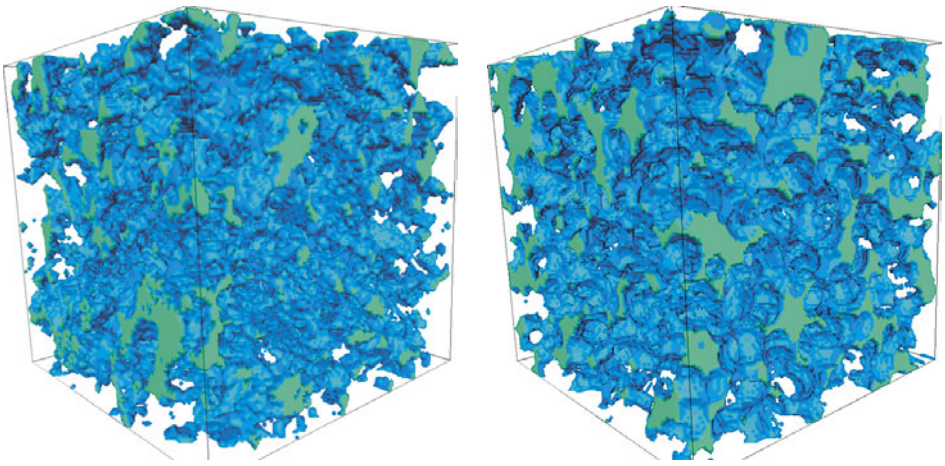


Fig. 2: Left: Tomographic image of a Berea sandstone. Right: Realisation of the fitted Boolean model (Visulization of the pores).

Funding:
Foundation Rhineland-Palatinate for Innovation

Partner:
Imtronic GmbH, Berlin
different companies and research institutes

Contact:
PD Dr. Joachim Ohser
Phone: +49 (0) 6 31/3 66 81-25
E-mail: ohser@itwm.fhg.de
Dr. Katja Schladitz
Phone: +49 (0) 6 31/3 66 81-33
E-mail: schladitz@itwm.fhg.de

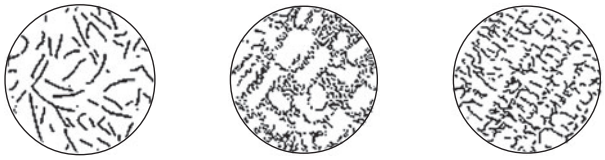
Classification of lamellar graphite in grey cast iron

By order of the Mannesmann-Rexroth foundry, a method for the automatic classification of lamellar graphite with respect to structure has been developed, i. e. with respect to the percentage of A-, D- and E-graphite according to EN ISO945: 1994.

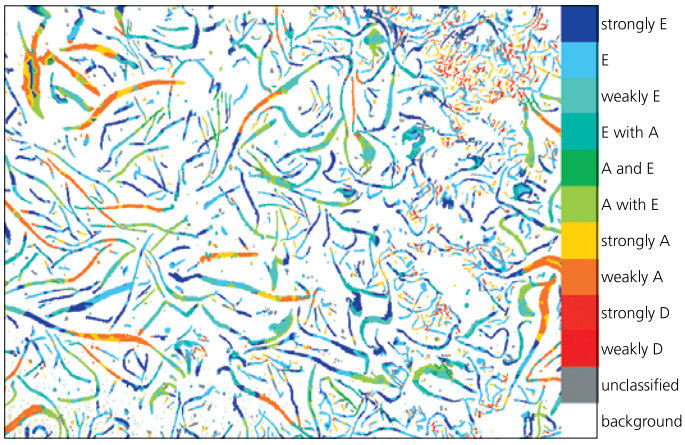
Up to now, the graphite evaluation of lamellar graphite is carried out visually by standard series images. This visual evaluation is not only time-consuming, it is also open for subjective interpretations and therefore not reproducible.

The automatic method was developed on the basis of sixty carefully binarized and classified images of mixed structures. First, each graphite pixel was assigned to one of 64 geometric types of neighborhood. This geometric classification is exclusively based on morphological operations in order to avoid instable object isolation. In an adaptive step using the visual classification given by Mannesmann-Rexroth, the geometric classes were assigned to the types of graphite.

The quality of the automatic classification was evaluated on the basis of another sixty images of mixed structures. The automatic classification comes closer to the visual classification of Mannesmann-Rexroth than comparative visual classifications. Hence, it was proved that the automatic classification of lamellar graphite can actually be applied in industrial production. Our method can thus contribute to an objective evaluation of graphite precipitations.



Standard series images for A-, D- and E-graphite.



Color coded geometric classification.
Automatic classification: 33 % A-, 6 % D-, 59 % E-graphite.
Visual classification by Mannesmann-Rexroth: 30 % A-, 10 % D-, 60 % E-graphite.

Partner:

Mannesmann-Rexroth AG, Lohr

University of Applied Sciences, Darmstadt

Contact:

PD Dr. Joachim Ohser
Phone: +49 (0) 6 31/3 66 81-25
E-mail: ohser@itwm.fhg.de

Dr. Katja Schladitz
Phone: +49 (0) 6 31/3 66 81-33
E-mail: schladitz@itwm.fhg.de

Data Compression with Wavelet Methods

ARGUS: image and video data compression

In the project ARGUS, the development of a data compression system has been continued. It has been integrated into a digital media archive.

Dealing with digital images and videos, scientists and engineers have found out that an image does not only express more than thousand words can do, but also that many thousand bytes of memory are necessary in order to save an image. Working with digital image and video material, one is very soon confronted with problems of data management, archives, data transfer or retrieval. Therefore, the application of digital images urgently implies the need for data compression.

The compression system is based on wavelet methods. Wavelets are a mathematical method for splitting a signal into different resolutions. A wavelet transformation provides the rough resolution image plus the series of detail images. The images have only the same size as the original image. If all the detail images are added to the rough image again, the result is the original image without any loss of data. The rough image and the series of detail images are then quantized in a second step. Quantization means that the halftones of the images are represented less precisely than originally computed. Here, we concentrate on eliminating only redundant data and saving the information content at the same time.

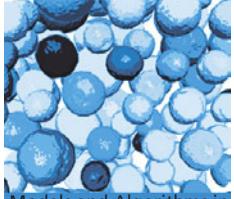
The ITWM has applied for a patent for the quantization method used in the project ARGUS (Cross Band Coding), and has examined the potential for improvement on its own expense.

Another objective of the project was the development of a compression service within an object-oriented distributed infrastructure, the so-called media archive®. It is a content management system with a client-server architecture and thus designed in order to recognize media objects with respect to their content and to file them in archives. The media archive is applied in the field of broadcasting, in production studios, in post production, in news, film and photo agencies, and in multimedia library systems.

Comparison between original picture and compressed picture (ratio 1:100).

Partner:
tecmath AG, Kaiserslautern

Contact:
Dr. Axel Becker
Phone: +49 (0) 6 31/3 66 81-31
E-mail: becker@itwm.fhg.de



Models and Algorithms in Image Processing

HECC: hyperelliptic curve cryptography

In order to guarantee the protection of information from unauthorized access in a time relying on electronic data transfer, a continuous development and refining of cryptographic methods is necessary. The application of public key cryptosystems plays an important part in reaching the objective of a secure communication.

The security of many public key cryptosystems is based on the difficulty of computing the discrete logarithm in finite Abelian groups. Here, the selection of the group is decisive. The initally proposed multiplicative groups of finite fields turned out to be not appropriate for cryptography. Here, the index calculus method yields a subexponential algorithm for the computation of the discrete logarithm, so that for these systems very large keys are necessary in order to ensure acceptable security.

The group of national points on elliptic curves avoid this problem because index calculus methods are useless here and no further subexponential algorithms for the computation of the discrete logarithm are known. Hence, they are the foundation for cryptosystems which guarantee the same security as, e. g., the actually leading system RSA, at the same time requiring essentially smaller keys. This makes them especially interesting for Smart Cards and other environments where only a limited memory is available. The run time behavior of elliptic curve cryptosystems also shows considerable advantages, thus they have become a serious competitor for RSA.

As a generalization of elliptic curves, hyperelliptic curves yield cryptosystems which at least warrant identical security. Due to their high flexibility with respect to the selection of parameters, they might substitute elliptic curve cryptography, should the latter prove to be insecure. Furthermore, they promise a better run time behavior because multiprecision arithmetic might become unnecessary.

While there are many theoretical results for elliptic curves, today we do not yet know enough about hyperelliptic curves in order to realize efficient cryptography in practice. In particular, no satisfying algorithms have been developed yet for the computation of appropriate curves. Besides, group arithmetic should be made faster in order to enable comfortable encryption and decryption times.

A prototype of such a system which we have implemented shows that it is possible to develop hyperelliptic curve cryptosystems which can be used in practice.

Our actual main research objectives now are the development of methods for the determination of hyperelliptic curves suitable for cryptography, and of a faster arithmetic.

Cryptographic tools play a decisive role in network security.

Partner:

BGS Systemplanung AG, Mainz

Contact:

Dipl.-Math. Norbert Göb
Phone: +49 (0) 6 31/3 66 81-31
E-mail: goeb@itwm.fhg.de

Dipl.-Math. Georg Kux
Phone: +49 (0) 6 31/3 66 81-23
E-mail: kux@itwm.fhg.de

Monitoring for Railway Systems

A close cooperation in the field of railways connects the ITWM and GE Harris Harmon Railway Technology, Bad Dürkheim. Within the last ten years, there have been different common projects. Here, the ITWM develops software for mostly LINUX-based systems for control and measurement. Especially important is the chassis monitoring sleeper (FÜS). This system is already applied in practice at a few hundred locations throughout Europe. Apart from developing extensive methods for signal analysis, the ITWM implements and supports the entire software.

Chassis monitoring sleeper

The control of overheated axle bearings and stationary brakes on passenger and freight trains requires a remote measurement method (see Figure 3).

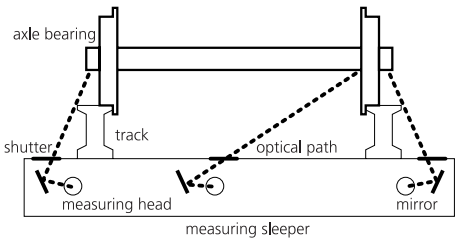
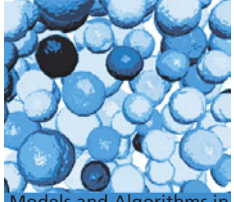


Fig. 3: Measuring process.

In the solution chosen here, the temperatures are measured by sensoring the infrared profile of the passing running gears. The A/D-values taken by an IR-sensor are transferred to the PC, where the temperatures are computed by the method described below.

Since these systems work without being permanently controled, apart from the pure measuring process, an appropriate self diagnosis system of the respective hardware and software must be integrated, as well as an exception and error handling system.

During the measurement, a large amount of data must be registered and evaluated. Changing sensor properties require a calibration and periodic recalibration. It is also evident that without calibrating and recalibrating the sensors, no exact measuring values can be registered, resulting in a wrong profile



of the curve. It can also occur that not only the values for one wheel are sensored, but also other external values (radiation from other objects) like reflection of the sun or brake blocks. For these cases, there are special methods in order to determine the correct temperature of the wheels and bearings. For the single steps of the data processing of the measured signals, please refer to the report of 1998.

The development and implementation of the algorithms had to account for the very high reliability requirements. The algorithms are continually refined and completed by further modules. The flexibility of the entire system is also improved.

Facility in the track.

System environment

The main server consists of an industrial PC and of special additional components with the operating system LINUX.

Apart from the software necessary for the evaluation process, further software packages, such as system diagnosis programs, drivers, user interfaces and server software have been developed. (For details, please refer to the ITWM report 1998, p. 37 and following pages.)

Application

The system is already applied in practice at approximately 350 locations in several European countries.

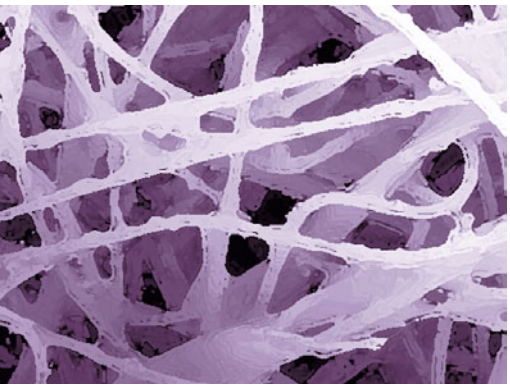
Partner:

GE Harris Harmon Railway Technology GmbH & Co. KG, Bad Dürkheim

Contact:

Dipl.-Math. Kai Krüger
Phone: +49 (0) 6 31/3 66 81-19
E-mail: krueger@itwm.fhg.de

Department of Flow in Complex Structures



In the department "Flow in Complex Structures", mathematical models and algorithms for the simulation and optimization of mainly flow dynamical processes in complex structures are developed. Special emphasis is directed towards the fields of porous materials (in particular, technical textiles) and filling processes (especially casting simulation of polymers and metals). Since the foundation of the department in the spring of 1999, five research areas have been established which will be described in detail in the following.

Simulation of porous materials

The projects deal with the design and optimization of technical textiles in very different fields, ranging from filter industries to the production of paper and diapers.

Virtual material design

With the tool of microstructure simulation, porous materials (fleeces, papers, foams) can be optimized with respect to their material properties.

Filling and casting processes

The simulation of filling processes, which involve the special difficulty of the numerical treatment of free surfaces, is the main competence of this research group. Apart from metal casting, an actual application is injection molding of fiber reinforced plastic parts.


Dr. Franz-Josef Pfreundt


Dr. Konrad Steiner


Dr. Irina Ginzburg


Dipl.-Math. Michael Hilden


Dr. Oleg Iliev


Dipl.-Math. Dirk Kehrwald


Dr. Peter Klein


M.Sc. Vsevelod Laptev


Dr.-Ing. Joachim Linn

Flow in
Complex Structures

High-water and risk management

For critical high-water situations, e. g., the overflow of sewerage systems or cellars, appropriate simulation methods are developed and a planning tool for municipalities and insurance companies is provided.

Parallel computing and visualization

The complicated flow simulations in complex structures require the use of parallel computer systems. Here, parallel algorithms are developed particularly for PC clusters.

Research activities

The emphasis of the scientific research is the further development of the generalized Lattice-Boltzmann method (LBM). LBM is appropriate in particular for flow simulations in geometrically complicated structures, as they occur in the department-specific applications (microstructure simulation, filling processes). The research takes place in close cooperation with the research group Technomathematics of the University of Kaiserslautern, and within a recently founded research association of the German Research Foundation (DFG).

Contact:

Dr. Konrad Steiner
Head of Department
Phone: +49 (0) 6 31/2 05-40 80
E-mail: steiner@itwm.fhg.de

Dr.-Ing.
Carsten Lojewski

Dr. Klaus-Peter Nieschulz

Dr. Doris
Reinel-Bitzer

Dipl.-Phys. Martin
Rheinländer

Dipl.-Math.
Stefan Rief

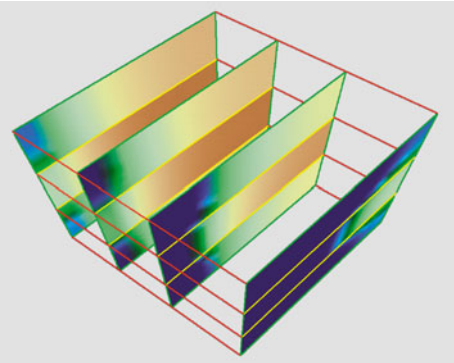
M.Sc.
Dimiter Stoyanov

Dr. Ramiro Guerra
Valdes

Dr. Andreas
Wiegmann

Dr. Aivars Zemitis

Simulation of Porous Material



Saturations in different cross-sections of a 3D multilayered material. (Simulations with VSIM).

Processes and applications

Porous materials play a key role in a large number of industrial processes. Our research work is mainly focused on textile materials, paper and membranes – it is, however, not restricted to these areas. The modeling and simulation of transport processes in porous materials is the main competence of this research group. Actual projects deal with the design and optimization of technical textiles for the production of filters, paper, diapers and fleeces.

Mathematical models and methods

The mathematical model of a saturated flow in porous media is based on Darcy's law. For an unsaturated flow, the special case of the Richards equation is considered. Special models for elastic porous materials are used for the computation of deformations. In any case, the material parameters (e. g., permeability) can be computed by the simulation of the microstructures (cf. p. 40, "Virtual material design").

In the case of non-isothermal processes, convection-diffusion equations are applied. The fictitious domain method and the level set method are used for complex geometries and/or moving boundaries.

VSIM – Flow in multilayer porous materials

In order to improve properties with respect to liquid or moisture transport, textile layers with different properties are often combined with each other (or with a membrane). Such combinations can, e. g., be found in the production of clothes and shoes and in the building industry.

Here, the already existing software tool VSIM for the simulation of saturated and unsaturated flows in a multilayer porous parallelepiped has been further refined. VSIM has a user-friendly interface and an extended data base with respect to textile materials and parameterizations (see ITWM reports 1998 and 1999).

For the simulation of certain specific problems, research software is developed which can be completed with a user-friendly interface and delivered upon request.

Flow in
Complex Structures

Liquid transport in diapers with superabsorbent polymers

Superabsorbent polymers (SAP) are used for hygienic materials in order to absorb liquids. The ratio of the absorption of free liquids by SAP and their swelling ratio are decisive for the performance of these materials. Usually, the absorption of liquids by SAP is modeled by a first order ordinary differential equation. The respective sink term appears in the Richards equation. Currently, the swelling of the SAP is accounted for by volume balances.

The simulation of the liquid transport in diapers in the presence of superabsorbent polymers allows the prediction of their performance with respect to the

- rate and amount of the absorbed liquid,
- amount of free liquid,
- occurrence of gel-blocking etc.

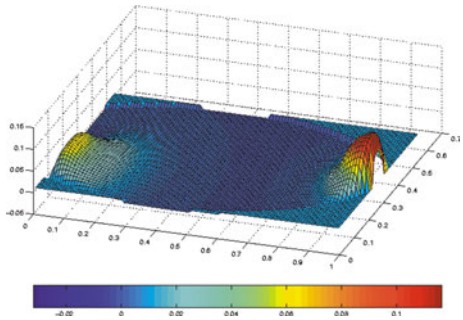
Type, amount and distribution of the SAP in a diaper can be optimized by numerical simulation.

Liquid transport in filters

One objective is the improvement of oil filter design by examining the ratio between the mass flux through an oil filter and the pressure drop, as well as the space distribution of the mass flux through the porous filter sheet.

The flow in liquid and porous media is modeled by the Navier-Stokes equations in purely liquid areas, and by the Brinkmann equation in saturated porous media. The numerical solution results from a fictitious domain approach and a finite volume discretization of the entire area.

The simulation of oil flow through a filter gives information about the local velocity and pressure distribution. The computation of the mass flux through the filter sheet shows how heavily the different areas of the filter are loaded. By a variation of the filter box shape, filters with a more uniform loading can be designed.

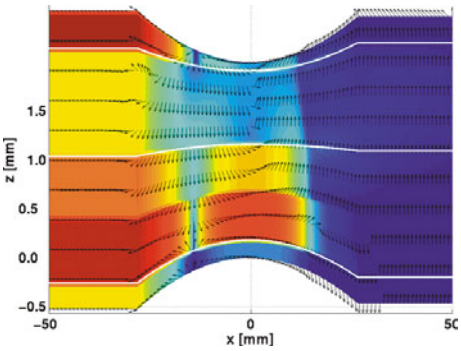


Distribution of the mass flux from the upper surface of an oil filter.
(Simulations of 3D flow in a filter box).

Contact:

Dr. Aivars Zemitis
Phone: +49 (0) 6 31/2 05-41 91
E-mail: zemitis@itwm.fhg.de

Dr. Oleg Iliev
Phone: +49 (0) 6 31/2 05-28 51
E-mail: iliev@itwm.fhg.de



Water flow in the pressnib.

Simulation of the press section of paper machines

Being 6-10 m wide and up to 200 m long, the paper machine is in the center of paper production. Main components are the forming section, press section and dryer section. In the forming section, the fiber suspension with a liquid fraction of up to 99 % is deposited on the forming fabric. By natural draining and the application of a suction box, the moisture is reduced to 80 %. In the press section, the paper layer, which is transported on a felt, is pressed, and in the dryer section, the moisture is again reduced from 50 % to approximately 5-8 % by means of steam-heated cylinders.

Press section

The importance of the press section is evident if we compare the costs of pressing and the costs in the case of thermal dewatering, which are more than ten times higher. The press section functions in the following way: the paper layer is transported through the press aperture on a felt. The paper-felt sandwich is then compressed, so that the water is pressed from the paper and absorbed by the felt. From the construction of the press to the design of the felt, there are innumerable factors which can influence the dewatering performance. Here, the felt has a key role. The base weave, which must be very stable from a mechanical point of view, must, e. g., also meet the requirements of high machine velocities (up to 2000 $m \cdot min^{-1}$) and be constructed in such a way that there is enough retaining capacity for the water pressed from the paper layer. Besides, the construction of the felt must also account for anisotropic permeabilities with respect to liquids, so that the dewatering flows in the aperture can be controled.

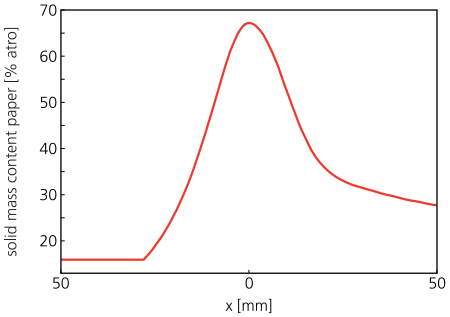
Modeling and simulation

Real tests of a new felt design are expensive and time-consuming. Here, mathematical modeling and computer simulation are intended to be an important tool for a fast and cheap previous testing and selection of new felts for paper machines on the computer.

The paper-felt sandwich is modeled as an elastic porous medium. The necessary material parameters like the permeabilities of the medium with respect to fluids, the visco-elastic parameters of the felt etc. are on the one hand determined by measurements. On the other hand, however, the flow parameters can also be computed by microstructure simulation at the ITWM. This independence from real measurements is of decisive importance particularly for the design of future felts. The validation of these virtual measurements is in good correspondence with existing data.

Results

By means of simulation, a comparative study of different real types of felt was carried out, which have been classified according to their dewatering performance. The quality of the classification corresponds very well to practical experience.



Varying solid mass content of paper.

Partner:
Thomas Josef Heimbach GmbH & Co., Düren

Contact:
Dipl.-Math. Stefan Rief
Phone: +49(0) 6 31/205-41 91
E-mail: rief@itwm.fhg.de

Simulation of drop distribution in the case of pharmaceutical sprays

Modern medicines are produced in different forms. This project deals with a propellant-free nebulizer which produces a finely dispersed, "soft" spray for the therapy of lung diseases (e. g., asthma, COPD). Here, the dose of the medicines and the distribution of drops in the spray are decisive. These two properties depend on the flow-specific conditions. The formation of drops in the spray is a very complex process. Therefore, apart from complicated measurements, theoretical studies are also necessary for a complete understanding of the nebulizer.

Spray "Respimat" – consisting of a mouthpiece with nozzle, a cartridge and a bottom part.

Method

Mathematical models and simulations are important tools for a better understanding of the laws to which the nebulizer is subject. The formation of drops within the device is based on the collision of two jets of liquid, which form a liquid film. Due to hydrodynamical instabilities, drops are formed at the boundary of this liquid film. Mathematical simulations allow the specific examination of the single steps of drop formation. In the course of the project for the determination of the spray properties, a specific software was developed, and software packages like FastFLO® and FLUENT® were used. Figure 1 shows the velocity field in the case of interaction between the liquid film and an obstacle.

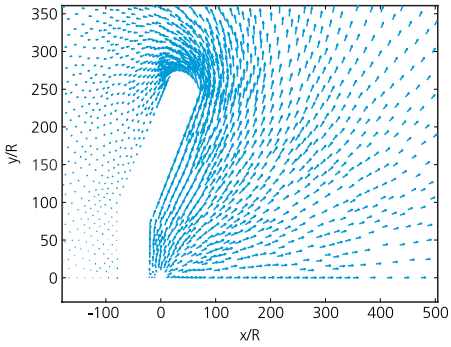


Fig. 1: Flow around an obstacle.

The development of a mathematical model accounting for the interaction between the liquid film and the nebulizer was an important part of the project. Here, a model was proposed which also simulates the reflection of the liquid film at the surface of the device. The form of the film was determined by the solution of differential equations. The simulated curve and a microscopic image of the liquid film are shown in Figure 2.

