Annual Report 2004

Fraunhofer-Institut für Techno- und Wirtschaftsmathematik ITWM

Content

Preface 4
- Profile of the Institute 6
- Competences and Main Subjects 7
- Customers and Cooperation Partners 8
- Board of Trustees 9
- Organizational Chart 9
- The Institute in Numbers 10
- Service for All – the EDP Group of the ITWM 12
- Looking Back at the Year 2004 14
- Future Prospects 15
- Completely integrated into the Fraunhofer-Gesellschaft 16
- The Fraunhofer-Gesellschaft at a Glance 18
- Fraunhofer Group Information and Communication Technology 18

Transport Processes 20
- Fluid-Structure Interaction 21
- Grid-free Methods 24
- Radiative Transfer and Parameter Identification 26
- Continuum Mechanical Product and Process Design 29

Flows and Complex Structures 32
- Hydrodynamics 33
- Complex Fluids 35
- Microstructure Simulation and Virtual Material Design 37
- Structural Optimization in Mechanics and Acoustics 40

Models and Algorithms in Image Processing 44
- Surface Inspection 45
- Analysis of Volume Images and Modeling of Microstructures 48
- Signal Analysis for Railway Systems 51
- Image and Sequence Analysis 53

Adaptive Systems 56
- CAD for Analog Circuits 57
- Monitoring and Control 59
- Biosignal Processing and Diagnosis Support 61
- Prognosis of Material and Product Properties 63
- Multiscale Structure Mechanics 65

Optimization 68
- Internal Logistics 69
- Global Logistics and Traffic 72
- Continuous Optimization 74
- Knowledge Management and E-commerce 77

Financial Mathematics 80
- Option Pricing 81
- Credit Derivatives 83
- Interest Rate Models 85
- Credit Risk 87
- Portfolio Optimization 88

Mathematical Methods in Dynamics and Durability 90
- Load Data Analysis 91
- Casting Simulation 93

Competence Center High Performance Computing 96
- Grid Computing 97
- Parallelization and Performance Analysis 98
- Visualization 100
- Molecular Materials Design 102
- Research Lab Distributed Computing: Lustre 104

Fraunhofer Chalmers Research Centre for Industrial Mathematics FCC 106
- Computational Physics 107
- Quality Engineering 108
- Bioinformatics and System Biology 110
- Financial and Insurance Mathematics 111

Appendix
- Talks 112
- Teaching Activities 115
- Publications 116
- Scientific Graduation Theses 119
- Participation on Fairs andConferences 120
- Guests 121
- Collaboration in Boards, Editorships 122

Preface

Today, applied mathematical research is highly estimated in industry. Enterprises are increasingly realizing that this kind of research, carried out either in-house or ordered from Fraunhofer or similarly structured research institutes, enhances innovation and strengthens competitiveness. The result of a survey carried out among industrial representatives throughout Europe by MACSI-Net, an initiative of European mathematicians funded by the EU, is a "Roadmap for Mathematics in European Industry". The Fraunhofer Institutes SCAI and ITWM are currently working on a position paper with respect to applied industrial mathematical research with the intention of adapting this roadmap to the special situation in Germany. Particularly relevant areas of mathematical technology in the future, also indicating important directions for the development of applied mathematics during the next decade, are: simulation, optimization and control, multiscale modeling and algorithms, modeling of risks and decisions subject to uncertainty, processing of data, texts, and images, mathematical software products, high performance and grid computing. Besides, in several of the current research disciplines and technologies, such as information technology, biotechnology, or nanotechnology, there is an above-average demand for mathematical methods and models.

Fortunately, mathematics is not regarded any longer today as a mere auxiliary discipline for other sciences; instead, it is a genuine technology on its own indispensable for economic competitiveness and the management of social tasks. Unfortunately, this opinion has not yet gained acceptance in Brussels and Berlin; nevertheless, it is increasingly accepted in industry. However, more than ever before we are convinced that a massive support of applied mathematics would be an essential contribution to a sustainable technological innovation in Europe.

The year 2004 was a year of confirmed continuity at a high level for the ITWM; it again brought significant growth with respect to budget, personnel, and returns. As predicted, returns from publicly funded projects have further decreased without any prospect of a basic change here. Hopefully, the announced initiatives with respect to a support of innovation and excellence will be really carried out in Germany. The *Land* Rhineland-Palatinate has initiated a university program called "Wissen schafft Zukunft" (Science Creates the Future), hereby giving an important signal also for the rest of Germany. Universities and research institutes in Rhineland-Palatinate can receive additional funding from this program, which is supposed to support high-tech research as well as better cooperation between universities and institutes. The ITWM is optimally qualified for this program due to its scientific reputation and its close cooperation with the Technical University in Kaiserslautern.

This cooperation will tend to be further reinforced by our new building in the direct neighborhood of the University, where all of our departments will return under a common roof. The construction is proceeding rapidly, and all the persons involved are convinced that we will already be able to move into our new rooms in the year 2005.
A large number of representatives from politics, economy, and research participated in the event of laying the foundation stone of the Fraunhofer Center. Especially Kurt Beck, Head of Government of Rhineland-Palatinate, recalled in his speech that it had only been ten years before that the *Land* Government and the Fraunhofer-Gesellschaft had agreed on identifying potential candidates for future Fraunhofer Institutes in Rhineland-Palatinate. Investments with respect to industrial mathematics and software engineering have amortized in record time. The research location of Kaiserslautern has been strongly reinforced by the new institutes. The decision with respect to the foundation of the new Max-Planck Institute for Software Systems at the locations of Saarbrücken and Kaiserslautern was certainly influenced by the successful foundation of the Fraunhofer Institutes in Kaiserslautern.

Further pleasant events in 2004 again were the presentation of a series of prizes and awards to different members of our institute. During the meeting of the Board of Trustees, Prof. Neunzert was awarded the Fraunhofer Medal for his contribution with respect to the integration of the ITWM into the Fraunhofer-Gesellschaft. In India, he received the highly esteemed "Zakir Hussain Award" of the Indian Society for Industrial and

Applied Mathematics (ISIAM) in honor of his untiring and successful support of the development of applied mathematics in India.

The ITWM and the company FSM! GmbH in Kaiserlautern together received the Innovation Award of Rhineland-Palatinate 2004 in the category "cooperation science / economy". Previously, this cooperation between the research group around Dr. Dietmar Hietel and Michael Heil from the company FSM! had already been awarded the "Professor-Adalbert-Seifriz-Preis für Technologietransfer". In the framework of this cooperation, a method has been developed for the mist-free spraying of claddings. "It is good to see the very successful results of a cooperation between a classical trade and a large research institute – an excellent research institute of the Fraunhofer-Gesellschaft", said Hans-Artur Bauckhage, the Minister of Economy of Rhineland-Palatinate, during the presentation of awards in Koblenz.

In 2004, several important changes took place within the institute with respect to personnel. As the successor of Prof. Neunzert, Prof. Axel Klar is now holding the Chair of Industrial Mathematics at the Department of Mathematics. Simultaneously, he became a member of the managing boards of the ITWM and will commit himself to the basic research, the support of PhD students, and the project work at the institute. Professor Klar is an excellently qualified mathematician who stands for a continuous quality of the competences of the ITWM in the fields of partial differential equations and scientific computing with innovative accents.

Besides, the Head of the department OPTIMIZATION was exchanged. Professor Stefan Nickel, who has been holding a professorship at Saarland University in Saarbrücken since 2003, transferred the position of Head of Department to PD Dr. Karl-Heinz Küfer. Stefan Nickel will become a member of the Scientific Advisory Board of the ITWM and will remain committed to the institute by consulting the department and representing the ITWM in different boards of the Fraunhofer-Gesellschaft. Karl-Heinz Küfer has received his PhD and his qualification as university lecturer in Kaiserslautern, and has been the leading head with respect to the development of the research area of radiation therapy planning at the department OPTIMIZATION for several years now. In this research area, the ITWM is closely and very successfully cooperating with the German Cancer Research Center in Heidelberg, the company Siemens AG, and the Massachusetts General Hospital (MGH) in the USA. Professor Thomas Bortfeld of Harvard Medical School and Karl-Heinz Küfer succeeded in acquiring together a large German-American research project supported by the American National Institute of Health. This type of project funding by American institutions, which is extremely rare in the German research environment, represents an extraordinary honor for the ITWM, all the more so because the proposal of MGH and ITWM belonged among the best 7 per cent of all the submitted proposals according to the referees' opinion.

Now I would like to wish you a pleasant reading of our annual report – please feel free to contact our scientists if you are interested in any of our new projects, or talk to us about proposals of a possible cooperation. We are always open to any new ideas and suggestions.

You can see how eager our colleagues are to move into their new rooms because the new photographs of the departments have already been taken in the shells of the unfinished building, which also runs like a thread through this annual report.

Prof. Dr. Dieter Prätzel-Wolters, Director

Profile of the Institute

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

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

It is the mission and task of the ITWM to meet complex challenges in technology, logistics, communication, and finances by the application of modern mathematical methods and to further develop applied mathematics by innovative ideas, creating practical solutions in cooperation with industrial partners.

Integral components of these solutions are consulting with respect to R&D problems, support with respect to the application of high performance computing technology, and the development of especially tailored software solutions.