Results

During the project, already existing models for the determination of the drop spectrum were refined. Thus, parameters of the spray (e. g., the fraction which can be inhaled) could be determined. Different properties of the nebulizer were varied, and the respective simulations were carried out. Thus, trends for the further development and improvement of the device could be identified.

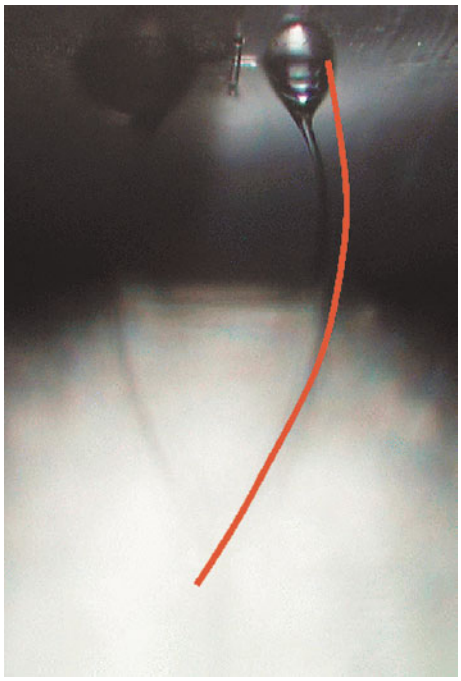


Fig. 2: Photo of the liquid film. The red curve corresponds to simulation.

Partner:

Boehringer Ingelheim, Ingelheim am Rhein

Contact:

Dr. Aivars Zemitis
Phone: +49 (0) 6 31/2 05-41 91
E-mail: zemitis@itwm.fhg.de

Dr. Oleg Iliev
Phone: +49 (0) 6 31/2 05-28 51
E-mail: iliev@itwm.fhg.de

Flow simulation in microstructures

Flow simulation in microstructures is very important because it allows the reduction of costs and time necessary for the development of new and improvement of existing materials, such as foams, fleeces, papers, felts and ceramics. When innovative products like filters, insulation materials or catalysts are developed, one often takes advantage of the macroscopic properties of these materials which are heterogeneous on a microscopic scale. The microstructure simulations connect the microscopic and macroscopic properties.

First, 3D-images of small sections of the material (with edge lengths of only a few millimeters) or small sections from realizations of material models (cf. p. 58, "3D-image analysis and modeling of microstructures") are simulated on the computer (see Fig. 3). Then, by means of special mathematical methods, i. e. the Lattice-Boltzmann method for the Navier-Stokes equations, which is particularly appropriate in the case of flows in complex geometries (cf. p. 45, "Modeling of mold filling processes by the Lattice-Boltzmann method"), and the mathematical method of homogenization, macroscopic material properties (e. g., permeability, capillary pressure, sound absorption) are computed from the flow through the microscopic structure. Figure 5 on page 42 shows an example for measured acoustic absorption properties of a fleece, and the acoustic absorption properties predicted by microstructure simulation for the same fleece.

Possibilities of flow simulation in microstructures

By simulation studies of variations of the material geometry (solid fraction, pore size etc.) and variations of the material properties (wetting properties, viscosity etc.), changes of important parameters depending on the material properties which have been varied, can be determined. In contrast to laboratory experiments, each single property can be controled and varied. Thus, production parameters with respect to technical requirements of components can be optimized, with respect to the material design.

During a verification and gauging phase, the results of the flow simulation are compared to measurements of exemplary samples of the real material.

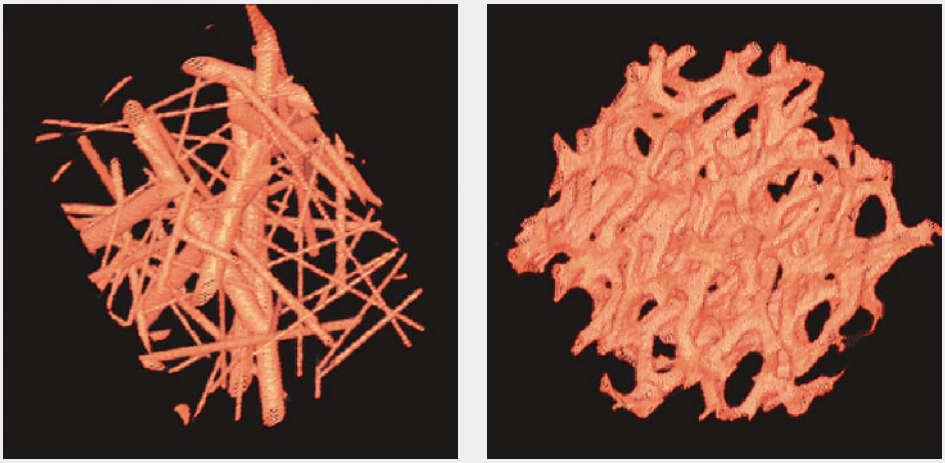


Fig. 3: Geometries where fluid dynamical simulations are performed.
left: simulated fiber material, right: tomographical image of a foam.

Flow in
Complex Structures

Flow simulation is possible for digital, three-dimensional images of the material, as well as for three-dimensional geometry models of the materials. At the ITWM, there are geometry models for different types of material (fiber materials, foams, grained materials) which account for the characteristic properties of these materials (e. g., porosity, radii of the fibers) – see p. 59, "Modeling of microstructures". Figure 3 (left) shows the model of an anisotropic fiber material with a given fiber radius distribution, Figure 3 (right) shows the image of a foam. If necessary, new models can be developed at the ITWM which are specifically designed in order to meet the customer's needs.

The flow simulation can be carried out for one-phase flows (e. g., air) and two-phase flows (e. g., water/air, oil/air).

The latest visualization techniques can illustrate the internal processes of the material and help to understand the technical relations.

Know-how of the ITWM

- knowledge of mathematical models (flow mechanics, acoustics, ...) and their numerically correct implementation,
- contacts to image-acquiring companies and especially to institutes of the Fraunhofer Society which are able to analyze microstructures or which are experienced in using them, e. g., Fraunhofer Institute for Destruction-Free Test Methods IZFP,
- fast software (cf. p. 49, "Parallel computing and visualization") and the corresponding computing power in order to be able to carry out detailed studies with good results,
- visualization and internet technology (see p. 51, "Visualization of dynamical and static volume data"), so that results can be presented fast and in a way which is easy to understand, and can be transferred back from the model to the application,
- due to the above mentioned know-how, capacity to be a competent partner and project coordinator of complex projects integrating many partners.

In the field of "Microstructure simulations", two master's theses are currently prepared with the subjects "Effective elasticity modules of microstructures" and "Fast solvers for states of equilibrium of the Stokes and Navier-Stokes equations". The results of this research will be applied later in the course of industrial cooperation projects.

The results of microstructure simulation are already used in several current projects with different industrial and research partners.

Partner:

Manufacturer of nonwovens

Filterwerk Mann+Hummel GmbH, Speyer

Contact:

Dr. Doris Reinel-Bitzer
Phone: +49 (0) 6 31/2 05-41 28
E-mail: reinel_bitzer@itwm.fhg.de

Dr. Andreas Wiegmann
Phone: +49 (0) 6 31/2 05-38 85
E-mail: wiegmann@itwm.fhg.de

Flow of air and oil in filters

Filters designed in order to de-oil air consist of different layers of glass fiber papers and nonwovens. The different material properties are decisive for the functioning of the filter. The objective is the development of a filter for a minimum residual oil fraction at a minimum pressure drop. First, the properties of glass fiber papers are determined by microstructure simulations. Figure 4 (left) shows the oil distribution in an anisotropic paper of the porosity 0.94. The oil is not wetting the fibers, i. e., drops are formed. If, however, the oil has wetting properties, oil layers develop along the fibers (see Fig. 4 right). Now, the average air velocity in the system is computed, which allows the determination of the relative permeability for different oil saturations. Besides, the capillary pressure for a given oil saturation can be computed from the pressure distribution. The permeability curve and the capillary pressure curve are the necessary input for a macroscopic simulation tool, which can compute characteristic properties of oil filters.

Acoustic absorption properties of fleeces

The acoustic absorption properties of technical textiles can be predicted from flow simulation results. First, models of the textiles are developed on the basis of microscopic and tomographic images, which are then used for the computation of material properties by flow simulation. These properties are necessary for the acoustic models. The correct prediction of acoustic absorption on the basis of the microstructure has been proved in the course of a publicly funded project in cooperation with a textile-producing company. According to the needs of our industrial partner, a tool is currently refined which is able to predict and optimize acoustic properties of certain technical textiles by appropriate acoustic models on the basis of flow simulations in microstructures, as well as on the basis of appropriate measurements.

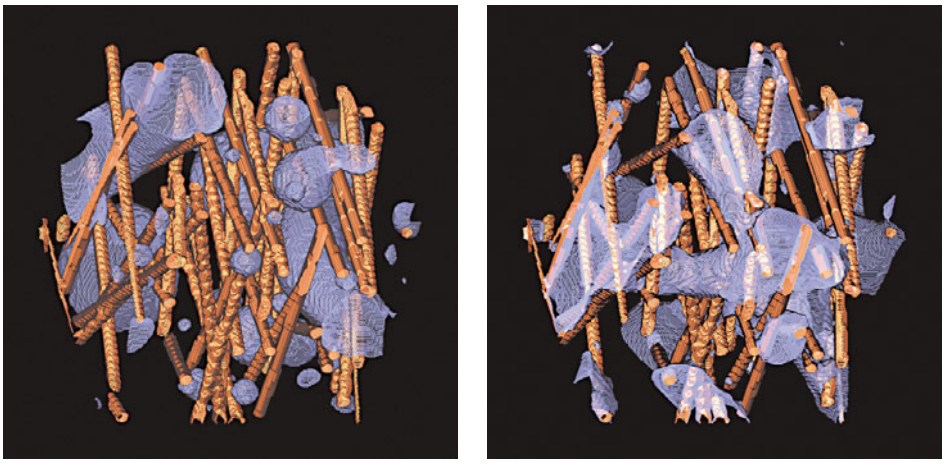


Fig. 4: Oil distribution in an anisotropic fibrous material.
left: oil is non-wetting, right: oil is wetting.

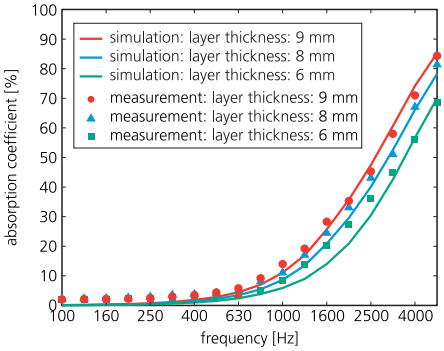


Fig. 5: View of measured absorption profiles and predictions based on microstructure simulation.

Flow around filaments in melt spinning processes

In the case of spinning machines for synthetic filaments (see Fig. 6), a polymer melt is extruded from several nozzles. The filaments are then cooled down by an air flow. The uniformity of the air flow is essential for the quality of the filaments. The objective is the optimization of the machines with respect to higher spinning velocities and filament densities at a constant quality level.

Simulation method

For the simulation of the spinning process, two different programs, which have been developed at the ITWM, are coupled. In the fiber module, a polymer filament is described as a free, viscous liquid jet. From the equations for mass, impulse and energy, temperatures, velocities and radii of the filaments can be computed. The data are determined for each filament of the nozzle plate. The temperatures and frictional forces of the filaments are then accounted for as sources of heat and local forces in the flow simulations of the air.

In the fluid dynamical tool, the flow of air around the filaments is computed by the Lattice-Boltzmann method (see p. 40, "Flow simulation in microstructures", and p. 45, "Modeling of mold filling processes by the Lattice-Boltzmann method"). Then, the resulting temperatures and velocities of the air at the positions of the filaments are again used as input for the fiber module etc. The frictional forces and heat transitions necessary for the coupling have been derived in the PhD-thesis of Thomas Götz for the special case of thin filaments.

Results

The simulation method was tested first by a comparison with experiments for different nozzle configurations. Figure 7 shows the filament temperature of the last row as a function of the distance from the nozzle in the case of six and twelve rows. If the rows are staggered, the cooling behavior is better than if the nozzles are positioned directly behind each other.

Additionally, the simulation program was validated by a comparison with experiments for three different polymers (PP, PET and PA) and for different air profiles.

Now, different nozzle configurations, air shaft geometries and air profiles can be simulated with the tested simulation tool, and the results can be compared in order to find an optimum spinning configuration.

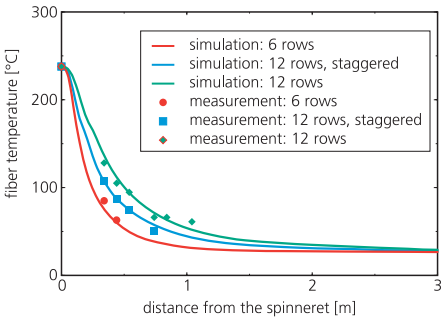


Fig. 7: Fiber temperature.

Fig. 6: Spinning machine of NEUMAG.

Partner:

NEUMAG GmbH, Neumünster

Contact:

Dr. Doris Reinel-Bitzer
Phone: +49 (0) 6 31/2 05-41 28
E-mail: reinel_bitzer@itwm.fhg.de

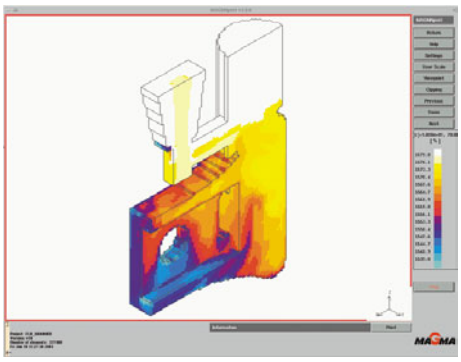


Fig. 8: Simulation of the temperature distribution in a hammer box using the ParPac solver integrated in MAGMASOFT®.

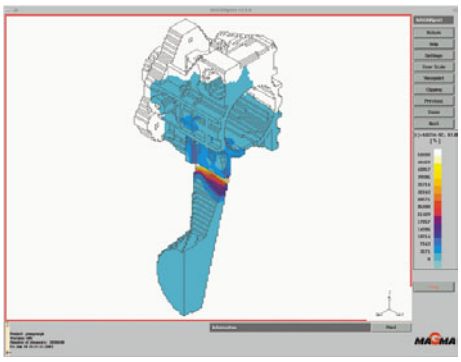


Fig. 9: Modulus of the flow velocity in a bump housing (result of a ParPac calculation).

Already since the beginning of 1996, the simulation of filling and casting processes has been a subject for research at the ITWM. Different projects with respect to solidification simulation have been carried out (see ITWM reports 1996 to 1999). Apart from individual computations by order of customers, carried out for different foundries with the software package MAGMASOFT® (mostly in smaller projects of demonstration character), from the beginning the main intention of the ITWM has been focused on scientific consulting. The emphasis of our work is the support of regional foundries, who are already using the software package MAGMASOFT, in the case of specific problems occurring with respect to the application of the software in everyday practice. For many years now, customers of the ITWM have been the companies HegerGuss and PHB Stahlguss. Because the common projects have been finished successfully, both companies intend to remain clients of the ITWM also for a medium-term range, taking advantage of the support with respect to the simulation of company-specific casting processes, so that successive projects have been agreed on.

The above mentioned activity of the ITWM was the basis for different projects in the field of casting processes. For example, a cooperation with the two foundries mentioned above was arranged, resulting in common projects with respect to the optimization of intra-company processes (see article in the report 1999 about the projects in the fields of preliminary costing / classification of molded parts and process simulation / timing of orders). Together with the company MAGMA, different projects were carried out successfully, supporting the improvement of the simulation program MAGMASOFT by the development and implementation of alternative numerical methods. Examples are the projects of software parallelization (see reports 1998/1999 with respect to the PARMAG project) and development of an alternative solver for the solidification simulation (see report 1999), projects which have been finished in the last few years. Currently, MAGMA and the ITWM are cooperating in the project ParPac. In the course of this project, the ITWM develops an adapted version of the Lattice-Boltzmann method which is appropriate especially for the modeling of mold filling processes during the casting of metals (see following page).

From many points of view, the equations for the modeling of mold filling processes during injection molding of synthetics are very similar to the equations for the filling process during the casting of metals. In both cases, there are coupled heat transfer and flow problems with a free surface. The main differences result from the rheology of the respective fluids. With respect to injection molding of fiber reinforced thermoplastics, not only the flow of the fluid ought to be computed, but also the distribution and orientation of the fibers in the thermoplast melt. Since the beginning of 1999, there is a cooperation in this field between the ITWM and the company MAGMA, and the Institute for Composite Materials (IVW) of the University of Kaiserslautern. At the ITWM, a software for the computation of the fiber orientation during injection molding of fiber reinforced thermoplastics (see p. 46, "Computation of the fiber orientation during injection molding of fiber reinforced thermoplastics") has been developed in close collaboration with MAGMA. The resulting software has also been implemented into the program SIGMASOFT® via an adequate interface.

Flow in
Complex Structures

Modeling of mold filling processes by the Lattice-Boltzmann method

Within the project ParPac, funded by the BMBF (Federal Ministry for Education and Research), a Lattice-Boltzmann method (LB method) was introduced for the simulation of the filling process, by means of which free surfaces can also be handled. The method is based on the reconstruction of the unknown occupation numbers at the surface by a type of Chapman-Enskog expansion, whose coefficients are determined by the boundary conditions for the interface between a liquid and a gas. Because instabilities occurred for high Reynolds numbers, we concentrated first on the construction of stabilized numerical schemes.

Up to now, three different variants have been considered:

The first method ("explicit upwind") consisted in replacing the kinematic viscosity ν with $\nu + \nu^{num}(Pe)$, where the numerical diffusion locally depends on the Peclet number.

In order to reduce the crosswind diffusion occurring in the case of more than one space dimensions, in the second approach the equilibrium distribution in the LB equation was formulated in such a way that the resulting macroscopic equations can contain different correction terms with respect to the diffusion tensor. Thus, LB analogs of full upwind scheme, streamline upwinds and several other methods have been introduced.

As a third possibility for the elimination of fluctuations, we considered the simplest turbulence model:

Smagorinski model:

$$\nu \to \nu + \nu_\Gamma \quad \text{with} \quad \nu_\Gamma = C_s^2 \|\mathbf{D}\|$$

The intrinsic locality of the LB method remains in all the new schemes, because all the components of the strain tensor **D** are differentiated from the non-equilibrium part of the distribution function.

The stabilized schemes are implemented in the ParPac library, being therefore available for all our applications. The structure of the boundary layers in Figure 10 illustrates that the numerical diffusion of the explicit upwind scheme does not influence the physical results too much. A detailed analysis of the stabilized schemes is the subject of a DFG project which has just been started.

The mold filling simulation from ParPac was coupled with the solidification simulation in MAGMASOFT. The energy equation necessary for the solidification simulation was solved by an operator splitting method. The convective heat transport was integrated in the ParPac code. The conductive heat transport is based on the solution in MAGMASOFT. As a first result of such a combined simulation, Figure 8 shows the temperature field of a hammer box.

Under realistic conditions, the compressibility can become extremely high (see Fig. 9). Therefore, within a joint project funded by the BMBF, we examine the possibility of a combination of our method with an adaptive space grid.

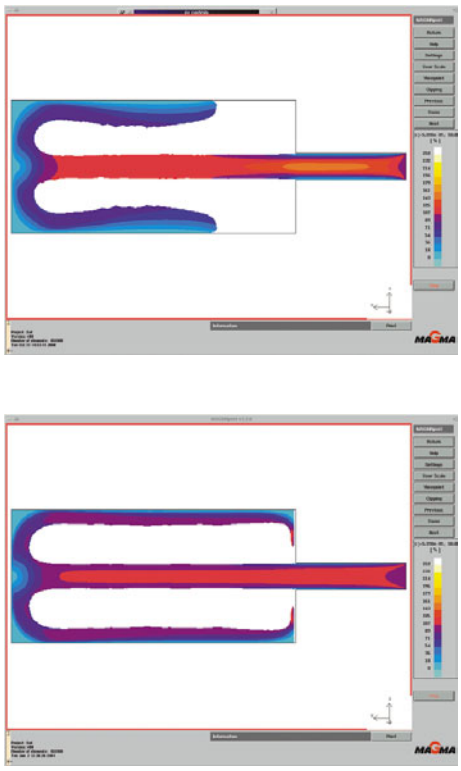


Fig.10: Modulus of the flow velocity in a 2D cavity at 50 % of the overall filling time (inlet velocity: U = 100 cm/s).
above: at Re = 50, viscous effects can be seen,
below: the shell-like boundary layer is typical for a flow dominated by inertial forces (Re = 500).

Partner:

MAGMA Gießereitechnologie GmbH, Aachen

Contact:

Dr. Irina Ginzburg
Phone: +49 (0) 6 31/2 05-41 38
E-mail: ginzburg@itwm.fhg.de

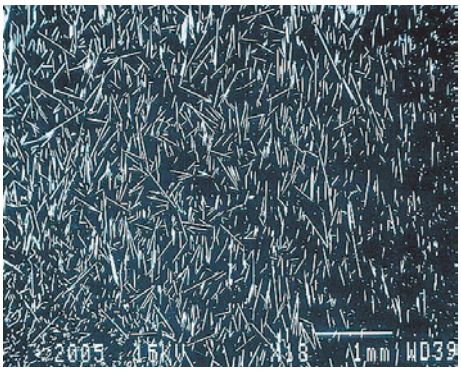


Fig. 11: Planar section surface (size: approx. 1 cm^2) across a fiber reinforced plastic part.

Computation of the fiber orientation during injection molding of fiber reinforced thermoplastics

For the simulation of the production process of injection molded parts consisting of fiber reinforced thermoplastics, the computation of the fiber orientation plays a decisive role. The knowledge about the space distribution and orientation of the reinforcing fiber particles is not only important with respect to the prediction of the anisotropic material properties of the resulting injection molded part. In practice, the fiber volume fraction usually is relatively high, therefore the rheology of the melt (and, thus, the course of the filling process) is also influenced by the orientation and the elastomechanical properties of the individual fibers.

Modeling of the fiber orientation dynamics

A simple approach for the modeling of the orientation dynamics of short fiber particles in a thermoplast melt is based on the description of the movement of rigid (ellipsoid) particles in a viscous fluid (as represented schematically in Fig. 12).

The center of mass of such a particle is influenced by the local flow velocity $\vec{\mathbf{U}}(\vec{\mathbf{r}},t)$ and moves with the fluid, and the particle is rotating around its center of mass under the influence of the local velocity gradient tensor. The rotational movement is described by the movement in space of a unit vector $\vec{\mathbf{p}}$ orientated along the symmetry axis.

In such a model, fibers can be described as "slim" ellipsoids by assuming a numerical value $\ell / d \gg 1$ for the so-called aspect ratio, i. e. the ratio of the length ℓ of the rotational ellipsoid and its diameter d.

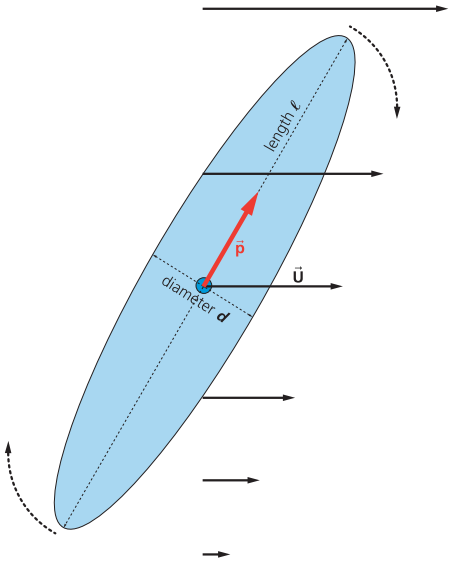


Fig.12: Motion of a rigid ellipsoidal particle under the influence of the local flow field.

Compared to the dimensions of a typical injection molded part, the dimensions of the individual fiber particles are extremely small. On the other hand, the number of fiber particles contained in a relatively small volume compared to the injection molded part, is very large. The micrograph shown in Fig. 11 gives an impression of the dimensions. This is the motivation for a transition to a macroscopic description of the local fiber orientation (FO) by a distribution function $\Psi(\vec{\mathbf{p}},\vec{\mathbf{r}},t)$ defined by averaging with respect to space. Accordingly, instead of the equations of motion of individual fiber particles, the Fokker-Planck equation of the distribution function is considered.

In order to reduce the numerical model for the computation of the orientation distribution to normal dimensions, a expansion of the distribution function according to moments is carried out, and the hierarchy of evolution equations of the moments resulting from this expansion is considered instead of the Fokker-Planck equation for the distribution function. The first non-trivial moment equation of this hierarchy is the so-called "Folgar-Tucker equation" (shortly: FT equation), which contains as a depending variable the matrix,

$$a_{ij}^{(2)}(\vec{\mathbf{r}},t) = \oint_{S^2} d\,\vec{\mathbf{p}}\, p_i p_j\, \Psi(\vec{\mathbf{p}},\vec{\mathbf{r}},t)$$

shortly called "FO tensor". The FO tensor can be determined experimentally - e. g., through the evaluation of micrographs - and gives important information about the local FO distribution which describes its properties to a large extent.

Mathematically, $a_{ij}^{(2)}$ can be characterized as a real, symmetric 3 x 3 matrix whose eigenvalues are all situated in the interval [0,1], and where the sum of the three eigenvalues is always exactly 1. The numerical value of an eigenvalue thus corresponds to the fraction of the fibers orientated locally in the direction of the respective eigenvector, so that the resulting local main orientation direction is the direction of the eigenvector belonging to the largest eigenvalue.

3D computation of flow and fiber orientation in a rib

In many commercial software packages for the simulation of injection molding processes, the flow as well as the fiber dynamics are modeled as 2D processes. This approximation simplifies the numerical computation considerably. However, useful results are only provided for appropriate geometries of the molded parts with uniformly thin walls. For example, a 2D approach is not able to describe "fountain flow effects" which are typical for a non-Newtonian behavior. In practice, these lead to a characteristic layer structure of the fiber orientation (considered realistically in 3D), which again is very important for the development of anisotropic material properties.

For the simulation of injection molded parts whose geometry shows essential three-dimensional properties (e. g., abrupt changes of the wall thickness or ribs), the application of (local) 2D models is no longer possible. In this case, 3D models are necessary for the computation of the flow as well as for the computation of the FO dynamics. An example for these 3D effects occurring for injection molded parts is illustrated in Figure 13, which shows the section of an image representing an area at the foot of a rib. The flow field was simulated with the software package SIGMASOFT, developed by the company MAGMA. Based on the flow field computed during the simulation of the filling process, the fiber orientation was computed according to the FT model. The local FO is represented by the vector of the main orientation direction (see above), and the local fraction of the fibers orientated along this direction is given by the colour scale. The different degree of orientation in the boundary and core layer can be realized very well. Particularly in the rib, a development of the FO can be observed which is caused by the local flow field and cannot be described by a simple 2D model.

Future developments

For a further development of the software module with respect to FO computation, we are planning to account for the effects of the local FO on the rheology of the melt during the computation of the flow field by the application of an anisotropic constitutive material law. This material law completes the scalar viscosity (which is isotropic if the FO effects are not accounted for) by an additive term depending on the components of the FO tensor, which results in an orthotropic viscosity tensor. The modeling of a fiber concentration inhomogeneous in space, which is currently assumed to be constant (as a first approximation) in the "simple" FT model, is also part of the enlarged model. Besides, in a publicly funded research project (in cooperation with the IVW), we will examine whether the model can also be applied to long-fiber reinforced thermoplastics.

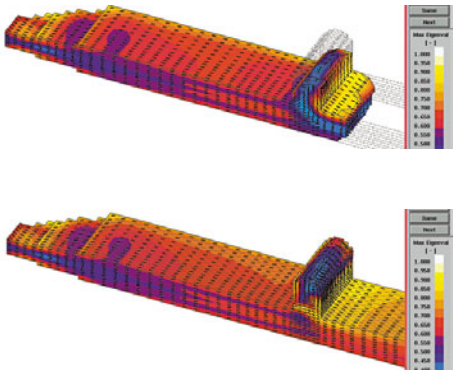


Fig. 13: Visualization of the results of a full 3D calculation of the flow field and the corresponding fiber orientation dynamics during the form filling process of a simple injection molded part using the SIGMASOFT postprocessor.

Partner:

Institut für Verbundwerkstoffe, Kaiserslautern

MAGMA Gießereitechnologie GmbH, Aachen

Contact:

Dr.-Ing. Joachim Linn
Phone: +49 (0) 6 31/2 05-41 36
E-mail: linn@itwm.fhg.de

Flood and Risk Management

Whitsun 2000 in Kindsbach, Germany. (Photo: G. Kries.)

In the case of heavy rainfall, the sewerage systems of housing estates often cannot cope with the large amounts of water. The situation is additionally aggravated by the high water of nearby rivers, and the consequence are large damages of buildings and of the city infrastructure. Here, a series of problems arises which are the subject of our research:

- utilization and overflow of the sewerage system, including possible flow paths at the surface,
- damage quantity and quality, e. g., depending on water level,
- calculatory proof of official regulations (European general water directive, EN 752: "Sewerage systems outside of buildings"),
- planning scenarios for the connection of new building sites to the sewerage systems and for the renewal of entire partial systems,
- problems of the insurance industry, as well as
- emergency management.

Mathematical modeling

These problems are solved by simulation models representing reality. Mathematically speaking, these models are a numerical realization of conservation laws (mass, momentum, maybe heat) which also account for different additional processes (e. g., evaporation). The subjects of our research are the modeling and the numerical treatment of the resulting systems of partial differential equations.

Project RisUrSim

The abbreviation stands for the EUREKA project "Risk Management in Urban Areas – Simulation and Optimization", funded by the Federal Ministry for Education and Research (BMBF).

An international project group headed by the ITWM and consisting of environmental engineers, municipal planning experts, insurance company experts and mathematicians, deals with different aspects of the problems described above. The result will be a software prototype designed as a tool for problem solution and development with respect to actual problems, which will serve municipalities, insurance companies and scientists at the same time.

Inundation of obstacles

The modeling of water flow is the subject of a PhD-thesis prepared by Michael Hilden. Usually, for the computation of inundation scenarios in urban areas, shallow water equations are applied where the vertical velocity components are neglected.

If water flows out of gully holes or across curbstones, these assumptions do not hold. In extreme cases, wrong results can lead to wrong statements (a cellar is inundated or not).

Currently, promising modification approaches of the shallow water equations are developed and tested.

Funding:

Federal Ministry for Education and Research
EUREKA/COST

Partner:

NTNU Trondheim (N), Dep. of Hydraulic and Environmental Engineering

University of Kaiserslautern,
Institute of Environmental Engineering

SINTEF Civil and Environmental Engineering, Trondheim (N)

Deutsche Rückversicherung AG, Düsseldorf

Stadtentwässerung of Cities of Kaiserslautern and Trondheim (N)

Contact:

Dr. Klaus-Peter Nieschulz
Phone: +49 (0) 6 31/2 05-40 01
E-mail: nieschulz@itwm.fhg.de

Parallel Computing and Visualization

Flow in Complex Structures

A few years ago, parallel computing took place almost exclusively in the fields of public research, meteorology, and at the sites of only a few large enterprises. Due to initiatives of the European Union and the increasing importance of simulation in industry, today the use of parallel systems is also possible in a commercial environment. The growing computing power of PCs and the possibility of connecting them through a network to PC clusters was an essential contribution to this process.

The ITWM is one of the pioneers with respect to the use of PC clusters in connection with industrial simulation problems. Already in 1995, first systems with applications developed at the ITWM on the basis of an individual LINUX distribution were delivered to customers. Today, the ITWM uses a PC cluster system of 64 CPUs and a high velocity network for the development of parallel software and the solution of industrial computation problems.

Currently, software packages developed at the ITWM are in principle prepared for parallel computer systems. Besides, existing commercial software packages are "parallelized" by the order of customers. The research is focused on the fields of parallel algorithms, dynamical load balancing, object-oriented software structures for parallel software, as well as on special aspects of cluster computing.

Large computing problems produce large amounts of data, which must be managed and analyzed efficiently. Therefore, the interactive visualization of these data is extremely important. The ITWM has developed a very fast, parallel method for the volume visualization on standard PC hardware under LINUX, which shows a way out of the visualization problem actually caused by often expensive special hardware and expensive computer components (cf. p. 51, "Visualization of dynamical and static volume data").

The activities of the year 2001 will be focused not only on the further development and expansion of the software basis, but also on a better combination of visualization and simulation, the development of grid applications (distributed computing on the internet), as well as on the improvement of the existing computing power.

The ITWM Myrinet-Cluster.

Contact:

Dr. Franz-Josef Pfreundt
Phone: +49 (0) 6 31/2 05-27 44
E-mail: pfreundt@itwm.fhg.de

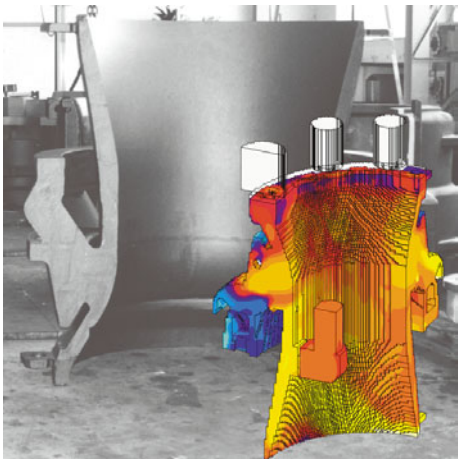
Dr. Peter Klein
Phone: +49 (0) 6 31/2 05-38 85
E-mail: klein@itwm.fhg.de

Dr. Carsten Lojewski
Phone: +49 (0) 6 31/2 05-41 28
E-mail: lojewski@itwm.fhg.de

Dipl.-Math. Dimitar Stoyanov
Phone: +49 (0) 6 31/2 05-41 90
E-mail: stoyanov@itwm.fhg.de

Part time employees:

Hwang Hu
Margarita Martin
Ciler Nerkiz
Arno Hornberger



Diffusor: Reality and simulation.

Simulation of filling processes

The example of a filling process simulation for gravity casting, shown left, is a typical example for a computation problem requiring a large memory and much computing time. Typical computing times for one-processor workstations are in the range of several days.

In cooperation with the company MAGMA casting technology, Aachen, the existing code was parallelized, and an entirely new code for the filling process simulation was developed at the ITWM (see p. 45, "Modeling of mold filling processes by the Lattice-Boltzmann method").

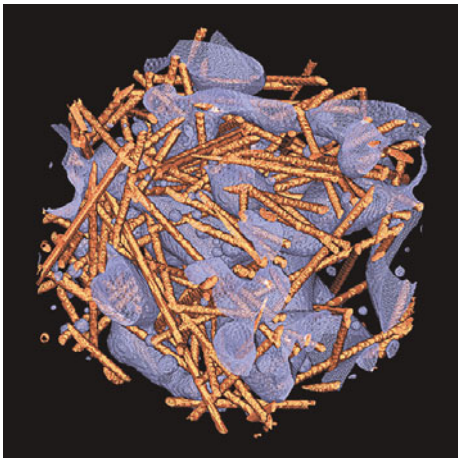
A central problem of the parallelization of filling process simulations is the constantly varying need for computing power. The objective of parallelization is the distribution of the computing domain between the individual processors and a dynamical adaptation in order to guarantee a well-balanced utilization of computing power, and the creation of data exchange mechanisms. These three basic requirements of parallelization were integrated into a completely object-oriented design, which allows for an almost automatic parallelization of applications. Mathematical optimization methods yield an optimum domain decomposition, at the same time minimizing communication. This software library is not only used for the simulation of filling processes at the ITWM, but also for other CFD codes.

The result is considerable: the computing time is reduced from days to hours, and due to a PC cluster technology which is not too expensive, this progress is also available for small and medium-sized companies.

Flow processes in porous materials

Multiphase flows in porous materials can be computed efficiently with the ParPac software, developed at the ITWM. The used periodic boundary conditions are the reason for a considerable need for communication, because the number of communication partners strongly increases. Especially for PC clusters, this is a problem. However, with the method of chromatically ordered communication patterns (cf. ITWM report 1999), developed at the ITWM, good scaling properties are nevertheless possible.

The ITWM was able to satisfy the extreme requirements with respect to computing power and memory especially in connection with two-phase flow problems of fluids of very different density. However, the computation of larger problems of microstructure analysis goes far beyond the current capacities of the parallel computer system available at the ITWM.



Two phase flow in a filter material.

Flow in
Complex Structures

Computational Steering

Despite strong efforts with respect to the shortening of computing times by parallelization and the acceleration of visualization, the simulation of an entire engineering process still requires very much time, especially due to the decoupling of the individual process steps, which is still usual today. Therefore, the interactive combination of design, computation, visualization and evaluation of results is the most important next step, which means: data produced by parallelization must also be processed parallely, the communication channels must be balanced or data compression methods must be integrated, and the whole development process must be controled by a user interface.

These ideas are the basis for the software development at the ITWM for high performance computers. Here, communication standards like MPI and COBRA are applied. The basis for the interface development is QT, and the operating system is exclusively LINUX.

Such a high performance potential was reached due to the extraction of core functionalities from the rendering kernel. In a second step, the individual autonomous units were examined and optimized for the use on modern Intel platforms. Thus, the computing time of single process sections could be improved essentially. Furthermore, the code was parallelized, so that the algorithm can now be applied on distributed memory machines, shared memory machines or on a mixed hardware topology. For all variations of the algorithm, the rendering kernel is based on a shift method.

Due to the high performance of this software-based visualization system, in combination with a less expensive basic hardware (PC cluster), small and medium-size companies are now also able to analyze complex data records interactively. Besides, the approach presented here can also help to save many resources in the fields of

- destruction-free testing,
- medical data analysis,
- visual debugging of numerical methods, and
- analysis and evaluation of simulation results.

Visualization of dynamical and static volume data

Due to the visualization of volume data by direct volume rendering methods, the access to the smallest information units of the 3d data set is possible. This direct voxel access enables the user to carry out a flexible data analysis. We developed a parallel, direct volume rendering method, which is able to operate interactively on large, four-dimensional data records. At the actual stage of development of the parallel visualization method, four-dimensional data records of the dimensions 163 x 270 x 304 x 106 can be visualized in real time in color (see Fig. 14 and 15).

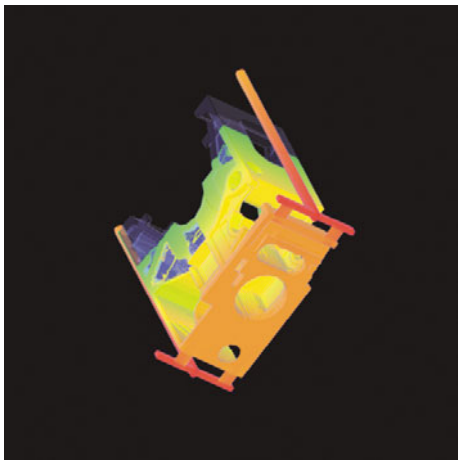


Fig. 14: Engine block.

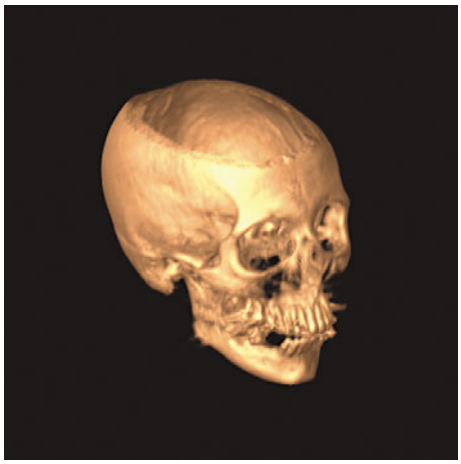
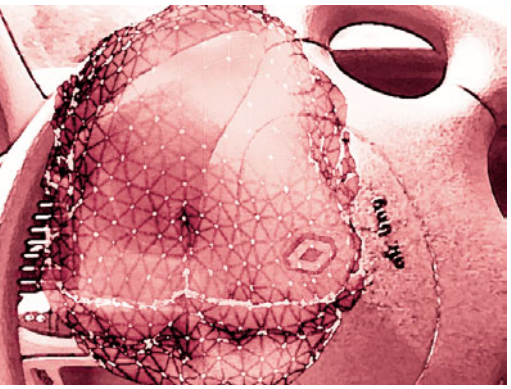


Fig. 15: Chapell-Hill-Head.

Department of Transport Processes



The development of the department of transport processes has been very successful during the first year after the restructuring of the ITWM, so that its profile reflected in the five fields of specific competence, i. e., flow dynamics, particle methods, radiation transport, kinetics, as well as simulation-based optimization and control, has been clearly reinforced.

In the field of *fluid dynamics*, a specialization with respect to the interaction of flows and flexible structures becomes increasingly evident. The considered structures include particles, filaments and sheets of paper, as well as three-dimensional bodies. The customer is offered everything from studies up to individual software tools. In most cases, the flow computations are done with the CFD tools FLUENT® and CFX®, which are then used as a basis for the continuum mechanical models of the flexible structures.

As a long-term perspective, we want to offer completely coupled solutions for fluid-structure problems, therefore the research will be focused on integrating the generalized SPH method developed in the field of *particle methods*. As a grid-free method, it can excellently be applied in the case of flow computations in time-dependent complex geometries (see project "Simulation of airbag inflation"). Thus, a software tool will be created with a wide range of applications. The research in the field of compressible flow has already advanced very far, actual projects deal with incompressible flows and multiphase flows, and first results are available for structure mechanical problems.

In the fields of *radiative transfer* and *kinetics*, the know-how of the department for the numerical solution of partial integrodifferential equations (Boltzmann equation, radiation trans-

Dr. Raimund Wegener

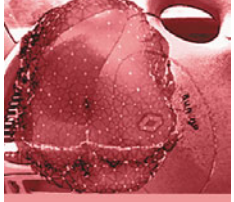
Dipl.-Ing. Sergej Antonov

Dipl.-Math. Maria P. Gualdani

Dr. Marco Günther

Dr. Dietmar Hietel

Dr. Jörg Kuhnert



port equation etc.) is reflected. In the last few years, large progress has been made with respect to the development of fast algorithms for the simulation of the cooling process of glass. The results are applied in the course of current projects, new research projects deal with the problem of radiation transport in scattering media, which is considerably more difficult.

Simulation-based control and optimization is a field of research which goes beyond the classical applications of simulation (planning, instrument for parameter variation, examination of process details, etc.). For example (project "Flange optimization"), continuous optimization problems are considered on the basis of simulations. Another project ("Mixing of granular material") integrates the simulation of a nonlinear diffusion process, which describes the depositing of granular material, into a control mechanism. In particular with respect to the solution of similar problems, the ITWM will be able to show its special competence as a mathematical research institute on a long-term range, compared to other competitors in the field of modeling and simulation.

Contact:
Dr. Raimund Wegener
Head of Department
Phone: +49 (0) 6 31/2 05-39 26
E-mail: wegener@itwm.fhg.de


Dipl.-Math.
Rainer Keck


Dr. -Ing.
Lutz Lenhart

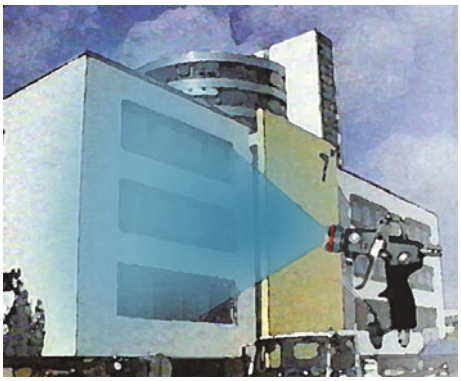

Dipl.-Math.
Guillaume Pierrot


Dr. Jan Mohring


Dipl.-Math.
Peter Schlosser


Dr. Norbert
Siedow


Dr. Sudarshan
Tiwari



Spray painting of claddings without overspray.

Many of the projects realized in the field of fluid dynamics deal with problems of interaction between flow and structure. Besides, more classical fluid dynamical problems are also examined, which are often the basis for the more complex problem solution with respect to structure-flow interaction. The structures exposed to a three-dimensional flow can be classified into three-dimensional, two-dimensional (e. g., bows), one-dimensional (e. g., filaments) and point bodies (e. g., droplets). Of course, basically all the objects are three-dimensional in a three-dimensional flow. However, an efficient modeling and simulation will always account for the specific properties of the structure. According to the classification,

- bows are represented as two-dimensional objects with a certain thickness, which is accounted for in the model especially with respect to the bending behavior,
- filaments are characterized as one-dimensional curves given by the center line with a certain diameter or a specific contour of the cross-sectional area,
- droplets are described as mass points according to their position, and their diameter or further form parameters are used in order to account for the forces acting on them.

In any case, the structure dynamics is described by a Newtonian equation of motion with interior and exterior forces. The exterior forces are essentially determined by the pressure and flow conditions around the structure. The modeling of the structure inherent interior forces strongly depends on the properties of the object. A combination of elasticity theory and asymptotic considerations depending on the structure class is typical for the projects which have been carried out up to now. In principle, problems in this area lead to three-dimensional flows in space which, additionally, are instationary due to the coupling with the structure movement and show all the usual difficult properties, such as interfaces and turbulence effects. Therefore, in the case of the successfully solved application problems, possible model simplifications were used to reduce the required efforts for the simulation. The actual flow simulations on the basis of the Navier-Stokes equations and the respective variants were mostly carried out with commercial software packages like CFX® or FLUENT®.

The activities during the year reported here were concentrated on the behavior of filaments and droplets, which will be explained in the following by two typical projects. For the time being, an industrial cooperation project for the simulation of the movement of a 2D structure, which was divided into three phases, has been finished at the beginning of the year 2000 by the development of a tool used by the project partner. Further projects belong to the field of classical flow mechanics and deal, e. g., with the transport of particles in a flow. As a future perspective, not only the projects initiated due to applications will be continued; a combination with the field of particle dynamics is also emphasized. A long-term objective is the further development of the ITWM's SPH code, resulting in an integrated tool which will allow for a completely coupled simulation of flows around the structures classified above and their dynamics.

NESPRI: Mist-free spraying of exterior facades

During the spraying process of exterior facades, tiny color droplets are forming which create a sort of mist. The resulting pollution of the surroundings, for example, of parked cars, is the reason why this is not a standard method in practice. The objective of the research association "NESPRI" is the solution of this overspray problem. Within the program "InnoNet", funded by the Federal Ministry for Economy and Technology, three research institutes and ten further partners from industry and craftsman's businesses have created a network where the necessary know-how and interdisciplinary competence are available. The ITWM is responsible for the field of modeling and simulation and has the function of the coordinator of this project, which is planned for a period of three years.

The first project steps which have been taken were intended to analyze the weaknesses of the current spraying technique, in order to create a basis for the development of appropriate alternatives. First, the process section directly after the diffusion is modeled and simulated at the ITWM. The diffusion through a fine nozzle is either airless or supported by air (AirCoat, HVLP). With respect to the airless technique, pressures of up to 150 bar are used. Due to the spraying, innumerable tiny color drops are created whose size distribution was measured at the IFF in Stuttgart. These drops are responsible for the overspray, because the movement of smaller droplets towards the wall is easily deviated.

The dynamics of the resulting almost spherical droplets can be modeled by a Newtonian equation of motion with the exterior forces due to gravity and surrounding air flow. Other influences, such as wind and sensitivity aspects due to the handling in practice, must be accounted for in further investigations. The simulation results provide a quantitative analysis for the evaluation of the different factors of influence. A comparison of the particle behavior for different diameters (see Fig. 1) gives an impression of the unavoidable, negative turbulence effects. The paths of the large particles are evidently less disturbed, resulting in the spraying cone which can be observed. The smaller particles are much more subject to the disturbances due to the main flow and the turbulence effects. Because of the stagnation point and the partial reflection of the air flow, the particles which have already been strongly slowed down are deviated considerably near to the wall.

Thus, the foundation for a further development is guaranteed, together with the other results of experiments within the association and results of business practice, as well as their interpretation. Therefore, the intention of the association NESPRI, i. e. the successful solution of the overspray problem, is positively confirmed.

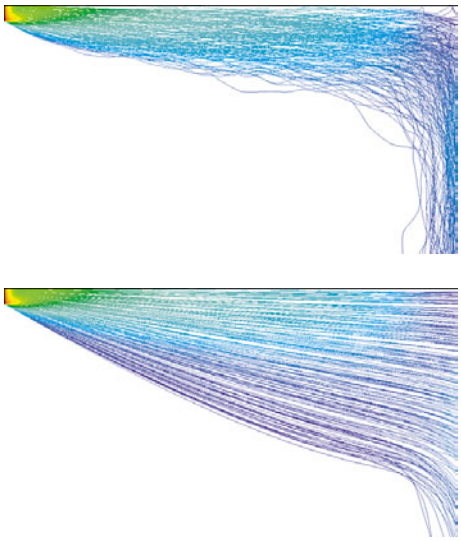


Fig. 1: Particle trajectories in turbulent free stream. above: diameter 20 μm, below: diameter 80 μm.