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

The ITWM is one of the leading partners providing mathematical research in industry. We intend to strengthen and expand this position.

Contact

Dr. Marion Schulz-Reese
Head of Administration
☎ +49 (0) 6 31/2 05-41 40
schulz_reese@itwm.fraunhofer.de

Competences and Main Subjects

Transport Processes

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

Flows and Complex Structures

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

Models and Algorithms in Image Processing

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

Adaptive Systems

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

Optimization

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

Financial mathematics

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

Mathematical Methods for Dynamics and Durability

- durability load data analysis and statistics
- dynamics and fatigue simulation
- functional performance optimization

Competence Center "High Performance Computing"

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

Fraunhofer Chalmers Research Centre for Industrial Mathematics

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

Customers and Cooperation Partners

For many years now, the ITWM has successfully cooperated with enterprises from many branches and of different sizes. In the year 2004, these were, among others:

- ABB, Västeras (Schweden)
- Abbott GmbH & Co. KG, Ludwigshafen
- Adam Opel AG, Rüsselsheim und Kaiserslautern
- ARNOLD & RICHTER Cine Technik, Stephanskirchen
- Audi AG, Ingolstadt
- BASF AG, Ludwigshafen
- Berlin-Brandenburgische Akademie der Wissenschaften, Berlin
- BMW AG, München
- BorgTec Systemhaus GmbH, Dresden
- DaimlerChrysler AG, Stuttgart
- Deutsche Apotheker- und Ärztebank, Düsseldorf
- Deutsches Krebsforschungszentrum, Heidelberg
- EKF diagnostic sales GmbH, Barleben
- Elmo Leather AB, Svenljunga (Sweden)
- ESI-Group, Paris (France)
- Eurofilters AG, Overpelt (Belgium)
- Fachhochschule Darmstadt
- Fachhochschule Aschaffenburg
- Fachhochschule Landshut
- Faurecia, Sassenburg
- FCC Göteborg (Sweden)
- Freudenberg Vliesstoffe KG, Weinheim und Kaiserslautern
- FSM! GmbH, Landstuhl
- GE Transportation Systems, Bad Dürkheim
- Gebrüder Gienanth-Eisenberg GmbH, Eisenberg
- Gießerei-Institut, Technische Universität Bergakademie Freiberg
- HegerGuss GmbH, Enkenbach-Alsenborn
- hg.zwo GmbH, Kaiserslautern
- Hoffmann und Engelmann AG, Neustadt an der Weinstraße
- HypoVereinsbank, München
- IBS Filtran GmbH, Morsbach
- Infineon Technologies AG, München
- Institut für Gießereitechnik GmbH, Düsseldorf
- Institut für spanende Fertigung, Universität Dortmund
- Institut für Verbundwerkstoffe IVW, Kaiserslautern
- Johnson Control GmbH, Burscheid
- Kotel AG, Neunkirchen
- Landesbank Baden-Württemberg, Stuttgart
- Landesbank Rheinland-Pfalz, Mainz
- Linux NetworX, Salt Lake City (USA) and Kaiserslautern
- MAGMA Gießereitechnologie GmbH, Aachen
- Mahle GmbH, Stuttgart
- Mann + Hummel GmbH, Ludwigsburg
- Maschinenfabrik Rieter AG, Winterthur (Swizerland)
- Massachusetts General Hospital, Boston (USA)
- Max-Planck-Institut für Plasmaphysik, Garching
- MiniTec GmbH & Co KG, Waldmohr
- Mobotix AG, Kaiserslautern
- müllers büro, Erzenhausen
- NEUMAG GmbH, Neumünster
- Odenwald-Faserplattenwerke GmbH, Amorbach
- Paul Wild GmbH, partu lapidaries GmbH, Kirschweiler
- Pressebüro Hansmann GmbH, Düsseldorf
- proALPHA Software AG, Weilerbach
- Procter & Gamble, Schwalbach im Taunus und Cincinatti (USA)
- psb GmbH, Pirmasens
- Rayonex Schwingungstechnik GmbH, Lennestadt
- Roche Diagnostics, Mannheim
- Römheld & Moelle, Mainz
- Ruck Ventilatoren GmbH, Boxberg
- RWE Power AG, Biblis
- Saint-Gobain, Auberville (France)
- Sandler AG, Schwarzenbach/Saale
- SAP AG, Walldorf
- Schott Glas, Mainz
- Shell International, Den Haag (Netherlands)
- Siemens AG (Medical Solutions OCS), Heidelberg
- Städtische Kliniken Frankfurt am Main-Höchst
- Stryker Leibinger GmbH, Freiburg
- tecmath AG, Kaiserslautern
- Tecnotessile Societa Nazionale di Ricerca tecnologica S. r. l., Prato (Italy)
- Tehalit GmbH & Co. KG, Heltersberg
- Temix S. r. l., Catania (Italy)
- Ultrafilter international AG, Haan
- Universität Freiburg
- Universität Karlsruhe
- Universitätsklinik Tübingen
- URSA International GmbH, Neu-Isenburg
- Verein Deutscher Gießereifachleute (VDG), Düsseldorf
- Verkehrsverbundgesellschaft Saar mbH (VGS), Saarbrücken
- Volkswagen AG, Wolfsburg
- Voith Fabrics GmbH & Co. KG, Pfullingen
- WestLB, Düsseldorf
- Zentrum für Europäische Wirtschafts-förderung, Mannheim
- ZF Lemförder Fahrwerktechnik, Lemförde
- Zimmermann Formtechnik GmbH, Weilerbach

Board of Trustees

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

Prof. Dr. Achim Bachem
German Aerospace Center DLR, Köln

Dr.-Ing. Erwin Flender
MAGMA Gießereitechnologie GmbH, Aachen

Wolfgang Habelitz
Member of the Ministry of Science, Further Education, Research and Culture in Rhineland-Palatinate, Mainz

Prof. Dr. Wolfgang Hackbusch
Max Planck Institute for Mathematics in the Sciences, Leipzig

Prof. Dr. Peter Jagers
Chalmers Tekniska Högskolan, Göteborg, Sweden

Dr. Wilhelm Krüger
tecmath AG, Kaiserslautern

Dr. Martin Kühn
SAP AG, Walldorf

Kurt Lechner
Member of the European Parliament, Kaiserslautern

Dr. Horst Loch
Schott Glas, Mainz

Dr. Ulrich Müller
Executive Member of the Ministry for Economy, Traffic, Agriculture, and Viniculture in Rhineland-Palatinate, Mainz

Dr. Jens Nonnenmacher
DZ Bank AG, Frankfurt

Dr. Bernd Reuse
Member of the Federal Ministry for Education and Research, Bonn

Dr. Werner Sack
Hilti AG, Schaan, Liechtenstein

Prof. Dr. Helmut Schmidt
President of the Technical University, Kaiserslautern

Dr. Jörg Steeb
Tehalit GmbH & Co. KG, Heltersberg

Prof. Dr. Wolfgang Wahlster
German Research Center for Artificial Intelligence, Saarbrücken

Organizational Chart

Director	Prof. Dr. Dieter Prätzel-Wolters		06 31/2 05-44 42
Scientific Advisory Board	Prof. Dr. Axel Klar		06 31/2 05-31 46
	Prof. Dr. Ralf Korn		06 31/2 05-44 71
	Prof. Dr. Helmut Neunzert		06 31/2 05-27 46
	Prof. Dr. Stefan Nickel		06 31/3 03-18 85
Competence Center "High Performance Computing"		Dr. Franz-Josef Pfreundt (CIO)	06 31/3 03-18 21
Central Services	Administration	Dr. Marion Schulz-Reese	06 31/2 05-41 40
	EDP	Dieter Eubell	06 31/2 05-44 43
	Public Relations	Ilka Blauth	06 31/2 05-47 49
		Dipl.-Math. Steffen Grützner	06 31/2 05-32 42
Departments	Transport Processes	Dr. Raimund Wegener	06 31/2 05-39 26
	Flows and Complex Structures	Dr. Konrad Steiner	06 31/3 03-18 20
	Models und Algorithms in Image Processing	Dr. Ronald Rösch	06 31/3 03-18 67
	Adaptive Systems	Dr. Patrick Lang	06 31/2 05-28 33
	Optimization	PD Dr. Karl-Heinz Küfer	06 31/3 03-18 51
	Financial Mathematics	Prof. Dr. Ralf Korn	06 31/2 05-27 47
	Mathematical Methods for Dynamics and Durability	Dr. Klaus Dreßler	06 31/3 03-18 69

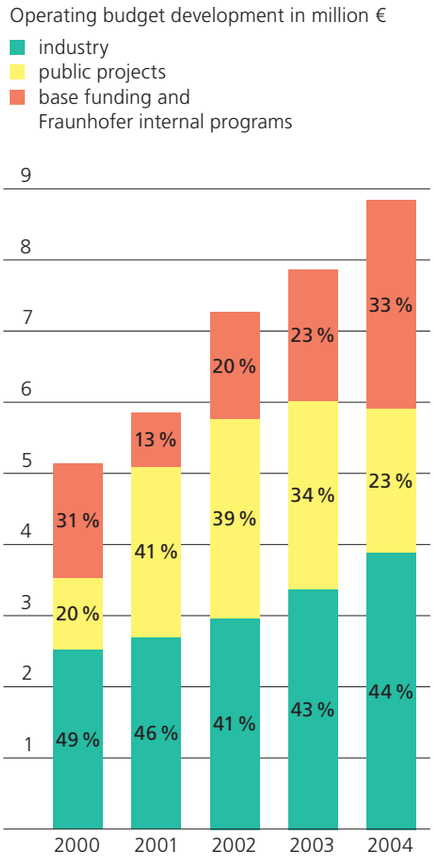
Budget

In contrast to the general trend within the Fraunhofer-Gesellschaft, the ITWM has shown a considerable growth also in 2004. Growth rates of 12 per cent with respect to the operating budget and 14 per cent with respect to returns are the positive messages of the year 2004.

Unfortunately, the ITWM participates completely in the downwards trend with respect to the development of the returns from publicly funded projects. As predicted, these are decreasing dreadfully. The returns from projects funded by the BMBF (German Ministry for Education and Research) alone have decreased by a dramatic 42 per cent compared to the previous year. We were able to compensate this lack of funding to a large degree by returns from projects funded by the *Land* and from internal programs. A real change of the trend for 2005 is not in sight yet. However, there is hope for a mean-term increase of returns from public projects. For example, the excellence program "Wissen schafft Zukunft" of Rhineland-Palatinate provides additional funding for the support of high-tech research at universities and research institutes. Several promising proposals submitted to the BMBF might also justify a little optimism.

Nevertheless, the ITWM's further increase of returns is estimated very optimistically. Due to its wide range of competences, the ITWM was able to acquire a large number of new customers also in 2004 and to establish further cooperation with industrial customers of many years.

All in all, the ITWM expects the growth barometer to indicate good weather also for 2005.

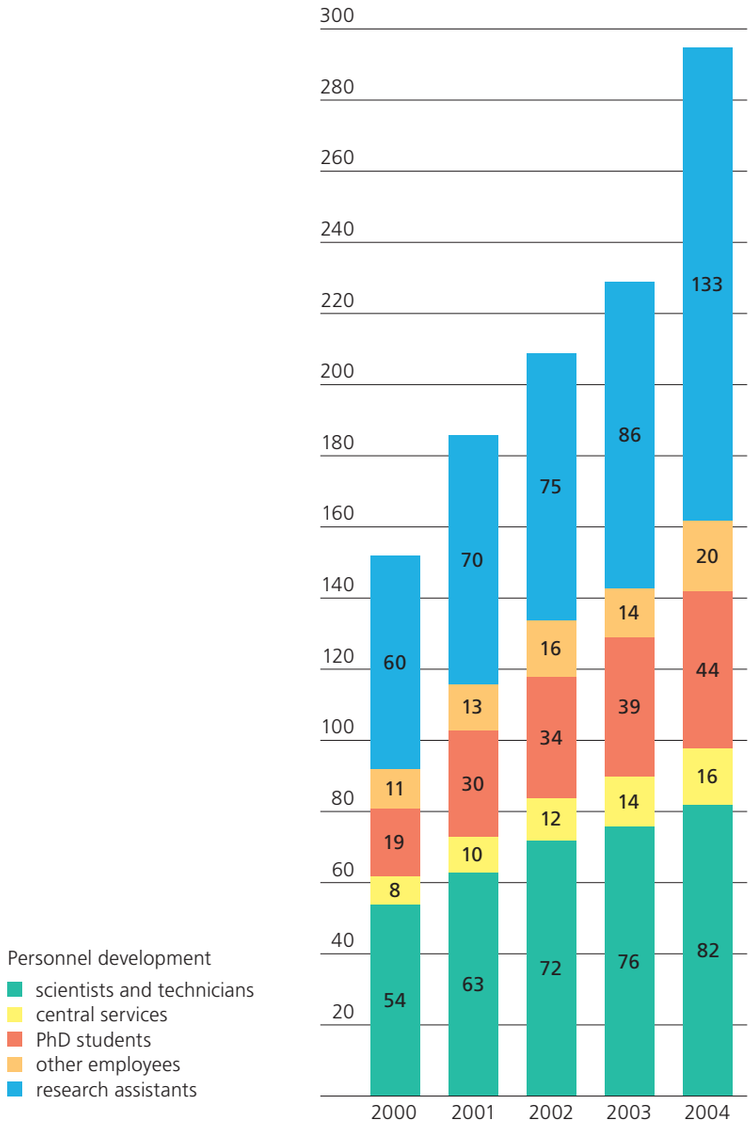


Budget development [thousand €]	2000	2001	2002	2003	2004
Operating budget	5 147	5 866	7 267	7 872	8 844
Investments	244	756	878	563	376
Total	**5 391**	**6 622**	**8 145**	**8 435**	**9 220**

Personnel development

In 2004, 142 colleagues were working at the Fraunhofer ITWM, among who were 82 scientists, 44 PhD students, and 16 colleagues in administration, EDP, and public relations. The number of research assistants, trainees, and graduate students, which has considerably increased this year, shows the large interest of pupils and students in the activities of the ITWM, as well as the importance of the intensive support of young scientists for the ITWM.

In November 2005, the ITWM will invite all of its former scientists and PhD students to a large alumni meeting in Kaiserslautern on the occasion of its 10th anniversary. It will be interesting to see which professional directions the individual persons will have taken. Fraunhofer Institutes are an excellent starting point for a university career – an entire number of 10 former colleagues have meanwhile accepted a professorship at a university or a university of applied sciences.



Service for All – the EDP Group of the ITWM

This annual report for the first time includes a presentation of the ITWM's EDP team. The four full-time employees and several part-time employees of the EDP team, together with Gabi Gramsch, who puts things in order at different places, consider themselves as internal service providers who have the task of making the working environment of the scientists and other employees of the ITWM as productive as possible, simultaneously working as cost efficiently as possible.

The abbreviation SLG for "system life guard" stands for a support service offered to all the users at the ITWM. It uses RT3 as open source help desk system and has answered approximately 2,000 support queries last year. The help desk system is supported by a wiki indicating current disturbances and assisting the user to find his/her way through the increasingly complex EDP landscape. User support is not always an easy job, and e-mail messages cannot always substitute direct communication – the human side must also be accounted for.

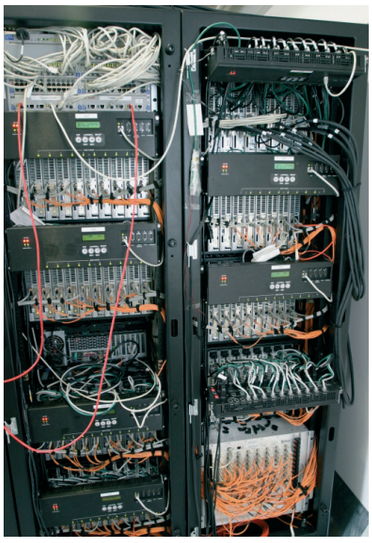
"Do good and talk about it" – in that sense we have installed large parts of an innovative Thin Client concept at the ITWM during the last two years. The objective was to free the working environment of noise and heat development, to make it more comfortable, to give the user access to his/her selected system by a virtualization concept, and to decrease support requirements simultaneously. 70 per cent of the scientists and all of the employees working in administration now have a comfortable working environment without any noise due to ventilators or hard disk movements.

Christian Peter, Mirko Spell, Dr. Franz-Josef Pfreundt, Martin Vogt, Dieter Eubell, Volker Hochgürtel, Martin Braun, Gabi Gramsch, Moritz Baumann

Since the foundation of the institute in 1995, Linux has been the central server operating system of the ITWM. First, because of a lack of better solutions, computers were operated with the system SLG Linux, which had been individually developed at the ITWM. In the year 2002, we changed to SUSE Linux. From the beginning, Linux has also been applied on the desktop. Today, approximately 30 per cent of the primary user systems are based on Windows. However, Windows as well as Linux are currently available to each user due to the virtualization concept.

Apart from the usual server structure, from the beginning the ITWM has also been operating parallel computer systems based on PC technology. Today, the PC clusters offer more than 200 high-performance modern CPUs with a main memory of more than 500 Gbyte for the computation of complex simulation problems. Many individual developments, but also a wide range of commercial software packages are applied and further developed here with respect to industrial cooperation projects and supported research projects. EDP tries to meet the continuously increasing demand for storage by high-performance file servers, a professional Tivoli-based backup and archive system, and sufficient scratch disk space.

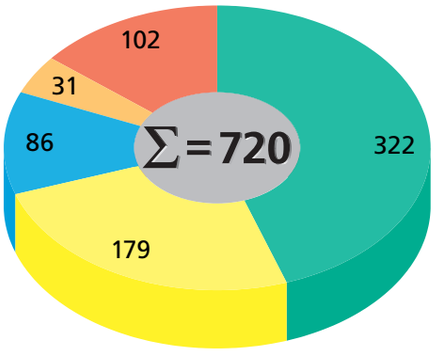
It is important for EDP as well as for the departments of the ITWM to keep in practice – almost nothing grows old as fast as IT technology. Therefore, we are continuously testing new technologies in cooperation with the COMPETENCE CENTER HIGH PERFORMANCE COMPUTING, at the moment, e. g., parallel file systems, in order to apply these at the appropriate time. Our special challenge of the year 2005 will be the moving to our new building, where we intend to make things even better.