Funding:

Federal Ministry for Economics and Technology BMWi (InnoNet-Program)

Partner:

Institut für Industrielle Fertigung und Fabrikbetrieb (IFF), Stuttgart

Institut für Maschinenwesen im Baubetrieb (IMB), Karlsruhe

Caparol Farbe Lacke Bautenschutz GmbH & Co Vertriebs KG, Ober-Ramstadt

J. Wagner GmbH, Markdorf

m2K Informationsmanagement GmbH, Kaiserslautern

De-Wa-Bo Malerbetrieb GmbH, Detmold

Habekost GmbH, Hildesheim

Heil Maler GmbH, Steinwenden

Hoops Malerfachbetrieb GmbH & Co KG, Velbert

Industrieanstriche und Malerwerkstätten Arenshausen GmbH, Arenshausen

renfordt Malerfachbetrieb GmbH, Iserlohn

Karl Stromberg GmbH & Co KG , Duisburg

Contact:

Dr. Dietmar Hietel
Phone: +49 (0) 6 31/2 05-40 82
E-mail: hietel@itwm.fhg.de

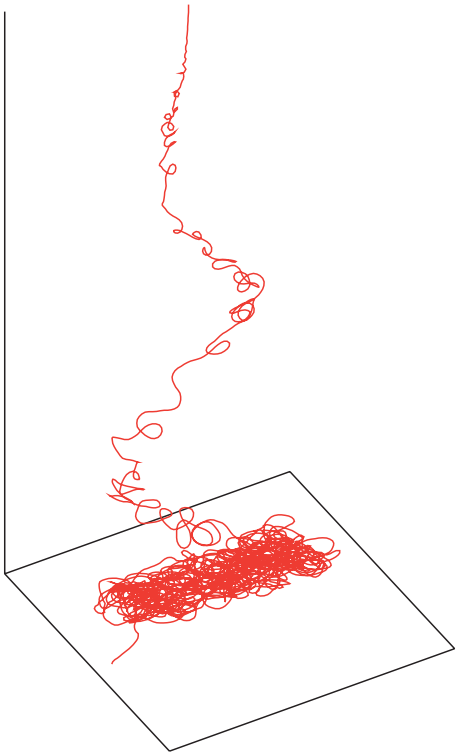


Fig. 2: Fibre structure with deposit part.

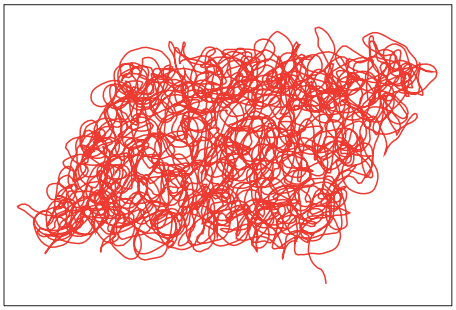


Fig. 3: Deposition on belt of single fibre.

Simulation of fleece production

In fleece production, oscillations of strings of single filaments are stimulated. The oscillating filaments are then laid down on a transport belt permeable to air, thus forming an area of flat textile structure. The oscillations are stimulated by periodic forces to which the filaments are subject. The respective two-dimensional flow computations were carried out during the first phase of the project, and a simple model of the movement of the filaments was developed (see ITWM report 1999). The following second phase has the particular objective of a more detailed modeling of the movement and the interior structure of the filaments. Simultaneously, in the course of another project, flow computations have been carried out which are intended to support the construction planning of a new production plant.

The single filaments considered during fleece production have a diameter of less than 0.1 mm and are already subject to drawing. The strain can be neglected, therefore the filaments can be described as curves depending on the filament lengths. The dynamics of the filaments is given by a Newtonian equation of motion:

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

On the basis of the linear elasticity theory, by means of asymptotic considerations the interior forces can be derived with respect to stresses and the bending depending on the E-module. The air forces f_L are divided into a deterministic part of the relative air movement directly around the filament, and a part of stochastic influence due to occurring turbulence effects. For the positioning of the filaments on the moving belt, specific boundary conditions have been derived. The end of the filament which is laid down at a certain time is determined by an implicit equation accounting for the frequently occurring case of the positioning of complete loops.

The numerical implementation of the models described above is done by coupling the two-dimensional flow computation and the dynamics of the filaments. Due to the high flow velocities and the continuous input of moment and energy, the effects of the moving belt can be neglected. The implementation of the nonlinear filament model is based on finite differences and the iterative solution of the resulting systems of equations. A typical example for the filament behavior which can be described by the model is shown in Figure 2, which also illustrates the positioning of a complete loop. The global oscillation with only a few extremal points mainly results from the partial forces depending on the relative flow velocities. The modulation of this movement with the formation of loops is due to the interaction between the stochastic turbulence effects and the interior bending forces.

The model was adapted to the concrete situation at the company Freudenberg by the identification of the model parameters and the validation by measurement results. Thus, simulations of the movement of single filaments have been carried out which are very close to reality. The simulation result visualized in Figure 3 is typical for the complex positioning already in the case of one single filament. In the future, we would like to be able to simulate the entire fleece production by considering whole strings of filaments attached to several spinning frames.

Partner:

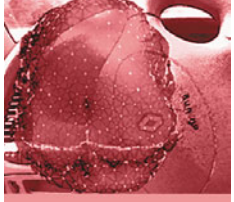
Freudenberg Vliesstoffe KG, Kaiserslautern

Contact:

Dr. Dietmar Hietel
Phone: +49 (0) 6 31/2 05-40 82
E-mail: hietel@itwm.fhg.de

Dipl.-Ing. Serguei Antonov
Phone: +49 (0) 6 31/2 05-41 27
E-mail: antonov@itwm.fhg.de

Particle Methods for Compressible and Incompressible Flows



Particle methods are numerical methods for the approximative solution of gas dynamical or hydrodynamical flow processes. Here, the term "particle" represents the numerical approach for the simulation of flow problems. The particle methods applied at the ITWM are based on the classical smoothed particle hydrodynamics (SPH) method and are refined versions of the latter. The mathematical and physical basis for a very large group of flow problems are the Euler equations (for nonviscous processes) and the Navier-Stokes equations (for processes viscous). From this point of view, particle methods do not differ from classical methods like finite volume methods (FVM) or finite element methods (FEM), because the same basic equations are used.

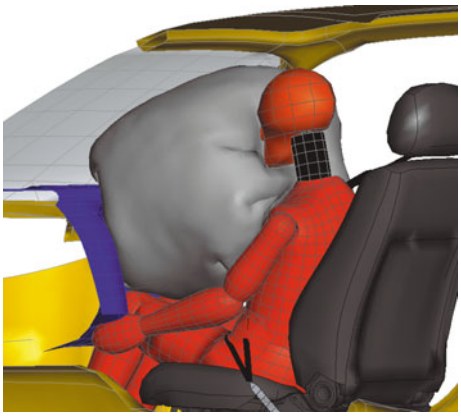
Here, particles are moving discrete numerical points. The flow area under consideration is evenly filled with particles, each one of them representing a small, local section of the fluid. Each particle carries important information about the local state of the flow, i. e., information about density, momentum and energy. Each particle moves at the flow velocity, and the relevant information is subject to changes. The objective of the numerical method is to approximate these changes on the particle path as precise as possible. In general, this requires the knowledge of the first and second order space derivative of the velocity field and the first order space derivative of the pressure.

The computation of these derivatives is not trivial, so that the problem of computing smooth derivatives from the discretely given parameters of pressure and velocity is considered to be especially important. An essential difficulty is that the particle positions as a geometric basis usually are unstructured in space and subject to strong changes in time. Our approach is the approximation of the derivatives on the basis of the moving least squares (MLS) or the least squares (LS) method. In the case of gas dynamical problems, apart from the MLS method, an upwind method developed at the ITWM is also applied, in order to stabilize the computing scheme.

Due to the complex computation of space derivatives, particle methods are complicated in comparison with other methods. However, they have several advantages which should not be underestimated. Because of the very simple grid structure (points), the generation and management of a geometric grid requires only an extremely short computing time, compared to FEM or FVM. Particularly in the case of moving flow geometries, this is an advantage because the particles follow the movement of the geometry. Therefore, the application of particle methods is especially useful for:

- flows with a very complex geometry,
- flows with a strongly time-dependent geometry,
- flows with free surfaces,
- multiphase flows.

Simulation of the deployment of a folded airbag.



Environment for the airbag simulation.

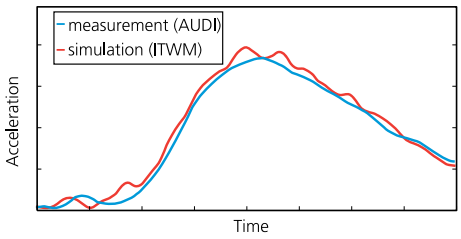


Fig. 4: Comparison between measured and computed accelerations versus time of a dummy interacting with a deploying airbag.

Simulation of airbag inflation

The ITWM has strongly engaged in the numerical simulation of the inflation of airbags, which are intended to protect passengers of an automobile in the case of a serious crash. Here, there is a cooperation with the software company "ESI Group", who is marketing a software package with a wide range of applications for the simulation of technically relevant processes, especially with respect to automobiles and airplanes.

The airbag is an example for fluid-structure interaction: the membrane of the airbag only moves depending on the pressure of the inflating gas on the membrane. On the other hand, the flow of the propellant is strongly influenced by the boundary condition of structure and position of the membrane. The research is focused on simulating the airbag inflation process as precise as possible, together with its interaction with the passenger. A decisive problem are possible injuries caused by the airbag.

For the simulation of the gas flow, the particle software of the ITWM was implemented into the software package of the company ESI. The reasons for the application of the particle method are obvious: the interior of the airbag is considered as a flow area with a complex and strongly time-dependent geometry. Moreover, the membrane of the airbag can be characterized as a free surface. Thus, the ITWM particle method is in advantage here, being faster by the factor of ten compared to the FVM by ESI in the case of airbag simulation.

The movement of the airbag membrane is simulated by the ESI software by means of FEM. At each time step, there is a data exchange between both programs. The pressure along the membrane is computed with the particle method, and then used as an input for the ESI software. The pressure is the boundary condition for the determination of the changing membrane position and the respective velocities. The new state of the membrane is returned to the particle software, where it is again used as a boundary condition.

Many problems which do not belong to the restricted numerical particle scheme have been and are still solved in cooperation with ESI. Examples are:

- the problem of determining relevant neighboring particles of a given point as efficiently as possible,
- the development of secure geometric criteria for the decision whether a particle is positioned within or outside of the airbag,
- a precise control of the time step length for the coupled method,
- the problem of formulating the particle behavior in the vicinity of sharp folds of the airbag.

Tests at the German automobile company AUDI have shown an excellent correspondence between computation and experimental results. The experiment covers the inflation process of a (not yet) folded airbag at the driver's seat that hits a dummy which, at the beginning, is positioned at a distance of only 5 cm from the airbag. The measured and the computed accelerations of the dummy are shown in Figure 4 (blue: measured, red: computed).

Partner:

ESI Group, Paris

Contact:

Dr. Jörg Kuhnert
Phone: +49 (0) 6 31/2 05-38 86
E-mail: kuhnert@itwm.fhg.de

Particle methods for multiphase flows

In the course of the DFG program AnumE (Analysis and numerics for conservation Laws), the particle method for compressible flows developed at the ITWM is currently further developed, so that the handling of incompressible flows will also be possible in the future. Because of the advantages of the particle methods mentioned above, many practical or technical applications are imaginable, especially in the field of incompressible flows, such as volcanic eruptions, bursting of dams, filling processes, injection problems or bubbles in a liquid. Therefore, the development of a directly incompressible numerical particle method is necessary.

A classical method for the solution of incompressible problems with a particle scheme is the so-called quasi-incompressible method. Here, a compressible particle formulation, which is understood very well in theory, is coupled with a very stiff thermodynamical state equation. The result are flows with very small Mach numbers, so that an incompressible flow is approximated. However, this approach has an important disadvantage: if the Mach number decreases, the time step for the numerical integration also decreases. Therefore, quasi-incompressible simulations require much computing time. In order to solve this problem, directly incompressible particle schemes are examined. The development of such a scheme is one of the essential subjects of the DFG project mentioned above, and there are already promising first approaches.

An essential motivation for this research are incompressible flows with free surfaces. Central problems are, for example, the finding of particles at the free surface and the formulation of the respective boundary conditions. The graphics in Figure 5 give an impression of the surface movement in the case of the so-called dam-breaking problem.

A further essential point of the DFG project is the problem of accounting for effects of surface tension in the particle formulation. Such effects are important wherever freely moving surfaces or phase interfaces appear. The forces of the surface tension are directly proportional to the curvature of the surface. It is a very complex problem to determine the exact curvature of a surface which is only given by discrete particles. Here, there is another least squares approach based on the attempt to describe a function which is as smooth as possible within the given surface points. This idea is currently investigated.

A third and final objective of the DFG project is the formulation of the particle method for multiphase flows. The most important problem is the determination and characterization of the phase interface. An essential point is the modification of the numerical particle scheme at the phase interfaces according to the physical conditions.

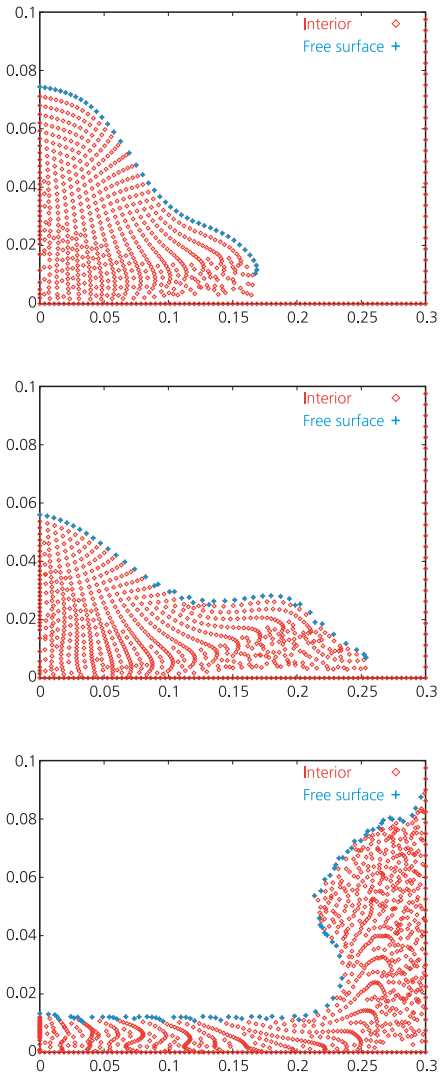


Fig. 5: Different time stages for the simulation of the breaking-dam- problem.

Funding:

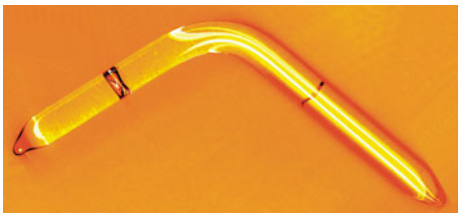
Deutsche Forschungsgemeinschaft (DFG)

Contact:

Dr. Jörg Kuhnert
Phone: +49 (0) 6 31/2 05-38 86
E-mail: kuhnert@itwm.fhg.de

Dr. Sudarshan Tiwari
Phone: +49 (0) 6 31/2 05-40 87
E-mail: tiwari@itwm.fhg.de

Radiative Transfer

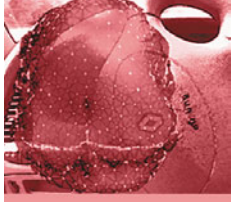


Radiative heat transfer in glass.

Spectral remote sensing.

In order to describe temperature profiles in semitransparent materials, apart from heat conduction and convection, thermal radiation must also be accounted for. In contrast to the processes mentioned first, thermal radiation is a strongly non-local phenomenon, which leads to a complex numerical simulation. A typical semitransparent material is glass. Commercial software packages include solution methods for the pure heat conduction, so that heat transport problems without radiation can, in general, be solved by industrial users. However, these software packages are not able to compute the heat transport by radiation in semitransparent media, or they can do it only within very narrow limits. The ITWM has developed a tool for the solution of realistic three-dimensional problems which can easily be implemented into commercial software packages. The computation of the radiation is based on special diffusion approximations which account for the geometric and physical properties of the problem. Depending on the surface structure of the medium surrounding the glass, the reflection of the radiation can be specular, as well as diffuse. By diffuse scattering at the background, the intensities of the different directions are coupled. This coupling is accounted for in the numerical realization for the one-dimensional and the three-dimensional case. Actual research activities deal with the examination of further physical processes, e. g., parameter identification particularly accounting for radiation, and development of efficient numerical methods for the radiation transport, also accounting for scattering effects.

Apart from simulation, measurements are the usual method for the determination of temperatures. A standard measurement method requiring contact to the material whose temperature ought to be determined, is the use of thermocouples or chains of thermocouples. In many cases (e. g., during hot forming processes), these cannot be used. Therefore, we are interested in remote temperature sensing methods. As a current standard measurement method, pyrometry is used for the determination of surface temperatures of opaque materials (i. e., impermeable for all wavelengths). Glass is a semitransparent material where, for certain wavelengths, radiation from the interior also reaches the surface and is subsequently transported away. This intensity depending on the wavelength can be used for the temperature reconstruction in the interior of the glass. For the solution of this inverse, ill-posed problem, an iteratively regularized Gauß-Newton method was applied together with a regularization operator adapted to the problem. In the evaluation of the measurement data, a radiating background material can also be accounted for. Together with the respective measurement technique for the determination of the thermal radiation for different wavelengths, we are for the first time able to carry out a remote sensing of temperature distributions also in the interior of the glass.



Heat transport between glass and mold during hot forming processes

In order to control the individual process steps during glass production technically, e. g., melting, hot forming, cooling, the heat transport in the interior of the glass, as well as between glass and melting tanks, molds or cooling devices must be described correctly. Particularly in the case of the hot forming process, the heat transport from the glass to the molding devices can not be neglected. For the numerical simulation of the heat transport during the hot forming process, the coefficient of heat transfer glass – mold is one of the necessary parameters. Hot glass comes into contact with a cooler mold. Between the glass surface and the mold, an air layer can develop during the cooling process due to the different thermal expansions. Without such an air layer, the glass "sticks" to the mold at the end of the pressing process. Such a "sticking" must absolutely be avoided during hot forming. All these effects influence the heat transport and its time-dependence. The mathematical modeling of these processes must account for the radiation of the semitransparent glass. The surface of the mold can reflect the radiation diffusely, as well as specularly. At the interface between glass and mold, interface conditions must be formulated for the description of the heat transport.

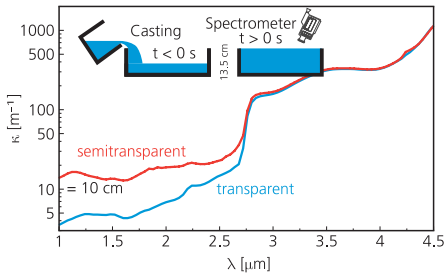
For the solution of the completely described one-dimensional transport problem, a numerical algorithm has been developed which computes the time-dependent temperature distribution in glass and mold. In comparison with already existing publications, the effects of material contact as well as of radiation on the heat transport glass – mold have also been accounted for.

In practice, the inverse problem is especially interesting: the determination of the coefficient of heat transfer, where additional measurement data are also accounted for. Here, the ITWM has also developed a solution which has been implemented into the respective software. By the application of this method to measurement data from laboratory experiments, provided by the company Schott, pure coefficients of contact heat transfer can be determined.

Thus, in the last few years a series of software solutions for the control of the temperature behavior has been developed for the glass producing industry:

- The temperature can be determined directly by a one- or three-dimensional simulation computation which accounts for the radiation transport important for the glass.
- The parameters necessary for the simulation can be determined indirectly from other parameters which are more easily available for engineers.
- From spectral radiative intensities measured by a spectrometer, the temperature can not only be determined at the surface, but also in the interior of the glass.

Figure 6 shows the good correspondence between simulation and measurements.



Casting experiment.

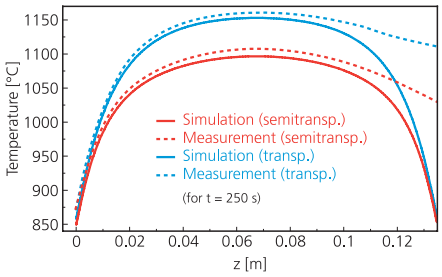


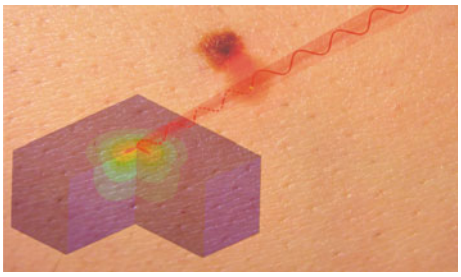
Fig. 6: Comparison of simulated and with pyrometer measured temperatures of two different glasses.

Partner:

Schott Glas, Mainz

Contact:

Dr. Norbert Siedow
Phone: +49 (0) 6 31/2 05-41 26
E-mail: siedow@itwm.fhg.de



Radiative transfer in biological tissue.

Radiation transport in strongly scattering media

Strongly scattering materials find very different technical applications. Ceramic materials are used as insulation material for the thermal insulation, e. g., of melting tanks in glass production. At high temperatures, these ceramics become semitransparent. In this case, the insulation properties are also influenced by thermal radiation, apart from heat conduction. In contrast to glass, ceramics are strongly scattering materials. In the field of medicine, photon and electron beams have been used for diagnostics and therapy already for some time now. For example, computer tomography for the diagnosis of cancer or dosimetry in cancer therapy have become standard methods of treatment. There is a range of research projects worldwide with respect to optical tomography for the realization of structures and properties of human tissue. The laser-induced interstitial thermotherapy is a promising approach for the treatment of brain tumors. Hence, there is a long list of potential applications in the fields of medicine and industry.

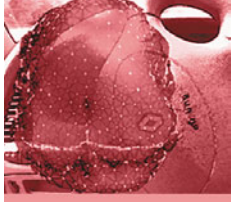
The radiation transport is described mathematically by an integro-differential equation, the radiation transport equation. The solution of these equations requires the application of numerical algorithms. Current numerical methods are either based on simple diffusion approaches, which only yield an inexact description of the respective processes, or on very time-consuming Monte-Carlo simulations for the modeling of the microscopic processes. Depending on the concrete model, the development of new, efficient numerical methods is absolutely necessary. In the last few years, numerical methods on the basis of asymptotic expansions have been investigated at the ITWM, which stand out due to a good exactness and very short computing time. However, this improved diffusion approximation is only based on two basic physical processes: emission and absorption. From a scientific point of view as well as due to practical requirements, the method should also be made available for strongly scattering media. For the numerical solution of the radiation transport equation, different classes of methods have been examined. If the scattering is dominating with respect to absorption, by asymptotic considerations the transport equation can be substituted by a diffusion equation which can be solved with standard methods. If the method of discrete ordinates is applied, this results in a very large system of equations, which is, however, sparse. An obvious solution algorithm is a preconditioned CG method, with the radiation transport equation without scattering as an appropriate preconditioner. The so-called DAS preconditioning uses the P_1-approximation. Especially for strongly scattering or optically thick media, this type of preconditioning is very effective. In the case of isotropic respectively linear isotropic scattering, the radiation transport equation can be formulated as an integral equation with a weakly singular kernel. Different discretization methods and panel cluster techniques have been examined theoretically, and comparative computations have been carried out for the one-dimensional case.