Server room: backside of the servers with a number of different cables

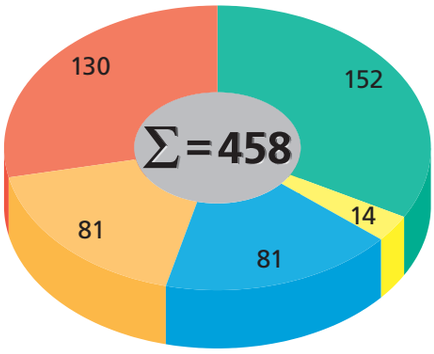
Operating CPUs according to processor classes

- Intel Xeon
- Intel Pentium
- AMD Opteron
- AMD Athlon
- Thin Client CPUs



Computer systems according to application

- Thin Clients incl. Linux-PCs
- Windows server
- Windows clients
- Linux server
- Linux cluster nodes



Looking Back at the Year 2004

February	Prof. Helmut Neunzert is awarded the Fraunhofer Medal
March	MAVO proposal of the ITWM with respect to “Simulated Reality” is accepted
April	Laying of the foundation stone of the Fraunhofer Center
June	ITWM contributes to the technology ship of the initiative “Wissenschaft im Dialog”
	25th Forum for Image Processing at the ITWM
July	Radiotherapy planning: project in cooperation with Harvard Medical School
September	“Professor-Adalbert-Seifriz-Preis für Technologietransfer” for NESPRI
October	Prof. Helmut Neunzert is given emeritus status
December	Innovation Award Rhineland-Palatinate for NESPRI
	Zakir Hussain Award for Prof. Helmut Neunzert

Fraunhofer Medal

Seifriz-Technologie-transfer-Preis

Future Prospects

Mit Gunst und Verlaub!

Vernehmt den Spruch aus luftiger Höh,
allwo nach altem Brauch ich steh':
Hoch lebe Kunst und Wissenschaft,
die Häuser baut und Werte schafft.

Seid willkommen zum Richtfest heut',
all Ihr Gäste und Handwerksleut.

Hier oben auf dem flachen Dach
steh ich als Zimmermann vom Fach,
wo einst der Dachstuhl des Zimmermanns Stolz
steht heut' Beton und Glas statt Holz.

Die Maurer, Flechter und Maschinisten,
die Helfer und Büroartisten,
sie alle gaben ihr Bestes her,
zu Stein ward hier ihr Fleiß nunmehr.

Die Öffentlichkeit verfolgt mit großem Elan,
was hier entsteht nah' an der Uni dran,
unter Webcam im World Wide Web,
sind wir live zu sehen im Internet.

So seh'n wir fertig die Hauptkonstruktion,
Elektriker und Installateure beeilen sich schon,
fertig zu stellen, was mit viel Bedacht
Architekten und Ingenieure hervorgebracht.

Mit Stahl und Glas in vielen Bereichen
setzen die Planer architektonische Zeichen.
Doch wenn der Architekt vom Büro herfliegt,
er an jeder Wand eine Katastrophe sieht.

Nun steht der Rohbau schon lang in voller Pracht,
viel Schweiß und Arbeit haben wir eingebracht,
was Menschengeist sich ausgedacht
wird hier mit Präzision gemacht.

Das Institut unseres Bauherrn soll gedeih'n
und wird der Raum dann wieder zu klein,
so bauen wir gern mit Wohlgefallen
noch weitere große Forschungshallen.

So wollen wir dies Werk nun weihen,
möge Gott es beschützen und lassen gedeihen.

Den ersten Schluck den Nutzern gleich,
dass Erfolg hier nie von dannen weich'!
So soll's in diesem Gebäude sein,
darauf trinke ich den goldenen Wein!

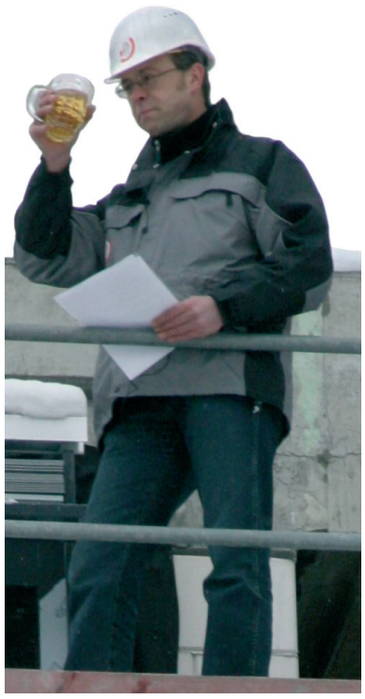
Der zweite Schluck soll jene laben,
die hier am Bau geholfen haben.

Nehmt hin den Dank, Ihr Handwerksleut,
auf Euer Wohlsein trink ich heut'.

Auch seien mit Ehren die genannt,
von denen der Plan des Baues stammt.

Der letzte Schluck, den ich nun leere,
er bring' dem Neubau Glück und Ehre,
für heut' und auch in Zukunft noch
darauf rufen wir ein dreifach
Hoch, Hoch, Hoch!

So werf' ich nun nach alter Sitte
das Glas hinab in Eure Mitte.
Des Glases Scherben, der funkelnde Wein,
sie sollen des Glückes Unterpfand sein.



Christian Lange on
February 23, 2005

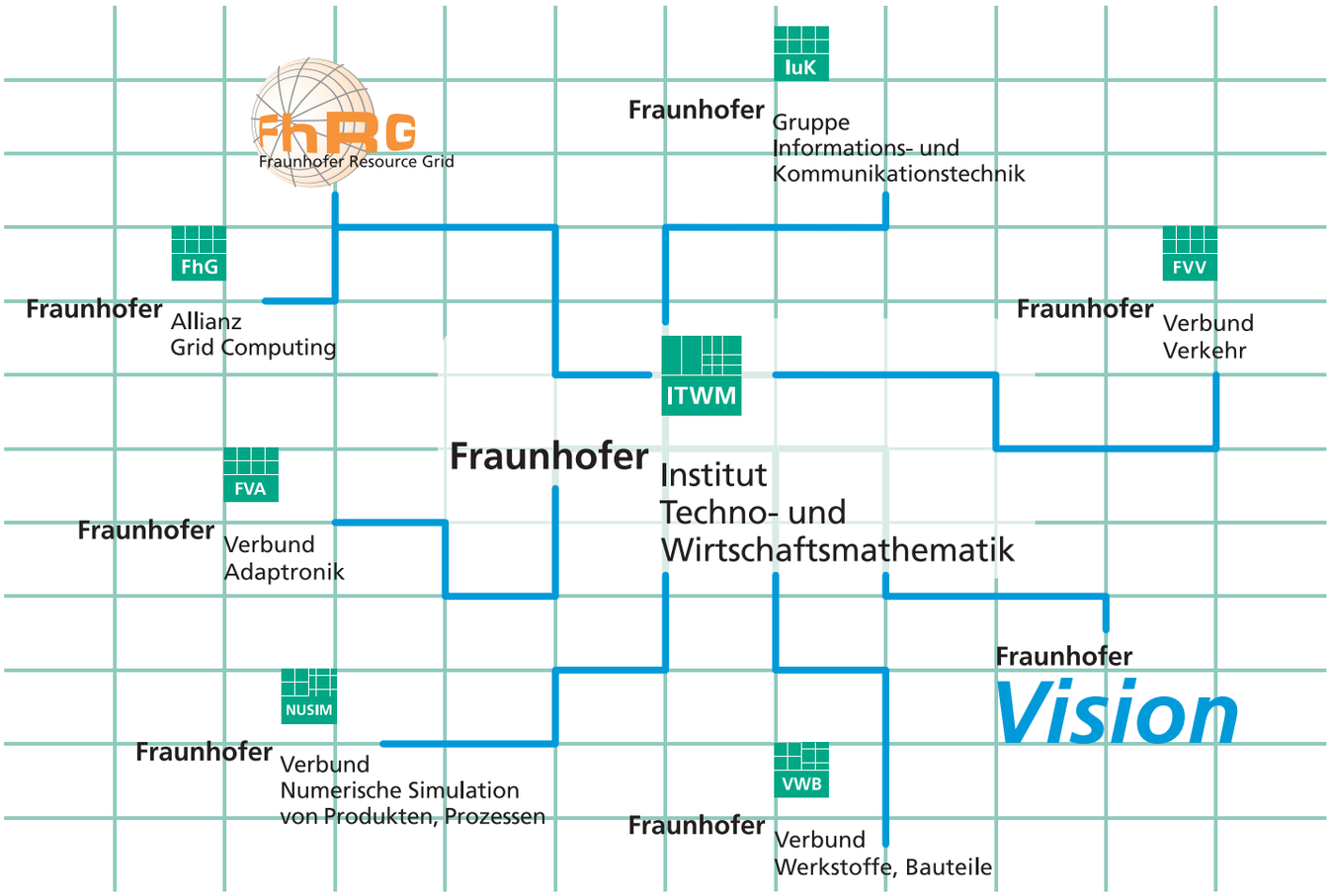
Completely integrated into the Fraunhofer-Gesellschaft

The ITWM is doing construction work – not only with respect to its new building, but also in order to further reinforce its position within the Fraunhofer-Gesellschaft. It takes part in each of the three large cooperation forms of the individual Fraunhofer Institutes – alliances, alliances with respect to special subjects, and networks – and stands for a fundamental component of applied research due to its mathematical competences.

If, however, customers ought to be able to utilize this research, access must be provided to the results and the services of the Fraunhofer-Gesellschaft first; this is the objective of the nine Fraunhofer networks which have been created by different institutes.

The ITWM is a member of two of them and has also given proof of being a good architect by substantially contributing to the development of the network "Grid Computing". Franz Josef Pfreundt, Head of the COMPETENCE CENTER HIGH PERFORMANCE COMPUTING, has participated in the initiation of the grid activities and now is the spokesman of the network. The network includes seven Fraunhofer Institutes and operates the "Fraunhofer Resource Grid" (FhRG). The parallel computers of the ITWM, which are part of the FhRG, and the applications which are computed there are an important contribution to the presence of the FhRG within the grid community. The ITWM especially develops new methods of resource management and grid benchmarking.

The ITWM is also an active architect within the Fraunhofer network "Vision", mainly due to the contributions of the department MODELS AND ALGORITHMS IN IMAGE PROCESSING in the fields of image processing systems, algorithms, and microstructure analysis. The close relations that have been established to the other institutes are especially helpful for the common acquisition of projects. In the same way, we are a beneficiary of the excellent public relations and marketing work done by the management in Erlangen: each year, a large number of potential projects are proposed to the network, and the ITWM profits respectively.



Basic elements of the network activities are the presentation during the fair CONTROL in Sinsheim every year, which is the largest trade fair in Europe with respect to quality control, and the invitation of industry and research institutes to VISION seminars, which offer the possibility to become acquainted with the latest developments in the field of image processing theoretically as well as practically.

The following principle also holds with respect to the alliances between individual institutes or with respect to special subjects: if you are joining forces, you can reach higher goals, and the wider range of competences provides a better chance of being realized on the R&D market than in the case of an individual institute. A really large alliance is the Fraunhofer ICT Group: it is Europe's largest research alliance for information and communication technology, and the results of the ITWM's membership of this alliance are impressive. In 2003, the ITWM had had the highest returns compared to the other members of the ICT Group, and it again had a leading position last year – overtaken only by the IDMT (Institute for Digital Media Technology) in Ilmenau, which was founded in 2004. The ITWM has taken the lead in a completely new research area, the so-called "Simulated Reality": in cooperation with two other members of the ICT Group, we are working on the future-oriented MAVO project (market-oriented strategic preliminary research) "Simulated Reality for the Design and Optimization of Products and Production Processes" (MAVO-SR PRO).

The particular importance of the ITWM within the alliance "Materials and Components" becomes clear by the fact that the ITWM has had a permanent guest status there since its integration into the Fraunhofer-Gesellschaft (2001), although it is already a full member of the ICT Group. A central research subject of the next few years will be the modeling and simulation of material and component behavior, especially with respect to a scale-independent and scale-integrating consideration. Within the different projects together with other institutes of the alliance "Materials and Components" the ITWM provides an indispensable basis for this research area due to its competence with respect to the development of multiscale simulation tools; particularly worth mentioning is the ITWM's membership of the MAVO project MMM Tools (Multiscale Material Modeling).

Within the seven Fraunhofer alliances with respect to special subjects, individual departments of certain institutes have joined forces in order to work together in a business area by combining their different competences.

Since the beginning of the cooperation, i.e. since March 2003, the ITWM has been a member of the alliance "Traffic and Transportation". It is primarily the department OPTIMIZATION that is closely cooperating and writing project proposals mainly together with the Fraunhofer IML (Institute for Material Flow and Logistics) in Dortmund. Further components of the ITWM within this alliance are the departments MATHEMATICAL METHODS IN DYNAMICS AND DURABILITY and MODELS AND ALGORITHMS IN IMAGE PROCESSING. By its membership of this alliance, the ITWM is well integrated into the portfolio discussion and can intensify the contact and exchange with the remaining 19 institutes. This cooperation is the foundation of further common projects in the future by which the ITWM will be able to reinforce its position within the Traffic alliance – a position that meanwhile has become very strong anyway.

The departments ADAPTIVE SYSTEMS and TRANSPORT PROCESSES of the ITWM have been members of the relatively young alliance "Adaptronics" virtually since the laying of its foundation stone, which was at the beginning of 2004. The mathematical competences of the ITWM with respect to modeling and simulation are a precious contribution to the development of a wide range of competences, which hopefully will result in better chances in the future with respect to the integration into large industrial cooperation projects as a consulting partner. The course has already been set: after the presentation of the alliance during MATERIALICA 2004 in München, the participation in the Adaptronic Congress 2005 in Göttingen is planned for this year.

The initiation of the alliance "Numerical Simulation of Products and Processes" has been a matter of important concern for the ITWM during the previous years – accompanied by the wish to bring together all the Fraunhofer Institutes interested in the development of numerical simulation methods in order to give an impulse for common activities. Today, an entire number of sixteen institutes deal with this domain of simulation which is decisive in every phase of a product's life cycle, from the material development to the introduction on the market. The ITWM has substantially contributed to the construction of this alliance, too.

Hence, the most important objective of the ITWM is a constructive and active integration of its own competences into the different projects. It was the first mathematically oriented institute to be given the name of Fraunhofer in 2001; due to the ITWM's activities, the integration into the Fraunhofer-Gesellschaft and its large number of cooperation projects can be considered as more than completed today.

The Fraunhofer-Gesellschaft at a Glance

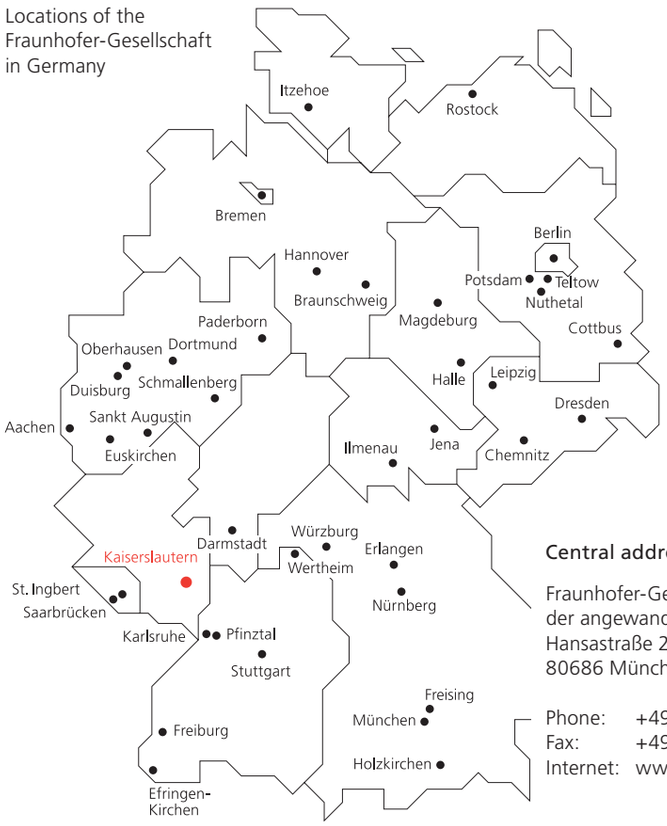
The Fraunhofer-Gesellschaft is the largest organization of applied research in Europe. As a non-profit organization, it currently maintains approximately 80 research units – including 58 institutes – at more than 40 locations throughout Germany. A staff of approximately 12,700 employees – mainly qualified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

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

Research areas of the Fraunhofer-Gesellschaft:

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

Locations of the Fraunhofer-Gesellschaft in Germany



Central address

Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V.
Hansastraße 27 c
80686 München

Phone: +49 (0) 89/12 05-0
Fax: +49 (0) 89/12 05-75 31
Internet: www.fraunhofer.de

Fraunhofer Group Information and Communication Technology

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

An entire number of 3,000 employees of 17 institutes, as well as an annual budget of more than 190 million Euros turn the ICT Group into the largest research alliance in Europe. Therefore, the technologies in our ten research areas cover the entire chain of value creation:

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

Management and Administration

Sandra Leugner, Katharina Parusel, Ilka Blauth, Ingeborg Woltmann, Dr. Marion Schulz-Reese, Markus Pfeffer, Prof. Dr. Dieter Prätzel-Wolters, Brigitte Williard, Prof. Dr. Helmut Neunzert, Prof. Dr. Axel Klar, Prof. Dr. Ralf Korn, Steffen Grützner

Transport Processes

Mathematical modeling, algorithms, simulation, and optimization in the field of continuum mechanical problems: these are the subjects of the department TRANSPORT PROCESSES. Within this research area, we develop especially tailored solutions for our customers by doing technical studies in the field of design, construction, and optimization. We additionally create concepts for software solutions and components, improve the performance of already existing software tools, and we develop individual tools.

Again, the year 2004 was a successful year of further economic growth. We are still concentrating on the following main subjects:

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

Our customers cover a wide range of different branches; there is, however, a certain emphasis on the fields of engineering, technical textiles, and glass industry.

In all the main subjects, we are primarily working on the development of our own software tools in order to supply these to our customers and, on the other hand, to concentrate existing competences on an even more successful participation in the R&D market. This annual report will present several examples.