Funding:

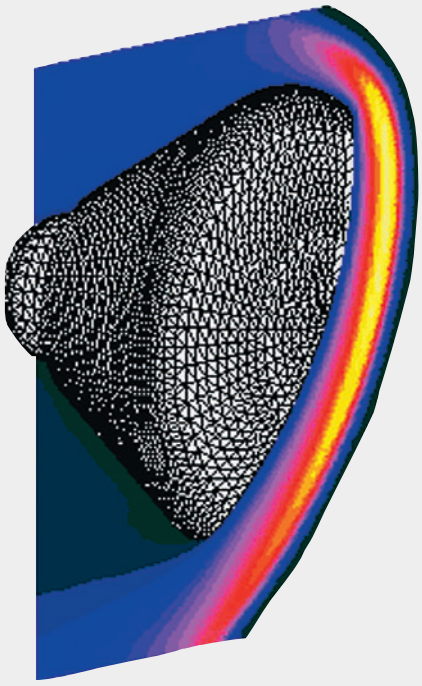
Foundation Rhineland-Palatinate for Innovation

Contact:

Dr. Norbert Siedow
Phone: +49 (0) 6 31/2 05-41 26
E-mail: siedow@itwm.fhg.de



The field of kinetics is based on many years of research with respect to the simulation of rarefied gas flows, done by the group around Prof. Dr. H. Neunzert. In connection with the European space programs, the simulation tool ParBoSS (Parallel Boltzmann Simulation System) has been developed, a completely parallelized, modularly structured tool for the solution of the Boltzmann equation, with modules, e. g., for vibration, rotation and chemistry. The tool is available at the ITWM and is maintained - however, a further development does not take place at the moment. Nevertheless, the know-how in the field of kinetic equations is still available through the colleagues at the ITWM, which results in a special competence with respect to the modeling of problems of particular scale character (microscopic, mesoscopic, macroscopic). The following example of a current research project shows the development of traffic flow models (macroscopic scale) on the basis of models of the individual driver's behavior (microscopic scale).



ParBoSS – Temperature distribution, reentry of ARD-Kapsel in the atmosphere.

Development, analytical foundation and numerical simulation of traffic flow models

In the future, realistic traffic flow models which can be handled numerically will be in the center of modern traffic control systems, helping us to make optimum use of our existing road network. In the field of traffic flow simulation on highways, especially macroscopic (hydrodynamical) models are used, apart from cellular automatons. In principle, these macroscopic models have an excellent potential to represent satisfactorily very different traffic situations. However, in the publications of the last few years, the correct form of the equations and of the occurring coefficients have been discussed controversially. In the current project, the controversy was decided in favor of the so-called Aw/Rascle model on the basis of a kinetic derivation procedure. A weakness of all the existing derivation methods for macroscopic equations is the detour via the numerical solution of the homogeneous stationary equations. Even the existence and uniqueness of such solutions are still the subject of current research projects for the models which have been developed up to now. Therefore, apart from the final justification of the Aw/Rascle model, the research was focused on the development and analysis of new kinetic models which can be handled analytically. Here, there was a further breakthrough. The objective of the actual research is the introduction and justification of diffusion terms in the macroscopic models.

Traffic flow on a highway.

Funding:

Deutsche Forschungsgemeinschaft (DFG)

Partner:

Prof. Dr. Axel Klar
Darmstadt University of Technology, Working Group Scientific Computing

Contact:

Dr. Raimund Wegner
Phone: +49 (0) 6 31/2 05-39 26
E-mail: wegener@itwm.fhg.de

Simulation Based Control and Optimization

Thermo-electrical flange.

Bass loudspeaker.

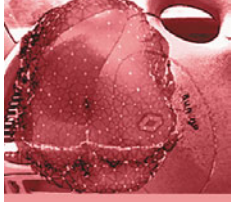
How must the component for the conduction of an electrical heating current be formed in order to guarantee a homogeneous temperature distribution? What is the correct voltage for a bass loudspeaker in order to reproduce a given acoustic signal without distortion? How must granular material be distributed on a stock in order to guarantee a uniform mixing result at every point?

Mathematically speaking, these problems, which appear absolutely different from each other at first sight, have a common structure:

- The interesting parameter is a field, i. e., a space- and time-dependent distribution: e. g., the sound field within and around the loudspeaker, the temperature field in the flange, or the mixing of material at different points of the mix bed. The dependence of these fields on geometric, material and further parameters can be described by partial differential equations or related models. Then, the simulation consists in the discretization and numerical solution of these equations, e. g., by means of finite element methods.
- The control or optimization refers to the minimization of one function of the field, e. g., the deviation of the sound pressure from the reference signal at a certain acoustic point, the variance of the flange temperatures, or the deviation from an intended mixing result in certain segments of a stock.
- The fields are not influenced by only a small number of parameters, among which appropriate ones could possibly be determined by trial and error. Moreover, whole parameter functions are required: voltages for all times during the operation of a loudspeaker, the thickness of the flange at every point of its area, or position, intensity of source and structure of the granular flow at each time of the stacking process.

The competence of the ITWM with respect to the solution of such problems, i. e., the coupling of control respectively continuous optimization with the solution of partial differential equations, will now be illustrated by three representative projects.

Mixbed.



Flange optimization

In glass production, flanges are used for the electric heating of platinum pipes through which the glass melt is flowing. The electric current *j* produces Joules heat in the pipe wall which can influence the temperature of the glass melt. The heating of the pipe by the flange should be homogeneous, in particular in order to avoid cristallizations of the glass melt at the pipe walls.

Such undesirable inhomogenities have a decisive influence on the quality of the glass. A control of the flange temperature exclusively by adjusting the intensity of the electric current is not sufficient in order to avoid these local effects. Therefore, the geometry of the flange must additionally be determined in such a way that in a section *S* in the vicinity of the electrical contact area, the temperature of the flange is constant. This optimal shape design is an inverse problem where, apart from the homogeneous temperature transferred from the flange to the pipe, further conditions must also be accounted for: the electric potential satisfies the potential equation, the temperature satisfies the heat conduction equation, and economic aspects must also be considered. The flange thickness is very small compared to the other dimensions, therefore the three-dimensional shape design problem can be reduced to a two-dimensional parameter identification problem by asymptotic expansion. The parameter function to be determined is the thickness $h(x,y)$ of the flange.

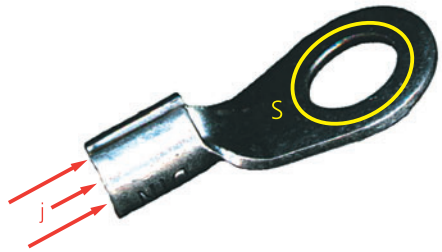
$$\vec{\nabla}_{(x,y)} \cdot \left(h(x,y) \vec{\nabla}_{(x,y)} \phi_0(x,y) \right) = 0 \,,$$

for $(x,y) \in \Omega$,

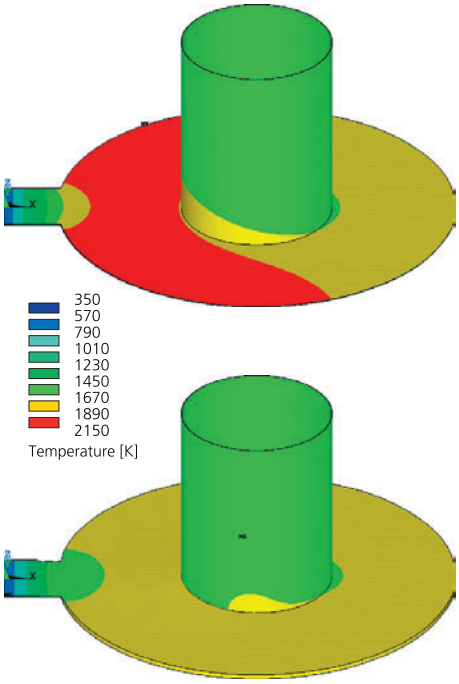
$$\vec{\nabla}_{(x,y)} \cdot \left(h(x,y) \vec{\nabla}_{(x,y)} T_0(x,y) \right) = -\frac{h(x,y)}{k_t} \frac{|\vec{\nabla}_{(x,y)} \phi_0(x,y)|^2}{\rho_e} \,,$$

for $(x,y) \in \Omega$.

This inverse problem was solved by Lagrange multipliers, and the respective software was developed. Thus, our industrial cooperation partner received a tool which allows an essentially simpler development of flanges according to the respective technical requirements.



Thermo-electrical flange.



Temperatures before and after optimization.

Partner:

Schott Glas, Mainz

Contact:

Dr. Norbert Siedow
Phone: +49 (0) 6 31/2 05-41 26
E-mail: siedow@itwm.fhg.de

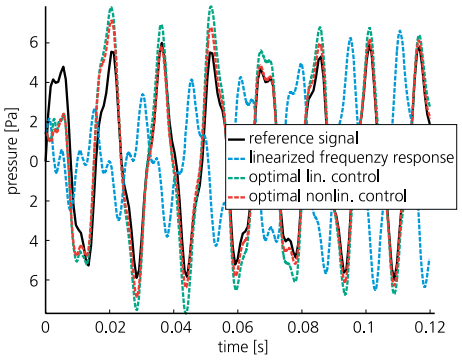
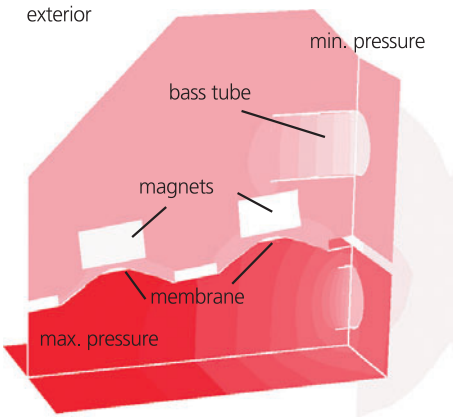


Fig. 6: Comparison of different controlers.



Simulated pressure distribution in a bass speaker.

Digital pre-equalization for compact loudspeaker boxes

On the market for professional sound systems, there is a demand for bass reflex loudspeakers with a higher performance and improved sound quality despite a smaller box volume. Therefore, the company KS Sound Systems develops compact bass loudspeakers with a new, DSP-based controler for the equalization of nonlinear distortions occurring in the case of high sound pressures and small boxes, and the minimization of the response time according to abruptly changing signals. The R&D project of the company is supported by the Investment and Structure Bank (ISB) in Mainz. As the scientific cooperation partner, the ITWM is responsible for the control concept and the software for the shape optimization of the box, which is based on nonlinearly computed sound fields with a high amplitude.

The control concept differs considerably from standard filters for the linearization of the frequency response, as well as from nonlinear filters, such as the mirror filter. The objective is the real time simulation of the nonlinear loudspeaker behavior by means of a digital signal processor, and the computation of the voltage in such a way that on the one hand, the sound pressure follows the incoming signal as exactly as possible, and on the other hand the electric and mechanical loads remain uncritical. The core of the real time simulation is a nonlinear state space model of the loudspeaker, which describes the time-dependent changes of the state variables, e. g., the excursion of the membrane, under the influence of the voltage. Additionally, the impedance is measured in order to correct the computed state. Based on this estimation and the incoming signal anticipated by a few milliseconds, the voltage is finally computed. Special challenges of the control problem are the nonlinearities, the real time computation and the objective function which varies due to its dependence on the reference signal. In order to solve the resulting optimization problem in intervals of 10 ms, it is reduced to the evaluation of a large polynomial with several variables by a combination of computer algebra and asymptotic analysis.

The second objective is the shape optimization of the box. Due to the high amplitudes, the system can no longer be described by the wave equation on which commercial acoustic software is based. Therefore, an approximation of the Euler equations has been derived at the ITWM which, in contrast to the wave equation, accounts for the excursion of the membrane not only to first but to second order. Nevertheless, for harmonic excitations it is still sufficient to solve linear Helmholtz equations.

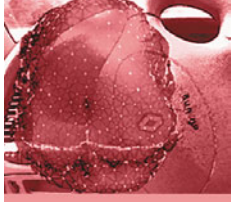
The effect of the controller was simulated for virtual bass loudspeakers which can be described exactly by nonlinear models of third order. Figure 6 shows the results for a loudspeaker with a weakly damped resonance of approximately 60 Hz. Compared to a linear controller functioning according to the same principle, the overshoot is reduced. A comparison with a standard filter for the linearization of the amplitude frequency response yields a shorter response time, a smaller nonlinear distortion factor, and a phase-true reproduction of the signal. Currently, a program is developed for the automatic parameter identification from measurement data, and the extended wave equation is implemented into the acoustic software HeSol which has been developed at the ITWM.

Partner:

KS Beschallungstechnik GmbH,
Hettenleidelheim

Contact:

Dr. Jan Mohring
Phone: +49 (0) 6 31/2 05-38 86
E-mail: mohring@itwm.fhg.de



Mixing of granular material

By order of the company MVT Mechanical and Process Engineering Bernhard Blatton GmbH, software for the control and simulation of mix beds was further developed. Mix beds are used for the homogenization and mixing of large amounts of different granular materials, e. g., in cement industry. The project was carried out in cooperation by the departments for transport processes and adaptive systems.

The bottom figure on page 30 shows a modern mix bed. The different materials are transported from separate stocks onto a common transport belt, crushed in the crusher, examined online with respect to their chemical composition, and finally piled up on the mix bed by the stacker. The mixing effect results from the process of reclaiming the material in slices at right angles to the stacked layers. The objective is to control the amount of material coming from the stocks in such a way that the composition of the reclaimed slices meets certain demands, e. g., remains within narrow limits around required values for chalk standard and silicate module. Additionally, the simulation of the mix bed determines how the premixed material is distributed across the stock and, finally, within the reclaimed slices. A determination by measurements is impossible for reasons of complexity.

In the course of a previous project at the ITWM, the mathematical and algorithmic foundations for the control and simulation of mix beds were laid, and a simulation tool was developed for research and advertising purposes. In the current project, the transport system must also be accounted for. The stocks are connected to the measuring device by transport belts of different length which are partly interconnected.

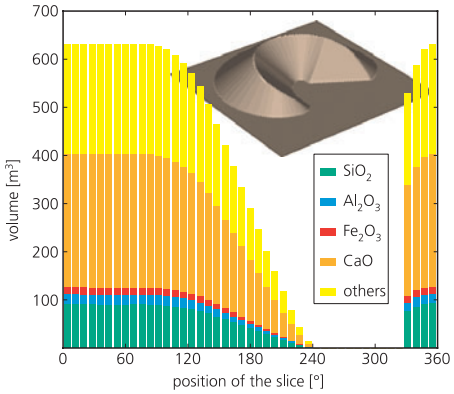
Among others, the following questions must be answered: When and in which amounts have those materials left the stock which are currently measured? When and how must the velocities of the transport belts be adjusted in order to reach the desired mixing effect at the discharge end of the belt, i. e., at a later time?

The premixing control has three essential aspects:

- From the measured composition of the premixed material, it is possible to conclude the composition of the materials in the stocks by means of an observer.
- The amount of material coming from the stocks must be controled in such a way that certain modules show optimum values. This results in a quadratic optimization problem with linear constraints.
- For an interpretation of the measurement results and for an adjustment of the transport velocities in good time, the transport system must be simulated.

The mix bed simulation is based on a fast solver for a known variational inequality, developed at the ITWM. The inequality describes the distribution of a granular material in the case of a weak material supply. The discretization error can be estimated exactly.

By means of the resulting software, it is possible, e. g., to quantify homogenization effects of the mix bed as a basis for guarantees, to reduce the size of the mix bed and the number of layers to the necessary dimensions, to compare different controllers, stacking and reclaiming schemes and to go through modifications.



Shape and composition of a round mixbed.

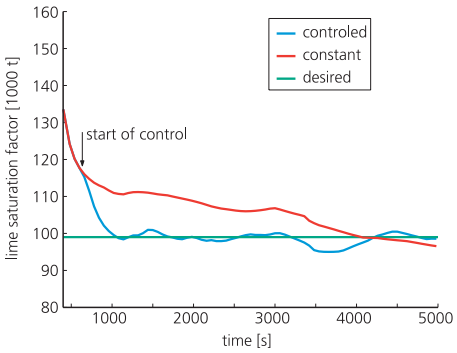


Fig. 7: Evolution of a quality parameter (lime saturation factor). In portions of 1000 t added previously to the mixbed, with constant and controled mixing ratio. The composition of raw materials changes randomly about certain mean values.

Partner:

MVT Maschinen- und Verfahrenstechnik Bernhard Blatton GmbH, Dillingen

Contact:

Dr. Jan Mohring
Phone: +49 (0) 6 31/2 05-38 86
E-mail: mohring@itwm.fhg.de

Dr. Günter Gramlich (Adaptive Systeme)
Phone: +49 (0) 6 31/2 05-27 42
E-mail: gramlich@itwm.fhg.de

ITWM becomes Fraunhofer Institute

It was the event of the year, and certainly the most important event in the five years since the foundation of the institute: the ITWM was accepted as a member of the Fraunhofer Society. For the first time, a mathematical research institute joined the group of application-oriented Fraunhofer Institutes - thus, an important event also in the history of the Fraunhofer Society. Consequently, the resonance in the newspapers was large.

From "Rheinpfalz", November 10, 2000:

Fraunhofer-Gesellschaft convinced by success – Institute for Industrial Mathematics becomes renowned institution

The Institute for Industrial Mathematics (ITWM) did not only celebrate its fifth birthday yesterday, but also its membership of the Fraunhofer-Gesellschaft from January 1st, 2001. Already in 1996, the first Fraunhofer Institute in Rhineland-Palatinate was founded in Kaiserslautern with the Institute for Experimental Software Engineering (IESE).

The director of the institute, Prof. Dieter Prätzel-Wolters, was delighted: "We have always strived for the integration into the Fraunhofer-Gesellschaft, and we are proud that we did it." In his words, the Fraunhofer-Gesellschaft is one of the leading research institutions in Germany with an excellent reputation especially in industry, a very helpful fact for the acquisition of projects. [...] Another positive sign for the scientific and industrial location of Kaiserslautern.

"Companies prefer to open up in the vicinity of Fraunhofer Institutes due to the know-how available. Besides, spin-offs of the institutes create new jobs, which will also attract students of mathematics." According to Prätzel-Wolters, the ITWM at the moment has 60 employees, 20 PhD-students and approximately 50 graduate and undergraduate assistants. As a future perspective, 250 employees are intended when the institute has grown to its full size.

Kaiserslautern

Institut bringt Synergie-Effekt

Zum 1. Januar wird das Kaiserslauterner Institut für Techno- und Wirtschaftsmathematik (ITWM) als erstes mathematisches Institut in die Fraunhofer-Gesellschaft aufgenommen. Das ITWM ist das zweite Fraunhofer-Institut in Rheinland-Pfalz. Es folgt dem Institut für Experimentelles Software-Engineering (IESE), das seinen Sitz ebenfalls in Kaiserslautern hat und vor einem Jahr den Status eines Fraunhofer-Instituts bekam. Der rheinland-pfälzische Wissenschaftsminister Jürgen Zöllner bezeichnete dies auf einem Festakt in Kaiserslautern als großen Erfolg für den Wissenschaftsstandort Rheinland-Pfalz. Professor Helmut Neunzert, Leiter des ITWM, und Professor Dieter Rombach, Leiter des IESE, versprechen sich von der räumlichen Nähe der beiden Institute große Synergie-Effekte. Die Arbeitsschwerpunkte des ITWM liegen im Bereich der Modellierung und Simulation von Produkten und Produktionsprozessen, der Qualitätskontrolle sowie der Optimierung. Gemeinsam mit den anderen Fraunhofer-Instituten will das Institut künftig den Zugang

Deutsche Universitätszeitung, Nr. 23/2000

Das erste Institut für Mathematik

KAISERSLAUTERN (dpa) – Das erste mathematische Fraunhofer-Institut in Deutschland entsteht Anfang nächsten Jahres in Kaiserslautern. Es soll unter anderem der Industrie, der Technik und der Wirtschaft bei der Computersimulation neuer Produkte oder Produktionsabläufe helfen. Wie der rheinland-pfälzische Wissenschaftsminister Jürgen Zöllner (SPD) gestern mitteilte, wird das Kaiserslauterer Institut für Techno- und Wirtschaftsmathematik (ITWM) zum 1. Januar 2001 in die renommierte Fraunhofer-Gesellschaft aufgenommen. Diese gilt mit bundesweit 48 Instituten als größte Organisation für angewandte Forschung in Europa und hat in Rheinland-Pfalz noch ein Institut für Experimentelles Software-Engineering, ebenfalls in Kaiserslautern.

Mainzer Allgemeine Zeitung, 10.11.2000

MATHEMATIK

Neues Fraunhofer-Institut

Das Institut für Techno- und Wirtschaftsmathematik ITWW in Kaiserslautern ist zum Jahreswechsel in die Fraunhofer-Gesellschaft eingegliedert worden. Damit erhält Rheinland-Pfalz sein zweites Fraunhofer-Institut. *DW*

Die Welt, 03.01.2001

MATHEMATIK

Fraunhofer-Institut in Rheinland-Pfalz

Das erste mathematische Fraunhofer-Institut in Deutschland entsteht Anfang nächsten Jahres in Kaiserslautern. Es soll Industrie, Technik und Wirtschaft bei der Computersimulation neuer Produkte oder Produktionsabläufe helfen. Das Kaiserslauterer Institut für Techno- und Wirtschaftsmathematik (ITWM) wird zum 1. Januar 2001 in die renommierte Fraunhofer-Gesellschaft aufgenommen. dpa

Hamburger Abendblatt, 21.11.2000

ITWM wird Fraunhofer-Institut

Festakt in Kaiserslautern

▸ KAISERSLAUTERN (cla). Das Kaiserslauterer Institut für Techno- und Wirtschaftsmathematik (ITWM) wird am 1. Januar 2001 als erste mathematische Einrichtung in die Fraunhofer-Gesellschaft aufgenommen. Die Forschungslandschaft werde dadurch um einen wichtigen Baustein erweitert, der hohes wissenschaftliches Niveau und breite Marktkompetenz vereine, sagte Wissenschaftsminister Jürgen Zöllner bei einem Festakt auf dem Campus der Universität. Bereits 1996 war mit dem Institut für Experimentelles Software Engineering das erste Fraunhofer-Institut in Rheinland-Pfalz gegründet worden – ebenfalls in Kaiserslautern.

Rheinpfalz, 10.11.2000

Fraunhofer übernahmen Mathematik-Institut

Die Fraunhofer-Gesellschaft steigt nun stärker in die Mathematik ein. Mit der Übernahme des Instituts für Techno- und Wirtschaftsmathematik (ITWM) in Kaiserslautern kann der Zusammenschluss von nunmehr 48 Forschungseinrichtungen dem wachsenden Bedarf der Wirtschaft an dieser Dienstleistung begegnen. Schließlich nutzt die Mathematik zum Beispiel bei der Optimierung von Produktionsprozessen.

Die Schwerpunkte des Instituts liegen vor allem in der Berechnung von Strömungen sowie von Gieß- und Filtrationsprozessen. Zudem sind bei der Simulation von Mikrostrukturen und bei der Bildverarbeitung viele Rechenschritte nötig, und daher eben auch die Vorarbeit von Mathematikern. **Tsp**

Tagesspiegel, 3.1.2001

Mathematisches Fraunhofer-Institut

KAISERSLAUTERN (dpa)

Das erste mathematische Fraunhofer-Institut in Deutschland entsteht Anfang nächsten Jahres in Kaiserslautern. Es soll unter anderem der Industrie, der Technik und der Wirtschaft bei der Computersimulation neuer Produkte oder Produktionsabläufe helfen. Wie der rheinland-pfälzische Wissenschaftsminister Jürgen Zöllner (SPD) mitteilte, wird das Kaiserslauterer Institut für Techno- und Wirtschaftsmathematik (ITWM) zum 1. Januar 2001 in die renommierte Fraunhofer-Gesellschaft aufgenommen.

Flensburger Tageblatt, 2.12.2000

The foundation of the ITWM is inseparably connected to the name of Professor Helmut Neunzert. It was him, who has been professor at the University of Kaiserslautern since 1974, who refuted the wide-spread opinion that mathematics was a purely theoretical science. [...] "Mathematics is everywhere", Neunzert has been preaching. In the beginning, people were sceptical; nevertheless, Neunzert's research group was increasingly successful, culminating in the foundation of the ITWM in 1995, an institute connecting mathematics and practice, scientific standards and business applications. Meanwhile, small and medium-sized companies, like HegerGuss in Enkenbach-Alsenborn, as well as big enterprises like VW, order tailored solutions for tricky problems at the ITWM.

For example, the research groups in Kaiserslautern compute how an airbag inflates, where the best stations are for changing trains/busses in a public transport community, or how risk factors for heart diseases can be determined from long-term electrocardiograms. This has finally convinced the Fraunhofer-Gesellschaft, too. When the institute was founded in 1995, the Fraunhofer-Gesellschaft remained still critical and did not necessarily believe in the possibility of earning money with mathematics – after all, 50% of the budget of Fraunhofer Institutes must be provided by orders from industry. Therefore, the ITWM was working according to Fraunhofer criteria during the last five years, while the basic financing was provided by the Land, which meant that things had to get moving at the ITWM.

After 1995, the number of employees rapidly increased from 15 to 60, in the first two years there was already a growth rate of up to 50 %, and the market for mathematics appeared to be quasi inexhaustible. In 2000, the annual budget reached ten million DM, 50 % stemming from industry and 25 % from publicly funded projects.