The term "Simulated Reality (SR)", which has been coined at the ITWM last year, determines our position within a new IT domain which refers to the blending of simulation, optimization, and virtual reality. A first example is "Acoustic SR" (see page 30). Even more important for the future is the Fraunhofer-internal research project "Simulated Reality for the Design and Optimization of Products and Production Processes (MAVO SR-PRO)", which is lead by the ITWM.

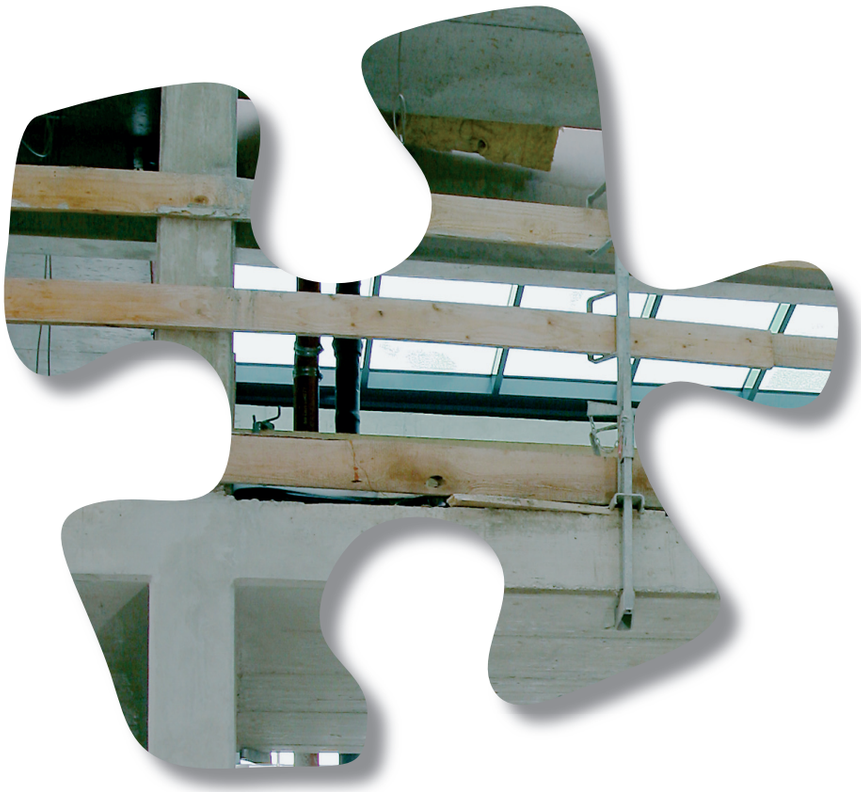
Dr. Raimund Wegener
☎ +49 (0) 6 31/2 05-39 26
wegener@itwm.fraunhofer.de

Fluid-Structure Interaction

The field of "fluid-structure interaction" covers the interaction of flows and 3d objects. The research mainly concentrates on fibers, i. e. line shape objects. A large number of contacts and cooperation projects with industrial partners could be realized in the field of technical textiles and engineering of the respective machines and plants. As a consequence, this business area of our department is currently the most increasingly growing one. The results of the previous years' research work are currently summarized by the development of the simulation tool FIDYST, which will be described in the following. Successively, further processes with respect to the production and processing of fibers are supposed to be integrated into this tool. One example of industrial application is represented by "Production of Nonwovens by ASON Technology".

During the development of FIDYST, a series of ideas for the improvement of the examined production processes has also been generated. The future aspect of such a tool, which is to be integrated into a systematic optimization, is a first step towards a real simulation-based reverse engineering. This idea is an essential component of our concept with respect to Simulated Reality, which will be integrated into the above mentioned Fraunhofer-internal research project. The simulation of the production of nonwovens therefore represents one of the pilot applications of the concept of Simulated Reality.

However, the research work with respect to fluid-structure interaction still also refers to planar structures (e. g., sheets of paper) and particle shape objects (e. g., droplets). The Annual Report 2001 included the project "NESPRI – mist-free spraying of claddings" (which was part of the program InnoNet of the Federal Ministry of Economy and Occupation (BMWA)) for the first time. Last year, this project received the Professor-Adalbert-Seifriz-Award for technology transfer between research institutes and trades, and the Innovation Award of Rhineland-Palatinate in the category of cooperation of research and economy.



Contact:

Dr. Dietmar Hietel
☎ +49 (0) 6 31/2 05-40 82
hietel@itwm.fraunhofer.de

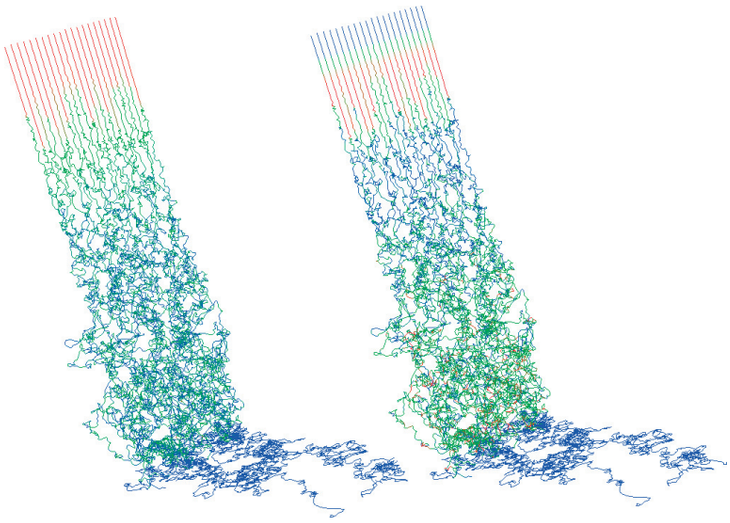
FIDYST – Fiber Dynamics Simulation Tool

The most important steps during the production of nonwovens are the spinning and the depositing process. During the spinning process, thousands of fibers are extruded by a large number of nozzles and spun by air flows. The deposition is determined by slowing down the air flow and the fibers in the vicinity of the deposition belt. The ITWM has developed new models and methods for the simulation of such processes in this kind of applications. These models are realized within the simulation tool FIDYST (Fiber Dynamics Simulation Tool). The most decisive aspect here is the interaction between filaments and flow, which is based on a stable model of the active forces.

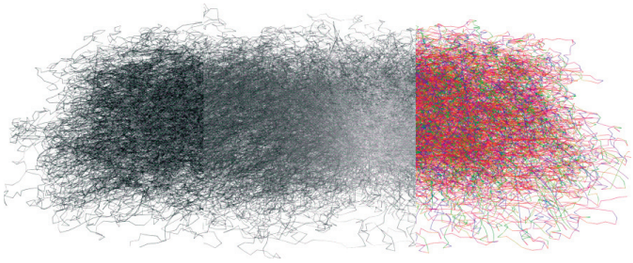
Due to its line shape geometry, a fiber can be described as a time-dependent curve. Along this curve, the different occurring forces are balanced. These forces are internal forces, such as elastic or viscous stresses and bending forces, as well as external forces caused by gravitation or the interaction with air, walls, or other fibers.

The modeling of turbulence effects is a particular challenge in this respect. A stochastic force model has been developed at the ITWM which accounts for the characteristic turbulent scales. The flow can be simulated by commercial CFD tools such as FLUENT© or ANSYS CFX© in combination with additional UDFs (User Defined Functions). In the spinning zone, the fibers influence the flow through air drag and heat transfer. The fibers cannot be represented individually due to their large number and therefore a homogenization approach is used. In the deposition zone, however, interaction is dominated by the effect of the air flow on the fibers. The response on the flow can therefore be neglected.

The simulations which can now be carried out on the basis of the developments at the Fraunhofer ITWM allow for new insights into the production processes of non-wovens and yarns. They can be applied in addition to experiments and help to estimate the potential of new technological ideas, to optimize process parameters, and to support the development of new and improved products.



Fiber dynamics and flow
(visualization Fraunhofer IGD)



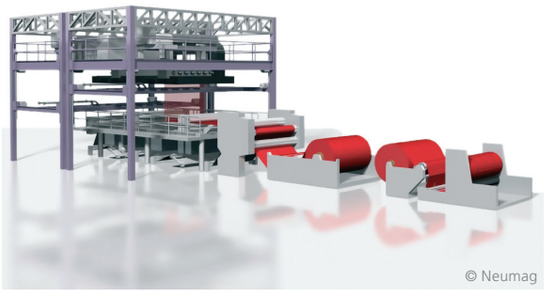
Structure of nonwovens
(visualization Fraunhofer IGD)

Production of nonwovens by ASON technology

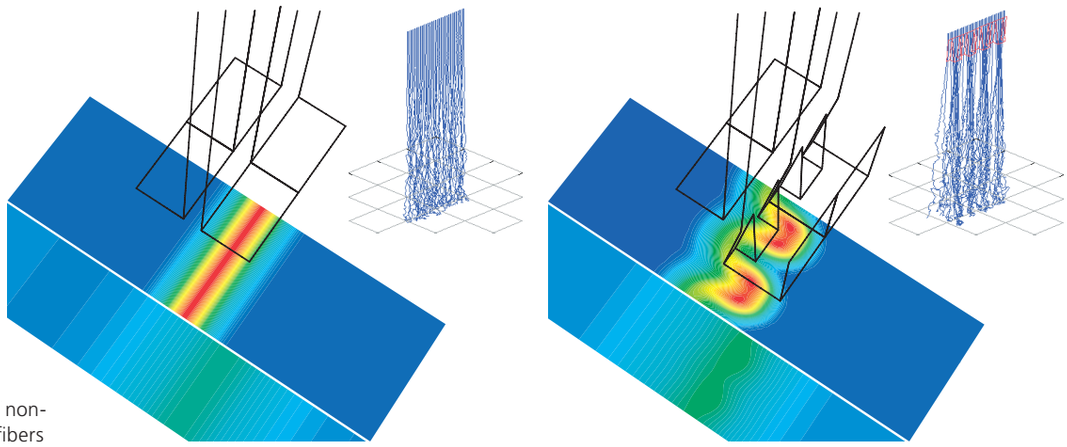
The planar structure of nonwovens results from the continuous deposition of hundreds and thousands of filaments on a belt or a roller. The movement of the filaments is determined by the air flow to which these are subject and by the filaments' own properties. On the basis of the pilot plant in Neumünster (cooperation of Neumag|Saurer and ASON), which was put in operation at the beginning of 2004, the production of nonwovens has been examined by the simulation of the fiber dynamics and their deposition on the belt.