When the ITWM proudly submitted this balance, the Fraunhofer-Gesellschaft had already been convinced long since. Already in June, 1999, a strict examination board recommended: "The ITWM has fulfilled the economic criteria of the Fraunhofer-Gesellschaft. There is no doubt that a successful Fraunhofer Institute can be founded on the basis of the results of the research and their applications."

Ein Fraunhofer-Institut für Mathematik

Das Institut für Techno- und Wirtschaftsmathematik (ITWM) in Kaiserslautern ist am 1. Januar der Fraunhofer-Gesellschaft eingegliedert worden. Es ist deren erstes Institut mit mathematischem Schwerpunkt. Zu dem Anschluß ist es gekommen, weil der Bedarf der Wirtschaft an mathematischen Forschungs- und Dienstleistungen ständig wächst. Die Arbeitsschwerpunkte des ITWM liegen in der Modellierung und Simulation von Produkten und Produktionsprozessen sowie der Qualitätskontrolle. Umfassende Erfahrungen bestehen unter anderem bei der Berechnung von Strömungen, der Simulation von Mikrostrukturen, der Bildverarbeitung, bei adaptiven, „lernenden" Systemen und bei der Optimierung von Standortplanung und Prozeßregelung. Das Institut ist Ende 1995 aus der Arbeitsgruppe Technomathematik am Fachbereich Mathematik der Universität Kaiserslautern hervorgegangen, die sich seit den frühen achtziger Jahren mit anwendungsorientierten Forschungsprojekten beschäftigt. In Kaiserslautern ist auch das Institut für Experimentelles Software-Engineering der Fraunhofer-Gesellschaft beheimatet. F.A.Z.

Frankfurter Allgemeine Zeitung, 3.1.2001

Institut nach Kaiserslautern

Das erste mathematische Fraunhofer-Institut in Deutschland entsteht Anfang nächsten Jahres in Kaiserslautern. Es soll unter anderem der Industrie, der Technik und der Wirtschaft bei der Computersimulation neuer Produkte oder Produktionsabläufe helfen. lrs

Mannheimer Morgen, 10.11.2000

„Beginn einer ganz neuen Ära"

Festakt zur Aufnahme des Instituts für Techno- und Wirtschaftsmathematik in Fraunhofer-Gesellschaft

Die Freude war groß, die Rednerliste lang: Die Aufnahme des Instituts für Techno- und Wirtschaftsmathematik (ITWM) in die Fraunhofer-Gesellschaft wurde gestern bei einem Festakt an der Universität als bedeutend für den Wissenschaftsstandort Kaiserslautern und das ganze Land bewertet.

Ein Glücksfall für Kaiserslautern: Zahlreiche Redner, darunter auch Wissenschaftsminister Jürgen Zöllner, würdigten gestern die Aufnahme des ITWM in die Fraunhofer-Gesellschaft. —FOTO: VIEW

Wissenschaftsminister Jürgen Zöllner war besonders stolz, dass mit dem ITWM und dem Institut für Experimentelles Software Engineering nun schon zwei von bundesweit 48 Fraunhofer-Instituten ihren Sitz in Kaiserslautern haben. Die Fraunhofer-Gesellschaft sei die größte Organisation für angewandte Forschung in Europa und zeichne sich durch eine einzigartige Marktorientierung aus. Das ITWM habe unter Beweis gestellt, dass Mathematik heute den Rang einer Schlüsseltechnologie habe. Zöllner: „Wenn man die Projektliste des ITWM anschaut, wundert man sich, wo Mathematiker überall ihre Nase reinstecken." Egal, ob es um Mikropumpen, Hüftprothesen, Preisbildung oder Krankentransporte gehe, das ITWM biete maßgeschneiderte Lösungen an. Zöllner bezeichnete es als wünschenswert, diesen realitätsnahen Einsatz von Mathematik in den Schulunterricht einfließen zu lassen. Nur so könne es gelingen, die Zahl der Studienanfänger in naturwissenschaftlichen und technischen Fächern wieder zu erhöhen.

„Die mitreißende Dynamik und Begeisterung der Mitarbeiter hat den Grundstock für den Erfolg des ITWM gelegt", sagte Hans-Ulrich Wiese vom Vorstand der Fraunhofer-Gesellschaft. Dem Institutsgründer und „Erfinder" der Technomathematik, Professor Helmut Neunzert, bescheinigte er, mit seiner Einschätzung, die Fraunhofer-Gesellschaft sei ein Schlaraffenland für Mathematiker, richtig zu liegen. Wiese zollte aber auch der Uni ein großes Lob: „Aus der Hochschule kommt ganz viel Kraft für die Arbeit am ITWM." Unipräsident Professor Günter Warnecke bescheinigte dem ITWM, in den vergangenen Jahren eine exzellente Leistung erbracht zu haben und würdigte vor allem den Einsatz von Neunzert. Mit ihm habe die reine Mathematik ihre Unschuld verloren, dank seiner Visionen habe das ITWM Fraunhofer-Status erlangt. Warnecke: „Neunzert ist ein Glücksfall für die Universität." Oberbürgermeister Bernhard Deubig betonte, es sei ein Glück für die Stadt, ein Institut wie das ITWM zu haben. „Es wird Kaiserslautern in ähnlicher Weise repräsentieren wie der 1. FCK. Neunzert-Schüler Wilhelm Krüger, Vorstandsvorsitzender der tecmath AG, der erfolgreichsten Uni-Ausgründung, betonte, die Aufnahme des ITWM in die Fraunhofer-Gesellschaft sei der Beginn einer neuen Ära. „Wir haben in Kaiserslautern bewiesen, dass Mathematik die Schlüsseltechnologie für Innovationen ist. Jetzt müssen wir den Schlüssel in die Hand nehmen und zeigen, dass wir die Besten sind."

Mit der Aufnahme des ITWM in die Fraunhofer-Gesellschaft werde auch der Wissenschafts- und Wirtschaftsstandort Kaiserslautern gestärkt, versicherte Institutsleiter Professor Dieter Prätzel-Wolters. 50 Prozent der Industrieaufträge des Instituts kämen von kleinen und mittelständischen Unternehmen aus der Region. (cla)

Rheinpfalz, 10.11.2000

ITWM initiative "Alliance for Mathematics": Mathematics from Rhineland-Palatinate for the whole wide world

"Mathematics is the specific competence of Kaiserslautern", was the opinion of leading minds from industry and science, who founded the "Alliance for Mathematics Kaiserslautern" at the end of the year 1999. Overall charge: the ITWM. Central idea: know-how refines the profile - an advantage for the region and a location factor worldwide.

On the 1st of May, the "Alliance for Mathematics" was presented in public for the first time, and proved to be a real child of Kaiserslautern. During the Regional Gardening Fair, the soccer legend Fritz Walter met his "twin" - and enthusiastic spectators did not only learn what this had to do with mathematics, they also had a lot of fun when the "twin" was put up for auction: a lifesize artificial statue, completely produced automatically and by means of mathematical methods.

The funds raised by the auction were used for the promotion of the next generation of scientists, a special objective of the "Alliance for Mathematics". By competitions, guided tours, trainee programs and the like, interest for mathematics should already be aroused at school. Training courses for teachers are also part of the program, and a regularly meeting association "School" tries to find a way for improving lessons in mathematics and carrying out sensible reforms.

Wie Förmchen für Weihnachtsplätzchen

Institut für Techno- und Wirtschaftsmathematik (ITWM) entwickelt Gleichungen, die die Welt erklären – Zweiginstitute im Visier

Von Susanne Schütz

▸ 7^2 ist an die Mauer gepinselt. Damit ist klar: Hier in Bau 49 können nur Mathematiker residieren. Doch die Botschaft versteht nicht jeder. „Wir bekommen manchmal Post an Gebäude 7 Quadratmeter", sagt Professor Helmut Neunzert kopfschüttelnd. Mit Mathe im Alltag kann eben nicht jeder etwas anfangen. Das will der Gründer des Instituts für Techno- und Wirtschaftsmathematik (ITWM) gern ändern. „Mathematik ist spannend. Die Welt hat nur ein falsches Bild von ihr."

Wer den 64-Jährigen trifft, glaubt ihm bedingungslos. Seine Begeisterung steckt an: Er nimmt ein Blatt Papier, springt auf, lässt es zu Boden segeln. „Sehen Sie das? Das kann noch keine Mathematik nachspielen."

Neunzert sucht nach Mustern. „Für mich ist Mathematik die Wissenschaft, die Ordnungsstrukturen liefert, in die wir die gegebene Welt einpassen können." Wie bei Förmchen für Weihnachtsplätzchen. „Wenn die Welt reinpasst, können wir sie vorhersagen." Umgekehrt heißt das: „So lange keine Ordnungsmuster da sind, ertrinken wir in Informationen."

Die Universität Kaiserslautern hat vom Elan des Münchners bereits profitiert: Neunzert hat hier mit Kollegen 1980 den Studiengang Technomathematik erfunden, der sich um Anwendung der Mathematik in der Technik dreht. Heute gibt es „technomathematics" weltweit. Obwohl zunächst viel Skepsis da war. „Ganz Deutschland hat gesagt: Das ist ein Quatsch", erinnert sich Neunzert amüsiert. Der Mathematiker, der seit 1974 in Kaiserslautern lehrt, war aber überzeugt: „Was wir den Leuten vorher beigebracht haben, war nicht das, was sie brauchen."

Der Studiengang und Neunzerts Arbeitsgruppe wuchsen schnell. Denn statt Realexperimenten setzte die Forschung zunehmend auf Computersimulationen. Und deren Sprache ist die Mathematik. Neunzert: „Von der Windel über Ölfilter bis zu Bagger oder Weltraumrakete: Immer stecken mathematische Gleichungen dahinter."

Feuchte Windeln und Finanzmärkte

Manchmal kann eine Gleichung ganz Verschiedenes beschreiben, sagt Neunzert: etwa die Strömung in Windeln oder das Verhalten von Finanzmärkten. Denn auch angewandte Mathematik lebt von der Abstraktion. „Wenn ich Probleme in Gleichungen beschreibe, lasse ich ja immer etwas weg." Durch die Abstraktion werde Ideentransfer möglich.

Das bezweifelte die Wirtschaft zunächst, erinnert sich Neunzert: „Die Industrie war am Anfang sehr zögerlich." Doch dann kam das europäische Raumfahrtprojekt Hermes, an dem die Kaiserslauterer Mathematiker in Konkurrenz zur Nasa an der Umströmung der Raumfähre arbeiteten.

Aus der Arbeitsgruppe ging 1995 das eigenständige ITWM hervor, das heute rund 100 Mitarbeiter hat. Von Anfang an stand es unter Fraunhofer-Verwaltung. Jetzt ist es geschafft: Ab 1. Januar 2001 wird das ITWM, das seit Juli von Professor Dieter Prätzel-Wolters geleitet wird, offiziell zum Fraunhofer-Institut. Zweigstellen sind ebenfalls schon im Blick. Im schwedischen Göteborg soll es 2001 losgehen, im italienischen Florenz 2002. Dort hat sich der ehemalige Oberbürgermeister – ein Mathematiker-Kollege – für die Technomathematiker stark gemacht, erzählt Neunzert. Und in Schweden hat Neunzert ein Blockhaus und ebenfalls wissenschaftliche Kontakte.

Hier können nur Mathematiker hausen: das künftige Fraunhofer-Institut für Techno- und Wirtschaftsmathematik residiert in Uni-Gebäude 7^2. —FOTO: VIEW

Mit Wissenschaft Geld verdienen ist das Ziel der Fraunhofer-Institute. So haben sich die Schwerpunkte der ITWM-Arbeit aus den Aufträgen der Industrie entwickelt. „Wir sind Spezialisten für alles, was die Unternehmen nicht von der Stange kaufen können", sagt Neunzert. Eine der ersten Auftraggeber in der Abteilung „Transportvorgänge": der Spezialglashersteller Schott aus Mainz. Das ITWM beschäftigte sich – erfolgreich – mit der Frage: Wie langsam muss Glas abkühlen, damit es keine Risse bekommt?

Weiter erforscht das ITWM die „Strömung in komplexen Strukturen". Ein Beispiel: Gemeinsam mit einer Softwarefirma simulierte das ITWM im Auftrag der Enkenbacher Firma HegerGuss, wie Motorblöcke fehlerfrei in Formen gegossen werden können. „Das sind sehr komplexe Strukturen, denn es geht um glühendes Eisen, das rast und spritzt und dann erstarrt."

Tischplatte oder Schrankrückwand

Produkte verbessern ist auch Ziel der Abteilung „Bildverarbeitung". So wurde etwa eine Software entwickelt, die Oberflächen wie hochwertiges Papier oder Holz auf Fehler untersucht. Neunzert zeigt auf das Furnier seines Tisches: „Der Computer soll dann entscheiden: Taugt das für einen Tisch oder nur für die Schrankhinterwand."

Wo muss ein Zwischenlager gebaut werden, um die Wege zum Kunden kurz zu halten? Damit beschäftigt sich die Abteilung „Optimierung" ebenso wie mit der Frage, wo in einem Skigebiet der einzige Rettungshubschrauber am besten positioniert ist.

Auch bei der Diagnose von Herzkrankheiten ist das ITWM aktiv. In der Abteilung „Adaptive Systeme" werden Langzeit-EKGs ausgewertet – von Herzpatienten, die später gesund wurden, noch krank oder gar verstorben sind. Neunzert: „Das ist eine irrsinnige Menge von Daten und wir suchen das Gesetz, das dahinter steckt." Wenn auch die bisher entwickelten lernenden System bereits eine „höhere Trefferrate" als andere Diagnoseinstrumente lieferten, sei das Gesetz noch nicht gefunden. „Das ist ein riesiges unverstandenes Feld." Neunzerts Zukunftsprognose: „Mathematik und Medizin sind die großen Themen der nächsten 20 Jahre."

Rheinpfalz, 3.11.2000

Mathematik-Allianz soll Standort stärken

Institut für Techno- und Wirtschaftsmathematik startet mit Hightech-Firmen außergewöhnliche Initiative

▸ Das Institut für Techno- und Wirtschaftsmathematik, das am 1. Januar das erste mathematische Fraunhofer-Institut wird, hat auch eine Außenstelle im PRE-Park eingerichtet. Unter anderem, um nah bei den Unternehmen zu sein, die Hilfe brauche. Denn immerhin verdient das Institut mit Auftragsforschung sein Geld.

Angestoßen hat das Institut im PRE-Park eine Initiative, die bundesweit einzigartig ist. „Mathematik-Allianz" heißt das Projekt, das vor allem von dem ehemaligen Institutsleiter Professor Helmut Neunzert initiiert wurde. Er ist überzeugt: „Qualifizierte Mitarbeiter werden immer mehr zu einem entscheidenden Wirtschaftsfaktor." Und befürchtet, dass im weltweiten Werben um die wenigen Fachkräfte Firmen in kleineren Städten, außerhalb international renommierter Metropolen wie Berlin oder München, schnell das Nachsehen haben werden. „Nur wer sich auf besondere Stärken besinnt und gezielt ein Profil aufbaut, kann Standortvorteile gewinnen", meint Neunzert.

„Kaiserslauterns spezifische Stärke ist die Mathematik", fanden deshalb führende Köpfe aus Wirtschaft und Wissenschaft und gründeten vor einem Jahr die „Mathematik-Allianz Kaiserslautern". Neunzert: „Zu Unrecht gilt Mathematik vielen noch als weltfremd. Sie ist heute eine wichtige Schlüsseltechnologie, ohne die auch die Weiterentwicklung der Informationstechnologie nicht denkbar ist." Mitglieder der Mathematik-Allianz sind das Institut für Technound Wirtschaftsmathematik, aber auch Hightech-Firmen wie die tecmath AG oder die LMS Durability technologies GmbH, die ständig nach qualifizierten Mathematikern suchen. Auch der Fachbereich Mathematik der Universität, der bereits in den 80er Jahren praxisnahe Studiengänge wie Technomathematik oder Wirtschaftsmathematik einrichtete, macht mit. „Das Umfeld von wissenschaftlichen Instituten, innovativen Firmen und Technologieförderung ist einzigartig", so Neunzert. „Wenn wir das nutzen, können wir entscheidend zur Stärkung des Wirtschaftsstandortes Kaiserslautern beitragen."

Die Mathematik-Allianz setzt auch auf Fachkräfte aus dem Ausland. So lockt der Fachbereich Mathematik mit englischsprachigen Studienangeboten, die an internationale Maßstäbe angepasst sind, eine Menge vielversprechender und oft bereits hochqualifizierter Ausländer nach Kaiserslautern - aus Indien, aus Südamerika, aus Osteuropa. Ein besonderes Anliegen der Allianz ist es aber auch, den Nachwuchs vor Ort zu fördern.

Ein „Arbeitskreis Schule", in dem zahlreiche Lehrer mitarbeiten, soll das Interesse der Schüler an Mathematik stärken und zum Studium ermutigen. Derzeit wird Unterrichtsmaterial erarbeitet, das Probleme aus der Praxis aufgreift und eigenständige Arbeitsweisen fördert. Fortbildungsangebote sollen die Lehrer für einen praxisorientierten Unterricht fit machen. Beim Land hat die Allianz den Antrag gestellt, in einem Modellversuch mathematische Fragestellungen aus Technik und Wirtschaft und anwendungsnahe Methoden in die Lehrpläne aufzunehmen.

Andere Aktionen richten sich direkt an die Schüler. So der „Praktikantensommer 2000", bei dem Schüler vier Wochen lang bei Mitgliedern der Allianz den Berufsalltag von Mathematikern kennen lernen konnten. Bis Oktober lief ein Wettbewerb, der eher „Jugend forscht" ähnelte als den üblichen Mathematik-Wettbewerben. Es galt Alltagsprobleme zu entdecken, die sich mit mathematischen Methoden lösen lassen.

Ziel der Mathematik-Allianz sind aber auch Unternehmenskooperationen und gemeinsame Forschungsprojekte. Auch auswärtige Unternehmen sollen einbezogen werden. (cla)

Rheinpfalz, 17.11.2000

KOMMENTAR

Originelle Idee

Von Claudia Schneider

▸ Gut verpackt und mit einer originellen Idee lässt sich auch eine trockene Materie wie Mathematik verkaufen.

Ausgerechnet Mathematik: Für diese trockene Wissenschaft, vielen seit der Schulzeit verhasst, die Werbetrommel zu rühren, ist wirklich schwer. Dennoch hat es die Mathematik-Allianz, ein Zusammenschluss von Unternehmen und Hochschuleinrichtungen, gestern geschafft, damit viel Volk anzulocken.

Die Halle 27 auf dem Landesgartenschau-Gelände war voll, als vorgeführt wurde, was man mit Hilfe von Mathematik alles machen kann. Etwa lebensgroße Statuen von prominenten Lauterern wie Fritz Walter, Bernhard Deubig oder Norbert Thines. Da wurde mal wieder deutlich: Gut verpackt, mit einer originellen Idee, lässt sich alles verkaufen.

Das Publikum war von der Promi-Show begeistert und ließ sich nebenbei gerne unterrichten, dass ohne Mathematik heute nichts mehr geht, es kaum eine technische Anwendung gibt, die ohne „Zahlenspiele" auskommt. Und erstaunt wurde registriert, dass Lautern zu den führenden Mathestandorten in der Republik zählt.

Die Rechnung der Mathematik-Allianz, durch unkonventionelle Aktionen auf sich aufmerksam zu machen, ist aufgegangen. Weil sie das Einmaleins beherrscht, Schwellenängste abzubauen. Werbung machen will die Mathematik-Allianz nun auch an Schulen, mit praxisbezogenen Projekten. So sollen Schüler etwa analysieren, wie man die Ampelanlagen in der Stadt optimieren könnte... —*Lokalseite 3*

Rheinpfalz, 2.5.2000

Fritz Walter trifft seinen Doppelgänger aus Styrodur

Mathematik-Allianz stellt lebensgroße Statuen prominenter Lauterer vor

Von unserer Redakteurin Claudia Schneider

▸ Fritz Walter, Bernhard Deubig und Norbert Thines sind die bekanntesten Lauterer. So viel steht seit gestern fest. Und was noch schöner ist: Die drei Promis haben jetzt Doppelgänger. Lebensgroße Abbilder, aus Styrodur gefertigt, die künftig auf der Gartenschau zu besichtigen sind. Die Statuen sehen den Originalen wirklich ähnlich, auch wenn der echte OB mittlerweile sogar ein Ideechen schlanker ist als der künstliche.

Ans Licht kam dies gestern auf der Landesgartenschau in der Halle „Westpfalz Innovationen", auf Einladung der so genannten Mathematik-Allianz. Sie hatte im März mit Hilfe der RHEINPFALZ-Leser die Promis ausgewählt und dann mit einem 3D-Bodyscanner der Firma Tecmath die Skulpturen anfertigen lassen, die jetzt vorgestellt wurden.

Das Spektakel, zu dem reichlich Prominenz aus Wirtschaft und Politik angerückt war, geriet recht kurzweilig. Da enthüllte SWR3-Moderatorin Stefanie Tücking im Beisein der Promis zunächst Thines statt Deubig, als die Skulptur des Oberbürgermeisters dran war, sagte sie: „Herr Deubig, jetzt machen wir Sie frei." „Los jetzt Jungs", nahm sie kein Blatt vor den Mund, als die Herren mit anpacken mussten.

Publikumsliebling bei der Show war freilich Fußball-Legende Fritz Walter, der bestens aufgelegt forderte: „Behalten Sie den alten Fritz noch lange in guter Erinnerung." Auch wenn er jetzt knapp 80 sei, die Weltmeisterschaft von 1954 bleibe für ihn unvergesslich. „Gott sei Dank sind die Tore geschossen", sagte er in Anspielung auf eine Hüft-OP und sein Leben mit einem Herzschrittmacher. Gänsehaut verursache ihm noch immer, dass die Leute ihn, egal ob in Düsseldorf oder Kaiserslautern, herzlich grüßten und als ihren „Walter Fritz" feierten. Und dann erzählte er noch von der schönen Fußballzeit, „bei der wir noch mit dem Herzen dabei waren", von dem Teamgeist, den gemeinsamen Fahrten mit der Elf zum Bad Dürkheimer Wurstmarkt.

Publikumsliebling auf der Landesgartenschau: Fritz Walter im Gespräch mit SWR3-Moderatorin Stefanie Tücking, links Norbert Thines. —FOTO: VIEW

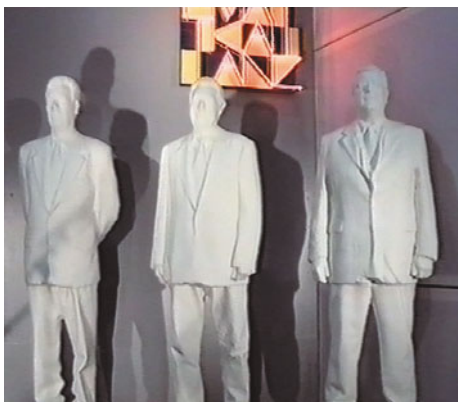
„Ein bunter Hund ist auch bekannt", erklärte sich Deubig seine Wahl, Thines hingegen gab sich eher überrascht, war froh, dass wohl sein soziales Engagement den Ausschlag gegeben hatte. Richtig spannend wurde es dann, als die Zwillinge von Fritz Walter und Co. unter den Hammer kamen. Die Nase vorn hatten bei der Versteigerung die Investoren der PRE, die sich die Fritz Walter-Skulptur für 8000 Mark schnappten. „Die Statue kommt in die Eingangshalle unseres Verwaltungsgebäudes", verriet PRE-Gesellschafter Michael Wenk.

Wozu der ganze Wirbel gut sein soll, machte Wilhelm Krüger, Vorstandsvorsitzender der Tecmath AG, deutlich. „Mathematik ist viel mehr als trockene Zahlentheorie. Sie ist lebendig, mit ihr kann man Produkte schaffen." Auch die Promi-Skulpturen beruhten auf Mathematik. Die bekannten Lauterer seien mit einem 3D-Bodyscanner mit Namen „Vitus", der weltweit einzigartig sei, vermessen und dann im Computer nachgebildet worden. Bei angewandter Mathematik sei Kaiserlautern führend, könne Weltspitze werden.

Helmut Neunzert, der Direktor des Instituts für Techno- und Wirtschaftsmathematik, stellte klar: In fast allen Dingen des täglichen Lebens stecke heute Mathematik, im Airbag, in Windeln, in Orgelpfeifen. Kaum eine technische Anwendung komme ohne Mathe aus, virtuelle Welten seien ohne sie nicht denkbar. Und: „Bei angewandter Mathematik spielt Kaiserslautern in der Champions League."