An entire series of parameter variations was carried out in order to evaluate the qualitative and quantitative effects of the fiber and the belt velocity. Apart from the belt velocity, variations mainly referred to the pressure at the offtake nozzle, which is decisive for the maximum fiber velocity. The results show a principal tendency of a preferred orientation of the fibers in production direction, which increases with a higher belt velocity and decreases with a higher offtake pressure. The respective direction distribution is in correlation with the values of material strength which can be measured in the nonwovens in the production direction and crosswise (MD/CD relation).

The main constructive challenge is a further improvement of homogeneity and the adjustability of the MD/CD relation according to customers' desires. One possible approach is the torsion of the spinning bar with respect to the belt. However, simulation results have shown that this is not very promising without any further modifications – especially with respect to the offtake nozzle. A respective realization in the pilot plant has therefore not been carried out yet. The simulations of the production of nonwovens are a supplementary construction tool by which experiments can be planned more exactly and partly be substituted. In the future, they should also become a production tool by which production parameters can be adjusted exactly and quickly to changing requirements. Due to the high – and particularly geometric – flexibility of ASON technology, this represents a large challenge for the simulation tool FIDYST.



Spinning and depositing plant Neumag|Saurer

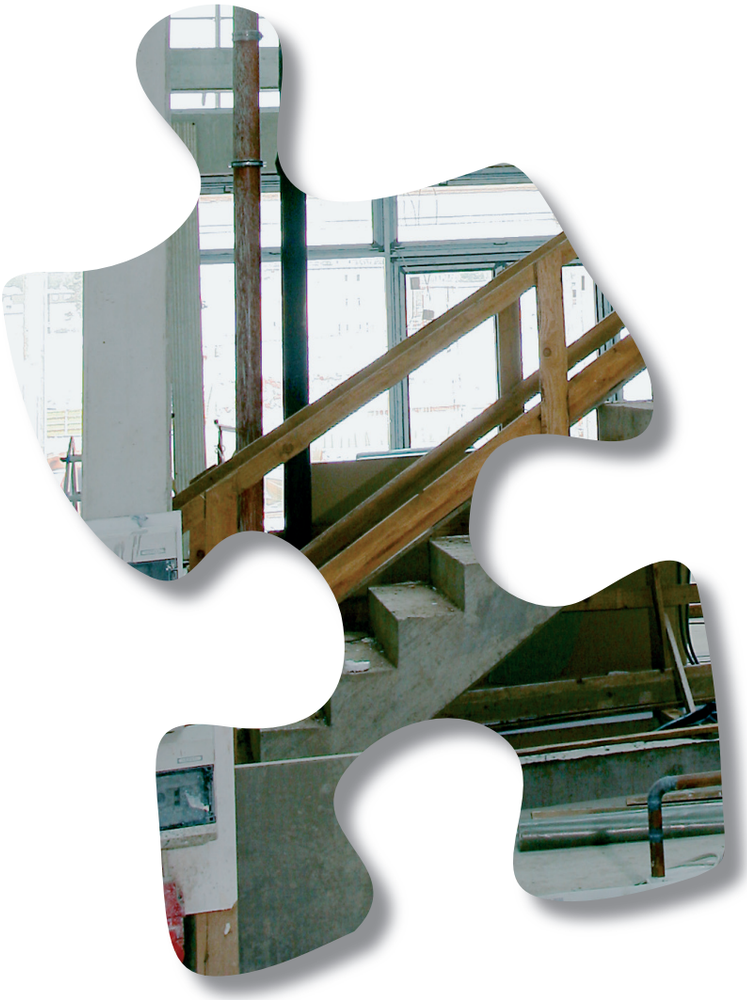


Simulation of the production of nonwovens: dynamics of flow and fibers

Grid-free Methods

FPM (Finite Pointset Method), which has exclusively been developed at the department, is a comprehensive software tool for continuum mechanical and especially flow dynamical problems. The fundamental ideas and theoretical advantages of the basic grid-free method have already been described in the previous years: by FPM, the flow dynamical field information (e.g., density, average velocity, temperature) is stored on information carriers (the so-called point sets) which can be positioned freely and are generally moving at flow velocity in the case of transient problems. FPM does not require a mesh, thus being able to overcome the performance limits of the existing CFD methods – Finite Element Method (FEM), Finite Differences Method (FDM), Finite Volume Method (FVM) – with respect to grid generation and adaptation and to allow for new domains of application. The method is superior to the classical methods in the case of those applications where the geometry of the flow field is rapidly changing with respect to time or where free surfaces and/or multiphase flows must be handled.

Based on the results with respect to compressible gas flows (airbag deployment, cooperation with ESI-Group, Paris), the field of incompressible flows has also been successfully covered within the last two years. Examples are the simulation of the refueling process of motor vehicles (cooperation with Volkswagen AG) and different simulation examples from glass industry (cooperation with Schott AG, Mainz). The most obvious progress of the previous year is the development of a stationary FPM solver. Additionally, the performance of the software with respect to pre- and post-processing has been improved to such a degree that first independent solutions for industrial clients could be successfully installed and applied.



Contact:

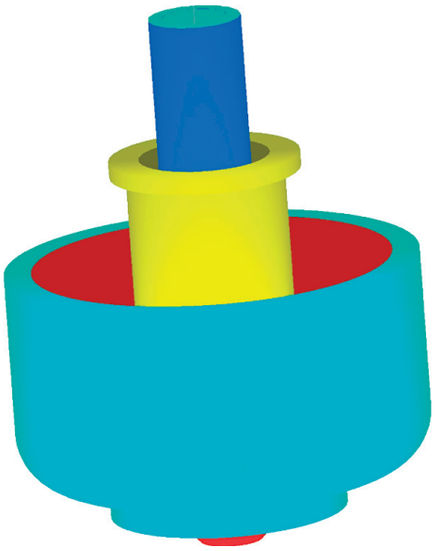
Dr. Jörg Kuhnert
☎ +49 (0) 6 31/2 05-40 87
kuhnert@itwm.fraunhofer.de

Simulation of a gob feeder

One example of an instationary flow problem with free surfaces is a gob feeder (TC-25), as it is used during the production of traditional tube screens. The example of the TC-25 demonstrates the manifold possibilities provided by the Finite Pointset Method (FPM) developed at the ITWM. During a continuous production process, a gob feeder dispenses of one drop of molten glass at a time within one cycle. The gob is fed into a mold, where it is molded in the form of a screen by a punch during a further step. The gob to be generated must meet certain requirements with respect to size and temperature. Besides, before such a technological process is put into operation, it must be guaranteed that these requirements will be continuously met during the entire production cycle. However, a gob forming process according to the TC-25 pattern is very sensitive, and there are several parameters which can have considerable effects on the forming process. Design can therefore be supported decisively by simulations.

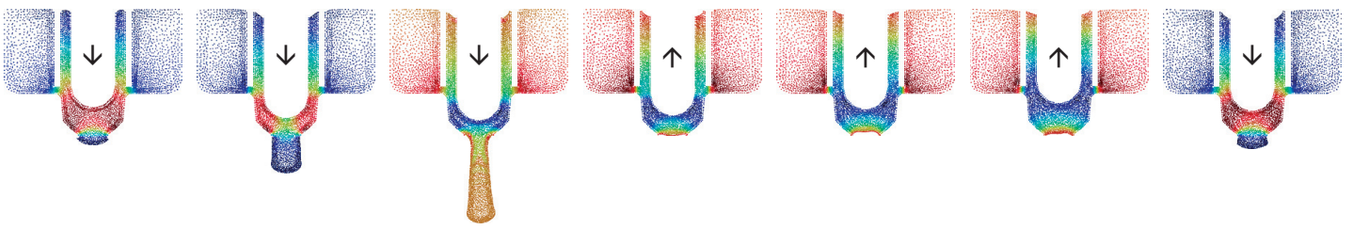
The TC-25 device consists of a tank which is open at the top and contains the glass melt. A tube inlet above the surface of the melt guarantees a continuous feeding of the glass melt. At the bottom of the tank there is a spout (outlet). A “needle” which is periodically moving up and down above the spout is responsible for the portioning of the mass flow of the glass. The upwards movement of the needle leads to a suction effect which prevents the glass melt from flowing through the spout. A cavity is filled with glass melt, which is then pushed through the spout by the successive downwards movement of the needle and thus takes the form of a gob. Each one of the gobs which are periodically created in such a way is cut off and drops into the mold, where it is finally molded into a screen. The needle itself is covered by a revolving tube which rotates around its own axis once per cycle, thus ensuring a thorough mixing of the glass melt.