—*Kommentar Lokalseite 1*

Rheinpfalz, 2.5.2000



The "digital twins" of the three most popular citizens of Kaiserslautern.

Mathematics of the heart

A few days ago on television:
A man drops dead on the street.

A new episode of a crime series?

No:
The scientific magazine "Sonde".

Its subject was: "Mathematics of the heart". However, no chance for murder or marriage was calculated - instead, the project "Risk parameters in the case of arythmic heartbeat" (cf. p. 72) was presented. Main characters: founding member of the institute Professor Helmut Neunzert, and the Department for Adaptive Systems. The research group is working on mathematical methods for the determination of risk factors for heart diseases from long-term electrocardiograms.

No question:
Mathematics can save lives!

Order of merit of Rhineland-Palatinate for the founding member of the ITWM

Highest regards were expressed to Professor Helmut Neunzert, founding member and director of the ITWM for many years. Due to extraordinary scientific merit, Prime Minister of Rhineland-Palatinate, Kurt Beck, presented the order of merit of the Land to the "worldwide pioneer for the integration of mathematics into applied sciences". Especially important for the Land was Neunzert's work in Kaiserslautern with respect to the foundation of the ITWM and its integration into the Fraunhofer-Gesellschaft.

Landesverdienstorden für Professoren der Uni

Für außerordentliche Verdienste um das Land Rheinland-Pfalz und vorbildliches Engagement für das Wohl der Gemeinschaft hat Ministerpräsident Kurt Beck gestern in Mainz die Professoren Dieter Rombach und Helmut Neunzert von der Universität Kaiserslautern mit dem Landesverdienstorden ausgezeichnet. Die beiden Professoren hätten sich im wissenschaftlichen Bereich hervorragende Verdienste erworben, erklärte Beck. Mit außergewöhnlichem Engagement habe Rombach das Institut für Experimentelles Software-Engineering aufgebaut, das als erstes Institut in Rheinland-Pfalz in die Fraunhofer-Gesellschaft aufgenommen wurde. Darüber hinaus habe er sich für die Weiterentwicklung der Computerbildung in den Schulen in Rheinland-Pfalz eingesetzt. Neunzert sei der Initiator und weltweite Pionier der Einbettung der Mathematik in die angewandten Wissenschaften. Durch seinen außergewöhnlichen Einsatz sei es ihm gelungen, das Institut für Techno- und Wirtschaftsmathematik an der Uni Kaiserslautern zu gründen, das in die Fraunhofer-Gesellschaft aufgenommen wurde. Damit sei zum ersten Mal das Fachgebiet Mathematik in der auf anwendungsorientierten Forschung spezialisierten Fraunhofer-Gesellschaft etabliert. (red)

Mit dem Landesverdienstorden wurden gestern die Uniprofessoren Dieter Rombach (links) und Helmut Neunzert (rechts) von Ministerpräsident Kurt Beck ausgezeichnet. —FOTO: VIEW

Rheinpfalz, 8.11.2000

Felix Klein Award 2000

Felix Klein: Professor for mathematics in Göttingen at the end of the 19th century, and pioneer of applied mathematics. Since July 2000, a prize donated by the ITWM carries his name. It is awarded once in four years for an extraordinary scientific publication, where a difficult problem of industrial practice is solved by mathematical methods. The first award winner in the year 2000 is David C. Dobson, professor for mathematics in Texas.

"To most mathematicians, Felix Klein is known for his contributions to pure mathematics, e.g. his systematization of geometry with his ›Erlanger Programm‹ in 1872, and not for his consideration of applications of mathematics. However, Felix Klein was a pioneer to connect mathematics to applications, which led to solutions on technical problems. He was aware that abstract-oriented, pure mathematics, was in danger of becoming isolated. Hence he moved to word on applied mathematics and applications-oriented themes himself. He adapted the Göttingen curriculum accordingly. He was able to gain support from heads of industry. These things sound like happening today. But Felix Klein did all these things approximately one hundred years ago."

(from the eulogy of Rolf Jeltsch, Confederate Technical University, Zurich)

New home for public relations

Although a building complex, intended to house all the Fraunhofer Institutes of Kaiserslautern, is planned, nobody is expecting to move before 2005. Nevertheless, the department for press and public relations has already moved now: since August, a pavillion in front of the main building offers ample space, and the situation on the upper floors has also relaxed again.

Lectures

[L1] Eley, M.:
A Tree Search Algorithm for Solving Heterogeneous Single- & Multiple-Container Problems
INFORMS Conference, San Antonio (USA), November 2000

[L2] Eley, M., Hamacher, H.W., Nickel, P., Tenfelde-Podehl, D.:
Integrierte Krankenhausplanung: Layout, Ablaufplanung und Transporte
GOR Arbeitsgruppensitzung OR im Gesundheitswesen, Wiesbaden (D), March 2000

[L3] Gal, T., Hanne, T.:
Nonessential Objectives and the LOOPS Method in MCDM
EURO XVII, 17th European Conference on Operational Research, Budapest (H), July 2000

[L4] Ginzburg, I.:
Effective Lattice Boltzmann Methods for porous media
Workshop "Porous Media", Lambrecht/Pfalz (D), June 2000

[L5] Ginzburg, I.:
New features in Lattice Boltzmann Methods
ParPac Workshop, Kaiserslautern (D), October 2000

[L6] Ginzburg, I.:
Lattice Boltzmann Method with Free Interface
GAMM Workshop "Discrete Modeling and Discrete Algorithms in Continuum Mechanics", Brunswick (D), November 2000

[L7] Gramlich, G.:
Zur Parameteridentifikation bei Drehstrommaschinen
GAMM-Arbeitskreis Identifikation und Modellvalidierung, Dresden (D), October 2000

[L8] Halfmann, T.:
Automatische Generierung von Verhaltensmodellen analoger Schaltungen aus Netzlistenbeschreibungen
Avant! Saber User Group Meeting, Munich (D), October 2000

[L9] Hamacher, H.W.:
A mixed integer programming approach to the multileaf collimator problem
XIII. International Conference on the Use of Computers in Radiation Therapy, Heidelberg (D), May 2000

[L10] Hamacher, H.W.:
Using Multicriteria and Discrete Optimization to Design better Cancer Radiation Plans
Université Libre, Brussels (B), September 2000

[L11] Hamacher, H.W.:
Using multicriteria and discrete Optimization to design better cancer radiation plans
5th Conference of the Association of Asian-Pacific Operations Research Societies within IFORS, Singapore, July 2000

[L12] Hamacher, H.W.:
Polynomial Algorithms for Multicriteria Network Location Problems; Optimization and Simulation Approaches for Evacuation Plans
CSIRO Melbourne (Australia), September/October 2000

[L13] Hamacher, H.W.:
Ganzzahlige Optimierungsansätze zur Lösung des Multileaf Collimator Problems
Deutsches Krebsforschungszentrum Heidelberg (D), December 2000

[L14] Hamacher, H.W.:
On p hub center problems in networks
EURO Working Group on Locational Analysis (EWGLA) XII Barcelona (E), December 2000

[L15] Hamacher, H.W.:
Optimization and Solution of Real-World Problems in the ITWM
ITWM Meeting, Gothenburg (S), November 2000

[L16] Hanne, T.:
A heuristic approach for a multistage lot sizing problem with dynamic production structure
EURO XVII, 17th European Conference on Operational Research, Budapest (H), July 2000

[L17] Hilden, M.:
Estimation of flood risk in urban areas
11th ECMI Conference (ECMI 2000), Palermo (I), September 2000

[L18] Iliev O., Stoyanov D.:
On multigrid solvers for 3D Navier-Stokes equations
3rd International Conference on Finite Difference Schemes, Palanga (LT), September 2000

[L19] Iliev, O.:
Numerical simulation of porous media flow in the presence of superabsorbers
Workshop "Porous Media", Lambrecht/Pfalz (D), June 2000

[L20] Iliev, O.:
On some discretizations for the pressure equation in multimaterial saturated porous media
Workshop "Porous Media", Lambrecht/Pfalz, June 2000

[L21] Kalcsics, J.:
Ordered Weber Problems on networks - A further analysis
EURO Working Group on Locational Analysis (EWGLA) XII, Barcelona (E), December 2000

[L22] Keck, R.:
The Finite-Volume-Particle Method
GAMM Workshop "Discrete Modeling and Discrete Algorithms in Continuum Mechanics", Brunswick (D), November 2000

[L23] Keck, R.:
Numerische Methoden zur Berechnung von Strömungs- und Wärmeübergangsproblemen
NUMET 2000, Erlangen, March 2000

[L24] Kuhnert, J., Tramecon, A., Ullrich, P.:
Advanced Fluid Structure Coupled Simulations for Airbag Deployment
EUROPAM, Nantes (F), October 2000

[L25] Kuhnert, J.:
Moving Least Squares in SPH: Upwind techniques and Boundary Conditions
5th Hirschegg Workshop on Conservation Laws, Hirschegg (A), September 2000

[L26] Kuhnert, J.:
A Particle Method for Modeling Gasflows Inside of Deploying Airbags (Finite Pointset Method)
Finite Points Set Seminar, ESI GmbH, Frankfurt/Eschborn (D), October 2000

[L27] Lang, P.:
Regulation Thermography and Long Term ECGs: Mathematics for Diagnosis Aiding in Medicine
4th Int. Conf. on Operations Research, Havana (Cuba), March 2000

[L28] Linn, J., Steinbach, J., Reinhardt, A.:
Calculation of the 3D fiber orientation in the simulation of the injection molding process for short-fiber reinforced thermoplasts
ECMI 2000 Conference, Palermo (I), September 2000

[L29] Maas, C., Wiegmann, A., Mücklich, F.:
Präparation und Schallabsorptionsoptimierung von verpressten Polyestervliesen
Internationale Konferenz über Materialographie, Saarbrücken (D), September 2000

[L30] Melo, T.:
A heuristic approach for a multistage lot sizing problem with dynamic production structure
OR 2000, Dresden (D), September 2000

[L31] Neunzert, H.:
Mathematik in der Medizin
University of Hamburg (D), January 2000

[L32] Neunzert, H.:
Industrielle Problemstellung für gitterfreie Verfahren
Oberwolfach (D), January 2000

[L33] Neunzert, H.:
Vorstellung der Mathematik-Allianz
Technologie-Beirat Rheinland-Pfalz, Mainz (D), January 2000

[L34] Neunzert, H.:
Festvortrag zur Emeritierung von Prof. Hoschek
Technical University of Darmstadt (D), February 2000

[L35] Neunzert, H.:
Technomathematics as a Study Programme
Technical University of Athens (GR), March 2000

[L36] Neunzert, H.:
Mathematics as a key for key technologies
Technical University of Athens (GR), March 2000

[L37] Neunzert, H.:
Vorstellung des ITWM
Sitzung des Senats der Fraunhofer-Gesellschaft, Munich (D), April 2000

[L38] Neunzert, H.:
Mathematik wird immer wichtiger
Vortragsreihe Studium Integrale, University of Kaiserslautern (D), May 2000

[L39] Neunzert, H.:
MINT-Professionals – Mangelware bei stark steigendem Bedarf
Technotag, University of Kaiserslautern (D), May 2000

[L40] Neunzert, H.:
Wissenschaft und Praxis: Kooperation einer Gießerei mit einem mathematischen Forschungsinstitut
Hochschulrektorenkonferenz, Treffen russischer und deutscher Rektoren, Berlin (D), June 2000

[L41] Neunzert, H.:
Participation an Round Table Discussion "Shaping the next century"
3. Konferenz der European Mathematical Society, Barcelona (E), July 2000

[L42] Neunzert, H.:
Fraunhofer-Mathematik, eine Gradwanderung zwischen Wissenschaft und Kommerz
Tagung der Deutschen Mathematiker-Vereinigung, Dresden (D), September 2000

[L43] Neunzert, H.:
Internationale Begegnungen in der Wissenschaft
University of Heidelberg (D), September 2000

[L44] Neunzert, H.:
Indienreise mit insgesamt 9 Vorträgen
IIT Madras, IISc Bangalore, IIT Delhi, University of Delhi, Roorkee University, November/December 2000

[L45] Nickel, P.:
Simulation und Online-Optimierung von komplexen Kommissioniersystemen
VDI-Seminar über Optimierte Kommissioniersysteme, Stuttgart (D), February 2000

[L46] Nickel, P.:
Discrete and Network Ordered Weber Problems
17th International Symposium on Mathematical Programming, Atlanta (USA), August 2000

[L47] Nickel, P.:
Mathematical Methods of Logistics
Universidad Nacional de Trujillo (Peru), October 2000

[L48] Nickel, P.:
Strategic Network Design
SAP-Workshop im Rahmen des Supply Chain Institute, Wiesloch (D), March 2000

[L49] Nieschulz, K.-P., Milina, J., Thomas, M., Schilling, W., Schmitt, T.G.:
Risk management for urban drainage systems -simulation and optimisation
International Symposium on Flood Defence, Kassel (D), September 2000

[L50] Ohser, J.:
Integralgeometrische Methoden zur Bestimmung der Quermaßdichten aus tomographischen Abbildungen von Mikrostrukturen
DMV-Jahrestagung 2000, Dresden (D), September 2000

[L51] Ohser, J.:
3d image analysis and its application in the investigation of X-ray microtomographic images of natural sandstone
International Conference on Spatial Statistics in the Agro-, Bio- and Geosciences, Freiberg (D), July 2000

[L52] Ohser, J.:
The application of 3d image analysis to the characterization of X-ray microtomographic images of natural sandstone
EUROMET 2000, Saarbrücken (D), September 2000

[L53] Pfreundt, F.-J.:
How to sell Mathematics
NERSC Berkeley (USA), September 2000

[L54] Prätzel-Wolters, D.:
Expertensysteme in der Medizin
34. medizinische Woche Baden-Baden (D), September 2000

[L55] Prätzel-Wolters, D.:
Rechnergestützte Medizindiagnostik in Kardiologie und Onkologie
Celle (D), May 2000

[L56] Prätzel-Wolters, D.:
Mathematik: eine Schlüsseltechnologie
Festakt des ITWM, Kaiserslautern (D), November 2000

[L57] Reinel-Bitzer, D.:
Mikrostruktursimulationen mit der Lattice-Boltzmann-Methode
DMV-Tagung, Dresden (D), September 2000

[L58] Rief, P.:
Non-Linear Flow in Porous Media - A Numerical Study of the Navier-Stokes System with Two Pressures
Workshop "Porous Media", Lambrecht/Pfalz (D), June 2000

[L59] Rief, P.:
Non-Linear Flow in Porous Media - A Numerical Study of the Navier-Stokes System with Two Pressures
"Multiscale Problems in Science and Technology", Dubrovnik (HR), September 2000

[L60] Rösch, R.:
Algorithmen zur Inspektion texturierter Oberflächen
15. Heidelberger Bildverarbeitungsforum, Heilbronn (D), November 2000

[L61] Schladitz, K.:
Statistical analysis of freeze fracture specimen
1st European Conference on Spatial and Computational Statistics, Ambleside (GB), September 2000

[L62] Schladitz, K., Gerber, W., Sandau, K.:
Automatic classification of lamellar graphite in grey cast iron
Poster, EUROMET 2000, Saarbrücken (D), September 2000

[L63] Schöbel, A.:
The delay mangement problem: Models and Solution Approaches
Conference on Computer Aided Scheduling, Berlin (D), June 2000

[L64] Schöbel, A.:
Design of Zone Tariff Systems in Public Transportation
OR 2000, Dresden (D), September 2000

[L65] Siedow, N., Brinkmann M., Fotheringham, U.:
Theoretical and experimental determination of thermal transport in technical glasses
11th ECMI Conference, Palermo (I), September 2000

[L66] Siedow, N., Loch, H.:
Mathematische Probleme der Glasindustrie
DMV-Tagung, Dresden (D), September 2000

[L67] Siedow, N., Brinkmann, M., Korb, T., Fotheringham, U.:
Fundamentals of Pyrometric Temperature Measurements in Hot Glass
International Conference of Advances in Fusion and Processing of Glass/DGG Annual Meeting, Ulm (D), May 2000

[L68] Siedow, N., Manservisi, P.:
An optimal control approach to an inverse thermoelectric problem
11th ECMI Conference, Palermo (I), September 2000

[L69] Siedow, N., Neunzert, H.:
Mathematical Problems in Glass Industry
Workshop about Free Boundary Problems in Industry, Newton Institute, Cambridge (GB), July 2000

[L70] Siedow, N.:
Mathematik im Glas
University of Saarbrücken (D), December 2000

[L71] Sommer, R.:
Computer-aided Symbolic Analysis and Behavioral Modeling for Systematic Analog Circuit Design
2nd SADE Workshop at ESSCIRC 2000, Stockholm (S), September 2000

[L72] Sonneborn, T.:
Polyhedral Properties of Hub Location Problems
8th Meeting of the EURO-Working Group on Transportation, Rom (I), September 2000

[L73] Steiner, K.:
Microstructure-Simulation in Porous Media
Workshop "Porous Media", Lambrecht/Pfalz (D), June 2000

[L74] Steiner, K.:
Simulation of Moisture Transport in Textiles - Microstructure simulation
Internationale Chemiefasertagung, Dornbirn (A), September 2000

[L75] Steiner, K.:
Lattice-Boltzmann Methoden für Navier-Stokes Strömungen mit freien Oberflächen
DMV-Tagung, Dresden (D), September 2000

[L76] Stoyanov, D., Iliev, O.:
On a flexible multigrid solver for 3D Navier-Stokes and Stokes equations
4th Summer Conference "Numerical Modelling in Continuum Mechanics: Theory, Algorithms, Applications", Prag (CZ), July/August 2000

[L77] Stoyanov, D., Iliev, O.:
On a flexible 3D multigrid Navier-Stokes solver with cell-based local refinement
2nd International Conference "Applied Mathematics for Industrial Flows" (AMIF), Il Ciocco (I), October 2000

[L78] Tiwari, P., Kuhnert, J.:
General Smoothed Particle Hydrodynamics for Viscous Flows
8th International Conference on Hyperbolic Problems, Theory, Numerics, Applications, Magdeburg (D), March 2000

[L79] Tiwari, P.:
SPH method for free surface flows
5th Hirschegg Workshop on Conservation Laws, Hirschegg (A), September 2000

[L80] Wegener, R.:
An explicitly solvable kinetic model for vehicular traffic and associated macroscopic equations
TMR Workshop on New Applications of Kinetic Theory, Göteborg (S), June 2000

[L81] Wegener, R.:
Forschungskooperationen von Wirtschaft und Wissenschaft - Innovationen durch Querdenker: Hochschulen als Motoren der wirtschaftlichen Entwicklung
Berliner Bildungsdialoge (D), September 2000

[L82] Wegener, R.:
Kinetische Verkehrsflussmodelle
Institutskolloquium Angewandte Mathematik, University of Hamburg (D), November 2000

[L83] Wiegmann, A.:
Structural Boundary Design via Level Set and Immersed Interface Methods
Workshop über Levelsetmethoden, Berlin (D), April 2000

[L84] Wiegmann, A.:
Structural Boundary Design via Level Set and Immersed Interface Methods
Interphase 2000 Konferenz, Berlin (D), October 2000

[L85] Wiegmann, A.:
Finite Differenzen Verfahren für elliptische Differentialgleichungen mit unstetigen Lösungen
University of Magdeburg (D), October 2000

[L86] Zemitis A., Jungemann, M., Papastavrou, A.:
About a level set-fictitious region method
International conference MMA2000, Riga (LV), June 2000

[L88] Zemitis, A.:
Level set-fictitious region method for elliptic problems
Workshop "Porous Media", Lambrecht/Pfalz (D), June 2000

[L89] Zemitis, A., Moog, M., Papastavrou, A.:
Levelsetmethoden für poröse Medien
Workshop über Levelsetmethoden, Berlin (D), April 2000

Publications

[P1] Baddeley, A. J. , Kerscher, M., Schladitz, K., Scott, B. T.:
Estimating the J function without edge correction
Statistica Neerlandica, 54 (2000), 3, p. 315-328

[P2] Becker, A.:
Vorrichtung und Verfahren zum Codieren von Wavelet-transformierten Video- und Bilddaten, sowie Verfahren und Vorrichtung zum Decodieren von codierten Wavelet-transformierten Video- und Bilddaten
Patent application 10038400.5

[P3] Becker, A.:
A Review on Image Distortion Measures
Berichte des ITWM, 19 (2000)

[P4] Bhattacharyya, A., Stoylov, V., Iliev, O.:
Evaluation of structural influence on performance of shape memory alloy linear actuators by sharp phase front-based constitutive models
Computational Materials Science, Vol. 18 (2000), p. 269-282

[P5] Bhattacharyya, A., Stoylov, V., Iliev, O.:
A moving boundary finite elelment method-based numerical approach for the solution of one-dimensional problems in shape memory alloys
Computer Methods in Applied Mechanics and Engineering, to appear

[P6] Carrizosa, E., Hamacher, H. W., Klein, R., Nickel, P.:
Solving Nonconvex Planar Location Problems by Finite Dominating Sets
Journal of Global Optimizaton 18 (2000), p.195-210

[P7] Chernogorova, T., Ewing, R., Iliev, O., Lazarov, R.:
On the discretization of interface problems with perfect and imperfect contact
In: Chen, Ewing and Shi (Eds), Proceedings of the workshop of computational physics, Beijing, China, August 2-6, 1999. Springer, 2000, p. 93-104

[P8] Daul, C., Rösch, R., Claus, B.:
Building a color classification system for textured and hue homogeneous surfaces: system calibration and algorithm
Machine Vision and Application 12 (2000), p. 137-148

[P9] Davtian, A., Hahn, U., Ohser, J., Stoyan, D.:
Estimating number density N_V – a comparison of an improved Saltykov estimator and the disector method
Image Anal. Stereol., 20, p. 2001-2006

[P10] Drikakis, D., Iliev, O., Vassileva, D.:
Acceleration of multigrid flow computations through a dynamic adaptation of the smoothing procedure
Journal of Computational Physics, Vol. 165 (2000), p. 94-100

[P11] Eley, M.:
Approaches for solving container loading problems
Operations Research Proceedings 1999, Springer Verlag Berlin 2000, p. 445-460

[P12] Eley, M., Hamacher, H. W., Nickel, P., Tenfelde-Podehl, D.:
OR im Krankenhauswesen
OR News, No. 10, November 2000, p. 9-13

[P13] Eley, M., Hamacher, H. W., Nickel, P., Tenfelde-Podehl, D.:
Integrierte Krankenhausplanung: Layout, Ablaufplanung und Transporte
Tagung der GOR Arbeitsgruppe OR im Gesundheitswesen, Wiesbaden 2000

[P14] Emmer, P., Klüppelberg, C., Korn, R.:
Optimal portfolios with bounded capital at risk
Report in Wirtschaftsmathematik 66 (2000)

[P15] Entchev, P., Lagoudas, D., Iliev, O.:
Domain Transformation Problems in 2D Oxidation
J. Mechanical Behaviour of Materials, Vol. 11, No. 4, 2000, p. 275-293

[P16] Feldmann, P., Prätzel-Wolters, D.:
Parameter Influence on the spectrum of index-2-Matrix polynomials
submitted to Linear Algebra and its Application

[P17] Fliege, J., Nickel, P.:
An Interior Point Method for Multifacility Location Problems with Forbidden Regions
Studies in Locational Analysis 14 (2000), p. 23-45

[P18] Ginzburg, I., Wittum, G.:
Two-Phase Flows on Interface Refined Grids Modeled with VOF, Staggered Finite Volumes, and Spline Interpolants
J. Comput. Phys. 166, 1 (2001)

[P19] Götz, Th.:
Coupling heat conduction and radiative transfer
submitted to Journal of Quantitative Spectroscopy and Radiative Transfer

[P20] Götz, Th.:
A spectrum preserving collocation scheme for Slender-Body Approximations to Stokes Flow
AG Technomathematik, Preprint 234, 2000

[P21] Götz, Th.:
On the numerical solution of an integral equation arising from slender-body approximations to Stokes flow
submitted to Journal of Engineering Mathematics

[P22] Götz, Th.:
Asymptotic Methods for Air-flow around fibers flow
submitted to Proceedings of the ECMI 2000 Conference, Palermo (I)

[P23] Götz, Th., Unterreiter, A.:
Analysis and numerics of an integral equation model for slender bodies in low-Reynolds-number flows
Journal of Integral Equations and Applications 12 (2000), No. 3

[P24] Günther, M., Klar, A., Materne, T., Wegener, R.:
An explicit solvable kinetic model for vehicular traffic and associated macroscopic equations
Comp. Math. Appl., to appear

[P25] Halfmann, T., Hennig, E., Sommer R., Thole, M., Wichmann, T.:
Compensation of a Closed-Loop CMOS OTA
3. Workshop zur Förderinitiative "Smart System Engineering", Berlin, April 2000 und 2nd SADE Workshop at ESSCIRC 2000, Stockholm (S), September 2000

[P26] Halfmann, T., Hennig, E., Sommer, R., Thole, M., Wichmann, T.:
Nichtlineare Schaltungsanalyse und Verhaltens-modellierung
3. Workshop zur Förderinitiative "Smart System Engineering", Berlin (D), April 2000

[P27] Halfmann, T., Thole, M.:
A Sizing Strategy for Combining DC & AC Constraints in Analog Circuit Design
Proc. 6th International Workshop on Symbolic Methods and Applications in Circuit Design (SMACD), Lisbon (P), October 2000

[P28] Halfmann, T., Wichmann, T.:
Behavioral Modeling: Methods, Applications, Perspectives
2nd SADE Workshop at ESSCIRC 2000, Stockholm (S), September 2000

[P29] Hamacher, H. W., Bruglieri, M., Ehrgott, M.:
Some Complexity Results for k-Cardinality Minimum Cut Problems
Technical Report, Report in Wirtschaftsmathematik No. 69, University of Kaiserslautern (D), Dept. of Mathematics, 2000

[P30] Hamacher, H. W., Klamroth, K.:
Lineare und Netzwerk-Optimierung - Linear and Network Optimization . Ein bilinguales Lehrbuch
Vieweg Verlag, 2000

[P31] Hamacher, H.W., Klamroth, K.:
Planar Location Problems with Barriers and Block Norm
Annals of Operations Reserach, 96 (2000), p. 191-208

[P32] Hamacher, H.W., Labbe, M., Nickel, P., Sonneborn, T.:
Polyhedral Properties of Hub Location Problems
ITWM-Report No. 20, June 2000

[P33] Hanne, T.:
Global multiobjective optimization using evolutionary algorithms
Journal on Heuristics 6, 3 (Special issue on "Multiple objective metaheuristics" edited by X. Gandibleux, A. Jaskiewicz, A. Freville, R. Slowinski), 2000, p. 347-360

[P34] Hanne, T.:
Review of "Joachim Paul Walser: Integer Optimization by Local Search"
Mathematical Methods of Operations Research, 51, 3, 2000, p. 515-516

[P35] Hennig, E., Sommer, R.:
Frequency Compensation of Closed-Loop Feedback Amplifier Systems
Proc. ISCAS 2000, Geneva (CH), June 2000

[P36] Hietel, D., Junk, M., Keck, R., Teleaga, D.:
The Finite-Volume-Particle Method
Proceedings GAMM Workshop on Discrete Modeling and discrete Algorithms in Continuum Mechanics, Brunswick (D), November 2000

[P37] Hietel, D., Steiner, K., Struckmeier, J.:
A Finite-Volume Particle Method for Compressible Flows
Math. Models Methods Appl. Sci. 10, No. 9, p. 1363-1382, 2000

[P38] Hilden, M.:
Estimation of flood risks in urban areas - the curb as a challenge for SWE
Mathematics in Industry (ECMI Subseries), Springer 2001, to appear

[P39] Iliev, O.:
A finite difference scheme of second order for elliptic problems with discontinuous coefficients
Differential equations, No. 4, 2000

[P40] Kalcsics, J., Melo, T., Nickel, P., Schmid-Lutz, V.:
Facility Location Decisions in Supply Chain Management
Operations Research Proceedings 1999, p. 467-472, Springer Verlag Berlin, (2000)

[P41] Korn, R., Korn, E.:
Option Pricing and Portfolio Optimization - Modern Methods of Financial Mathematics
AMS, Providence, December 2000

[P42] Korn, R., Wilmott, P.:
Optimal investment under the threat of a crash
Report in Wirtschaftsmathematik 64 (2000)

[P43] Korn, R.:
Value preserving portfolio strategies and a general framework for local approaches to optimal portfolios
Mathematical Finance, Vol. 10, Issue 2, Oxford, 2000, p. 227-241

[P44] Kuhnert, J., Tramecon, A., Ullrich, P.:
Advanced Air Bag Fluid Structure Coupled Simulations applied to out-of Position Cases
EUROPAM Conference Proceedings

[P45] Kuhnert, J.:
An Upwind Particle Method for Compressible Euler and Navier Stokes
Equations (to appear)

[P46] Lang, Ch., Ohser, J., Hilfer, R.:
On the analysis of spatial binary images
J. Microscopy, to appear

[P47] Lang, P., Prätzel-Wolters, D., Wirsen, A., Kulig, P.:
Sensitivity and Robustness Analysis for Construction and Monitoring of Turbine-Generator Shafts
Springer-Verlag, 2000

[P48] Martin, R., Röbbers, E., Halfmann, T., Hennig, E., Sommer, R., Thole, M., Wichmann, T.:
Analyse und Kompensation eines Instrumentenverstärkers
3. Workshop zur Förderinitiative "Smart System Engineering", Berlin (D), April 2000

[P49] Milina, J., Nieschulz, K.-P., Selseth, I., Schilling,W.:
A Proactive Approach to Flood Risk Management in Urban Drainage Systems
to appear in Urban Drainage Modeling (UDM01). Maksimovic, C. (Hrsg.), American Society of Civil Engineers, ASCE

[P50] Nagel, W., Ohser, J., Pischang, K.:
An integral-geometric approach for the Euler-Poincaré characteristic of spatial images
J. Microscopy, 189, p. 54—62

[P51] Neunzert, H.:
Mathematics as a key to basic and high technologies
in "Mathematics and its Applications to Industry", Indian National Science Academy, New Delhi, 2000

[P52] Neunzert, H., Siddigi, A.H.:
Topics in Industrial Mathematics
Kluwer 2000

[P53] Neunzert, H., Siedow, N., Zingsheim, F.:
Simulation of the Temperature Behaviour of Hot Glass during Cooling
in: Cumberbatch, E., Fitt, A., Mathematical Modeling: Case Studies From Industry, Cambridge University Press

[P54] Nickel, P., Schöbel, A., Sonneborn, T.:
Hub Location Problems in Urban Traffic Networks
in: Niittymaki and Pursula (Eds.): Mathematical Methods and Optimization in Transportation Systems, Kluwer academic publishers, 2000

[P55] Nickel, P., Tenfelde-Podehl, D.:
Planning and Organization in the Hospital
Operations Research Proceedings 1999, Springer Verlag Berlin 2000, p. 548-553

[P56] Nickel, P., Wiecek, M. M.:
Multiple Objective Programming with Piecewise Linear Functions
Journal of Multi-Criteria Decision Analysis 8, p. 322-332 (2000)

[P57] Nieschulz, K.-P.:
Gemeinsam gegen nasse Füße - Internationales Forschungsprojekt zu Überflutungsrisiken gestartet
In: Uni Spectrum, 4/2000, Kaiserslautern (D), p. 17

[P58] Nieschulz, K.-P., Milina, J., Thomas, M., Schilling, W., Schmitt, T. G.:
Risk Management in urban drainage systems - simulation and optimisation
In: Toensmann, F., Koch, M. (Eds.), River Flood Defence, Vol. 1. Kassel Reports of Hydraulic Engineering No. 9/2000; p. F253-F262

[P59] Ohser, J., Mücklich, F.:
Statistical Analysis of Materials Structures
J. Wiley & Sons, Chichester, London, New York

[P60] Ohser, J., Sandau, K.:
Considerations about the estimation of size distribution in Wicksell's corpuscle problem
In: K. Mecke, D. Stoyan (Hrsg.), Statistical Physics and Spatial Statistics — The Art of Analyzing and Modeling Spatial Structures and Pattern Formation. Ser. Lecture Notes in Physics, Springer-Verlag, Berlin, New York, Tokyo, p. 185-202

[P61] Orlik, J., Mikhailov, S.E.:
Homogenization in Integral Viscoelasticity
Zeitschrift für Angewandte Mathematik und Mechanik (ZAMM), GAMM 2000 Annual Meeting, to appear

[P62] Orlik, J.:
Transmission problem for viscoelastic aging
Zeitschrift für Angewandte Mathematik und Mechanik (ZAMM), Vo. 80, Suppl. 2, p. 405-406, 2000

[P63] Orlik, J.:
Transmission and Homogenization in hereditary Viscoelasticity
submitted to Proceedings of ECMI 2000, Palermo (I),

[P64] Rodriguez-Chia, A., Nickel, P., Puerto, J.:
A flexible approach to location problems
Mathematical Methods of Operations Research 51 (2000), p. 69-89

[P65] Schladitz, K.:
Estimation of the intensity of stationary flat processes
Adv. Appl. Prob., 2000, 32, p. 114-139, SGSA

[P66] Schladitz, K., Baddeley, A. J.:
A third order point process characteristic
Scand. J. Statist., 2000, 27, 4, p. 657-671

[P67] Sethian, J.A., Wiegmann, A.:
Structural Boundary Design via Level Set and Explicit Jump Immersed Interface Methods
Journal of Computational Physics, 163, No. 2, p. 489-528, 2000

[P68] Siedow, N., Brinkmann, M., Korb, T.:
Remote Spectral Temperature Profile Sensing
Mathematical Simulation in Glass Technology, Schott-Schriftenreihe, Vol. 8, Springer-Verlag

[P69] Siedow, N., Brinkmann, M.:
Heat Transfer between Glass and Mold during Hot Forming
Mathematical Simulation in Glass Technology, Schott-Schriftenreihe, Vol. 8, Springer-Verlag

[P70] Siedow, N., Loch, H., Manservisi, P.:
Shape Optimization of Flanges
Mathematical Simulation in Glass Technology, Schott-Schriftenreihe, Vol. 8, Springer-Verlag

[P71] Sommer, R., Hennig, E., Thole, M., Halfmann, T., Wichmann, T.:
Analog Insydes 2 - New Features and Applications in Circuit Design
Proc. 6th International Workshop on Symbolic Methods and Applications in Circuit Design (SMACD), Lisbon (P), October 2000

[P72] Stoyanov, D., Iliev, O.:
On a multigrid, local refinement solver for incompressible Navier-Stokes equations
Mathematical Modeling, to appear

[P73] Stoyanov, D., Iliev, O.:
On a flexible tool for upscaling porous media flow problems
Journal on Theoretical and Applied Mechanics, to appear

[P74] Tiwari, P.:
Application of Moment Realizability Criteria for the Coupling of the Boltzmann and Euler Equations
TTSP, Vol. 29, No. 7, 2000

[P75] Tiwari, P.:
A LSQ-SPH Approach for Solving Compressible Viscous Flows
submitted to HYP2000 Proceedings

[P76] Tiwari, P., Kuhnert, J.:
LSQ-SPH Method for Simulations of Free Surface Flows
submitted to JCP

[P77] Tiwari, P., Manservisi, P.:
Modelling Incompressible Navier-Stokes Flows by LSQ-SPH
submitted to SIAM J.Sci.Comp

[P78] Urbassek, H. M., Klein, P.:
Constant-Pressure Molecular Dynamics of Amorphous {Si}
Phys. Stat. Sol. (b) 217, p. 461, 2000

[P79] Wegener, R., Klar, A.:
Vehicular Traffic: From Microscopic to Macroscopic Description
Transport Theory and Statistical Physics 29 (3-5), p. 479-493, 2000

[P80] Wegener, R., Klar, A.:
Kinetic Traffic Flow Models
in: Bellomo, N., Pulvirenti, M. (Hrsg.): Modeling in Applied Sciences: A Kinetic Theory Approach. Birkhäuser 2000, p. 263-316,

[P81] Wegener, R., Klar, A.:
Kinetic Derivation of Macroscopic Anticipation Models for Vehicular Traffic
SIAM Journal on Applied Mathematics No. 60 (5), 2000, p. 1749-1766

[P82] Wichmann, T., Thole, M.:
Computer Aided Generation of Analytic Models for Nonlinear Function Blocks
Integrated circuit design: power and timing modeling, optimization and simulation: 10th International Workshop, Proc. PATMOS 2000, Göttingen (D), Springer, 2000

[P83] Wichmann, T.:
Computer Aided Generation of Approximate DAE Systems for Symbolic Analog Circuit Design
ZAMM, Proc. Annual Meeting GAMM 2000, Göttingen 2000, to appear

[P84] Wichmann, T.:
Controlling the Index during Nonlinear Behavioral Model Generation
Proc. 6th International Workshop on Symbolic Methods and Applications in Circuit Design (SMACD), Lisbon (P), October 2000

[P85] Wiegmann, A.:
Analytic solutions of a multi-interface transmission problem and crack approximation
Inverse Problems, Vol. 16, 2000, p. 401-411

[P86] Wiegmann, A., Bube, K.P.:
The Explicit Jump Immersed Interface Method: Finite Difference Methods for PDE with piecewise smooth solutions
SIAM Journal on Numerical Analysis, Vol. 37 No. 3, p. 827-862, 2000

Scientific Theses for Grading

done or supervised by employees of the ITWM

[G1] Budiarto, E.:
Mathematical Simulation of Liquid-Vapour Phase Transition
Masterthesis, University of Kaiserslautern, Dept. of Mathematics

[G2] Coros, C. A.:
Higher Order Rosseland Approximation
Diploma thesis, University of Kaiserslautern, Dept. of Mathematics

[G3] Fender, I.:
Advanced numerical algorithms for elliptic equations with variable coefficients
Diploma thesis, University of Kaiserslautern, Dept. of Mathematics

[G4] Götz, T.:
Interactions of Fibers and Flow
Dissertation, University of Kaiserslautern, Dept. of Mathematics

[G5] Hausbrandt, P.:
Modellierung und Realisierung einer (n-k)-Regel als Neuronales Fuzzy-System
Diploma thesis, University of Kaiserslautern, Dept. of Mathematics

[G6] Hennig, E.:
Symbolic Approximation and Modeling Techniques for Analysis and Design of Analog Circuits
Dissertation, University of Kaiserslautern, Dept. Elektrotechnik

[G7] Heusermann, K.:
Optimal Shape Design for Heat Radiation in Industrial Furnaces
Diploma thesis, University of Kaiserslautern, Dept. of Mathematics

[G8] Jungemann, M.:
Fictitious Domain Methods for Elliptic Problems
Diploma thesis, University of Kaiserslautern, Dept. of Mathematics

[G9] Kuhnke, D.:
Homogenization of the Heat Conduction in Ceramic Materials
Diploma thesis, University of Kaiserslautern, Dept. of Mathematics

[G10] Küster, M.:
Numerische Umsetzung integralgeometrischer Methoden in der räumlichen Bildverarbeitung
Diploma thesis, University of Kaiserslautern, Dept. of Mathematics

[G11] Lojewski, C.:
Eine parellele Systemarchitektur für die Visualisierung statischer, zeitabhängiger Volumendaten
Dissertation, University of Kaiserslautern, Dept. of Computer Science

[G12] Moog, M.:
Level Set Methods for Hele-Shaw Flow
Dissertation, University of Kaiserslautern, Dept. of Mathematics

[G13] Mühlhäuser, W.-F.:
Active Contour Methods for the Segmentation of Flame Images
Diploma thesis, University of Kaiserslautern, Dept. of Mathematics

[G14] Nida, M. von:
A Lagrangian Method for Fracture Dynamics
Diploma thesis, University of Kaiserslautern, Dept. of Mathematics

[G15] Orlik, J.:
Transmission and homogenization in hereditary viscoelasticity with aging and shrinkage
Dissertation, University of Kaiserslautern, Dept. of Mathematics

[G16] Pudasaini, P. P.:
Mathematical Simulation of Free Surface Segregation in Granular Materials
Masterthesis, University of Kaiserslautern, Dept. of Mathematics

[G17] Schick, Ch.:
Adaptivity for Particle Methods in Fluid Dynamics
Diploma thesis, University of Kaiserslautern, Dept. of Mathematics

[G18] Sühling, M.:
Computational Aspects of Multi-Scale Optical Flow
Diploma thesis, University of Kaiserslautern, Dept. of Mathematics

[G19] Wiese, M.:
Symbolic Pole/Zero Approximation in Analog Circuit Analysis using Equation-based Simplification driven by Eigenvalue Shift Prediction
Diploma thesis, University of Kaiserslautern, Dept. of Mathematics

Participation on Fairs and Conferences

1. Hannoversche Software-Tage für die Wasserwirtschaft
Hannover (D), March 2000, Participation

11th ECMI Conference (ECMI 2000)
Palermo (I), September 2000, Participation

9th International MAGMASOFT Usermeeting
Vaals (A), Participation

Bayern-Innovativ
Hof (D), April 2000, Exhibitor

BMBF Statusseminar
Dresdner Bank, Frankfurt (D), December 2000, Poster: Umweltgerechtes Betanken

Forum Verbundwerkstoffe und Polymere
Mainz (D), Participation

Hannover-Messe Industrie
Hannover (D), March 2000, Exhibitor

IFIP WG2.5 Working Conference 8 Software Architecture for Scientific Computing Applications
Ottawa (CAN), October 2000, Participation

Interfab HealthCare 2000
Nürnberg (D), May 2000, Exhibitor

Internationale Chemiefasertagung und -messe
Dornbirn (A), September 2000, Exhibitor

INTERGEO Fachmesse für Geodäsie und Geoinformatik
Berlin (D), October 2000, Participation

JPEG2000 Meeting No. 20-22
Arles (F), Rochester (USA), New Orleans (USA), Participation

Kickoff-Meeting "Mathematics, Computing and Simulation for Industry - MACSI-net"
Amsterdam (NL), November 2000, Participation

Kolloquium "Modellierung von Höhendaten für hydrologische Fragestellungen"
Bundesanstalt für Gewässerkunde, Koblenz (D), May 2000, Participation

MEDICA-2000
Düsseldorf (D), November 2000, Exhibitor

Stand of the ITWM at the MEDICA Fair 2000.

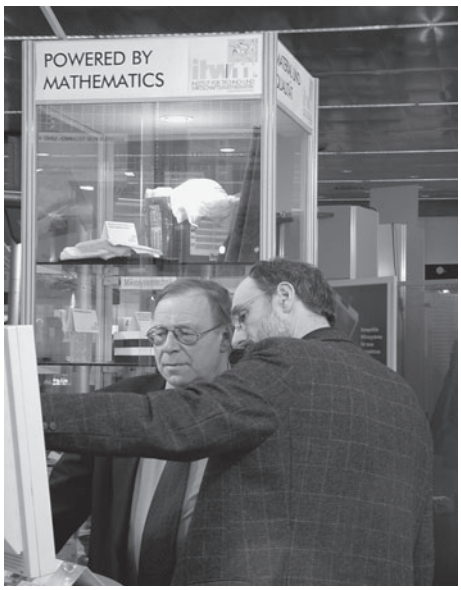
Symposium und Fachausstellung "Zulieferer Innovativ"
Ingolstadt (D), July 2000, Exhibitor

Systems 2000
Munich (D), November 2000, Participation

TMR – Workshop on "Differencial Equations in Industrie and Commerce"
Oxford (GB), Participation

Vorbeugender Hochwasserschutz auf kommunaler Ebene
Institut für ökologische Raumentwicklung e. V., Dresden (D), December 2000

Workshop "Porous Media"
Lambrecht/Pfalz (D), June 2000, Organisation



Minister of trade and commerce of Rhineland-Palatinate, Hans-Artur Bauckhage, at the stand of the ITWM at the Hannover Fair Industry.

Lectures Held by Guests

Benz, Prof. W.
University of Bern (CH)
Modeling brittle fracture with SPH
May 2000

Bordag, Prof. L.
Sofia-Kovalevskaja-Gastprofessur, Kaiserslautern (D)
Typische Probleme bei radialen Stevenrohrabdichtungen
February 2000

Borland, N.
Melbourne (Australia)
Aircraft Rotation Problems
November 2000

Fößel, P.
Erlangen (D)
Hardwareimplementierung von Waveletkompressionen – Oberflächeninspektion
October 2000

Grötschel, Prof. M.
Berlin (D)
Frequenzvergabe im Mobilfunk
June 2000

Hackbusch, Prof. W.
Leipzig (D)
Hierarchische Matrizen - Ein neues numerisches Werkzeug
November 2000

Hahn, H. K.
Bremen (D)
Neue Anwendungen der schnellen Wasserscheidentransformation in der medizinischen Bildverarbeitung
November 2000

Ilchmann, Prof. A.
Ilmenau (D)
Adaptive Regelung bei Funktionaldifferentialgleichungen mit Anwendung in der Biotechnologie
November 2000

Kaasschieter, Dr. E.F.
University of Eindhoven (NL)
Analytic and Numerical Modeling for Flow in Porous Media
March 2000

Karkkainen, Prof. T.
Optimization of Conducting Structures
October 2000

Klein, Prof. R.
Institut für Klimafolgenforschung Potsdam (D)
Multiple Scales Asymptotics for Atmospheric Flows
March 2000

Kollonko, Prof. M.
Kosten-Nutzen-Analysen für Investitionen in Bahnverkehrsnetze
May 2000

Mauser, Prof. N.
University of Wien (A)
Asymptotische Analysis von nichtlinearen Schrödingergleichungen der Halbleitermodellierung
February 2000

Mladenovic, Prof. N.
Belgrad (YU) / Montreal (Canada)
An Oil Pipeline Design and Pooling Problems
November 2000

Nachtigall, K.
Dresden (D)
Workshop "Anschlusssicherung im öffentlichen Nahverkehr"
September 2000

Nonnenmacher, Dr. D.-J.
Dresdner Bank
Independent Price Verification
March 2000

Petzold, M.
Berlin (D)
Singularitäten bei Interface-Problemen und ihre Behandlung mit a-posteriori-Fehlerschätzern
May 2000

Puerto, J.
Sevilla (E)
Kompaktkurs Spieltheorie
March 2000

Sarti, Dr. A.
Berkeley (USA)
Subjective Surfaces: a Geometric Model for Boundary Completion
July 2000

Schäfer, Prof. M.
TU Darmstadt (D)
Numerische Simulation gekoppelter Fluid-Struktur-Probleme
May 2000

Schloder, Dr. J.
Heidelberg (D)
Numerische Verfahren zur Schätzung von Parametern in Differentialgleichungen
November 2000

Schramm, J.
RWTH Aachen (D)
Mathematisch-numerische Modelle im Wasserbau – Einsatzgebiete und Anwendungsgrenzen
March 2000

Solin, Dr. P.
Linz (A)
Analytische und numerische Verfahren für die Simulierung von transonischen Strömungen in Düsen
June 2000

Stürzbecher, V.
Neustadt/Weinstraße (D)
Gestaltbildung in nichtlinearen dynamischen Systemen
May 2000

Toivakka, Prof. M.
University of Turku (SF)
Particle dynamics in pigment coating colors
March 2000

Collaboration in Boards, Editorships

Dr. Axel Becker

- Member of the Joint Photographic Experts Group 2000 (ISO/IEC JTC1/ SC29/WG01)

Prof. Dr. Horst W. Hamacher:

- Operations Research Spektrum (Editor)
- Mathematical Methods of Operations Research (Book Editor)
- Asian Pacific Journal of Operations Research (Editorial Board)
- Studies in Locational Analysis (Co-Editor)

Prof. Dr. Helmut Neunzert

- Evaluation of Mathematics in Finland (Finnish Akademy of Science, February / March 2000)
- Evaluation of the swedish research program "Nutek" (May 2000)
- Member of the international jury for Wittgenstein and Start prices (Wien (A), June 2000)
- MACSI-Net, member of the Strategic Committee
- 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)

PD Dr. Stefan Nickel

- VDI expert committee on simulation and optimization
- OR-Letters (Advisor)
- Mathematical Methods of Operations Research (Advisor)
- European Journal of Operations Research (Advisor)
- Zentralblatt für Mathematik (Advisor)
- Mathematical Reviews (Advisor)

PD Dr. Joachim Ohser

- head of the expert group "Quantitative Metallography" of the DGM-committee "Metallography"

Prof. Dr. Dieter Prätzel-Wolters

- ECMI – Council
- GAMM expert committee "Dynamics and Control Theory"
- MACSI-Net – Executive Committee
- Spokesman of the "Graduiertenkolleg Technomathematik" at the University of Kaiserslautern
- International Program Committee MTNS 2002

Dr. Ronald Rösch

- VDI/VDE-GMA-committee "Digital Image Processing in Automatization Technology"
- VDI/VDE-GMA-committee "Software and Software Quality in Measurement"