The ITWM has taken part in a very extensive benchmarking with respect to the TC-25, which has resulted in the proof that such a process can be simulated by FPM without problems.



Geometry of the gob feeder TC-25

Pressure field during the process including the direction of the punch movement



Radiative Transfer and Parameter Identification

In many production processes where materials or components are heated or cooled down, radiation plays an important part in the heat balance. In contrast to diffuse heat conduction, which can easily be described mathematically and simulated by different commercial software packages, radiation is essentially more complex. A satisfactory simulation (with respect to the aspects of computing time and exactness) by standard software is therefore only possible for the case of pure surface radiation or for optically dense media. In semi-transparent media such as glass, however, thermal radiation from the volume is not to be neglected. The situation becomes even more complex in the case of an examination of scattering media, e. g., biological tissue.

During the past few years, the department TRANSPORT PROCESSES has developed extensive know-how in the field of radiative transfer, which has successfully been applied to a series of industrial projects, mainly in cooperation with the company Schott AG in Mainz. Current research at the ITWM concentrates on the development of the institute's own software basis for the simulation of radiative transfer, to be integrated into the software package FLUENT©. This software will be described in detail in the following.

The industrial projects with respect to heat transport have additionally resulted in a special competence in the field of "inverse problems and parameter identification" in the last few years. The project "Local Application of Drugs to the Inner Ear" represents an example of the interesting interaction between forward simulation and parameter identification. It also shows how mathematical competence can very easily be applied to very different problems due to the basic models (heat conduction, diffusion).

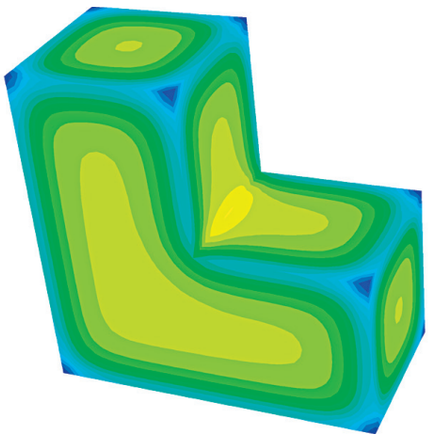
Contact:

Dr. Norbert Siedow
☎ +49 (0) 6 31/2 05-41 26
siedow@itwm.fraunhofer.de

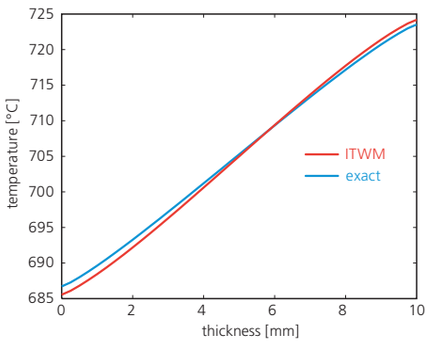
RADEFF – Efficient radiation simulation with FLUENT©

The coupling of thermal radiation and heat conduction and/or flow problems is a high-dimensional nonlinear problem. Three classical simulation methods can be applied to the radiative part of such problems. The Rosseland approximation describes the radiation as a correction of the coefficient of heat conduction, neglecting all the information about the geometry. The method can therefore easily be implemented and works very fast. However, reasonable results are only supplied for optically thick media. The P_1-approximation is a direction-independent and wave-length-dependent diffusion approximation of the radiation. In contrast to Rosseland, geometry information is also accounted for, which is, however, paid for by considerably more computing time. Nevertheless, this method is another inexact one if applied to optically thin media. The Discrete Ordinate Method (DOM) is based on a real direction discretization of the entire radiative transfer equation, resulting in a very exact method. However, in the case of entirely three-dimensional geometries the required computing time is scarcely justifiable. The three methods described above are entirely implemented in FLUENT©.

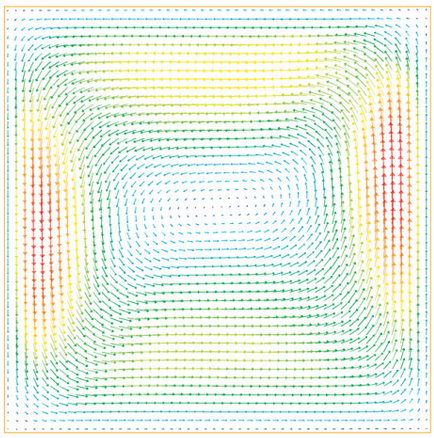
RADEFF, which has been developed at the ITWM, is an approximation method for the numerical solution of the radiative transfer equation. It is based on a formal integration of the radiative transfer equation, which results in an adequate modeling of the source and diffusion terms of the energy balance equations. Generally speaking, the method represents a good compromise between the fast Rosseland and the exact Discrete Ordinate Method, as is shown by different application examples. Wave-length-dependent absorption and the entire geometry information are simultaneously accounted for. RADEFF is up to ten times faster than the classical DOM in the case of sufficiently good exactness. The method is implemented in FLUENT© in the form of a UDF (User Defined Function) and is already applied in projects with respect to the simulation of heat conduction in semi-transparent materials. The current research work is concentrating on benchmarking and further development with respect to different boundary conditions. RADEFF in combination with FLUENT© offers to a company the basis of especially tailored simulation solutions with respect to heat conduction in semi-transparent materials.



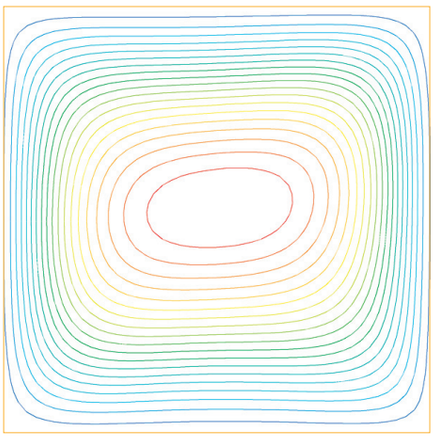
Cooling of a glass block



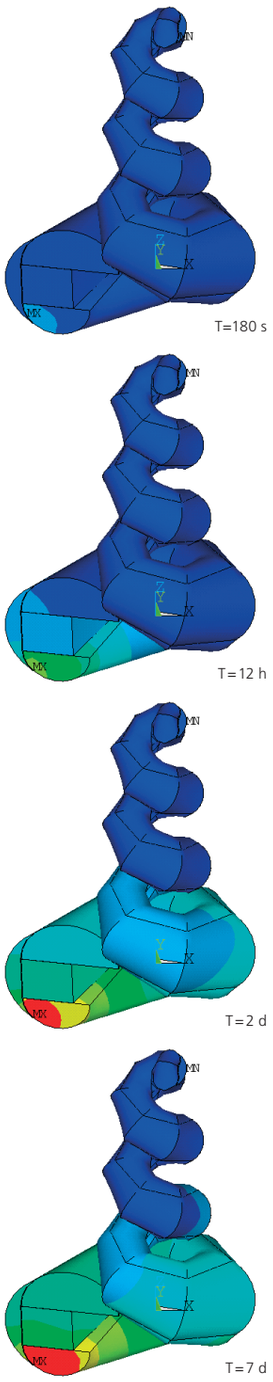
Stationary temperature of a heated glass pane: ITWM solution and exact solution



Convective flow and radiation: velocity



Convective flow and radiation: streamlines



Concentration gradients of a drug in the cochlea

Local application of drugs to the inner ear

Diseases of the inner ear, such as an acute hearing loss with or without tinnitus, belong to the most frequently occurring chronic diseases in Germany. Currently applied therapies include, among others, intravenous infusions; opinions about the effects of these are, however, controversial. Studies have shown that only very high doses of pharmaceuticals yield a measurable level of active agents in the inner ear, which may, however, cause undesirable systemic side effects. Therefore, medical research has focused for a considerable time now on local therapy methods by which the pharmaceuticals can be taken to the round window membrane in an adequate way, from where they can directly diffuse into the inner ear. At the moment, lacking knowledge about the kinetics of pharmaceuticals in the inner ear is one of the main reasons of uncertainty with respect to the application of this method; therefore, extensive animal testing becomes necessary. However, the morphologic properties of the inner ear of different species also differ, so that the results of animal testing cannot be transferred directly to human beings.

A cooperation project between the Department of Otolaryngology, Head and Neck Surgery/Hearing Research Center of the University Hospital Tübingen and the ITWM has now resulted in the development of a mathematical model for the computer simulation of agent distribution in the liquids of the inner ear in the case of a local application of pharmaceuticals. A simplified three-dimensional geometric model of the cochlea has been developed with the software package ANSYS© and used for the simulation of drug application (diffusion process). The necessary physical parameters – permeabilities, diffusion and transition coefficients – were taken from the respective literature as far as they were available.

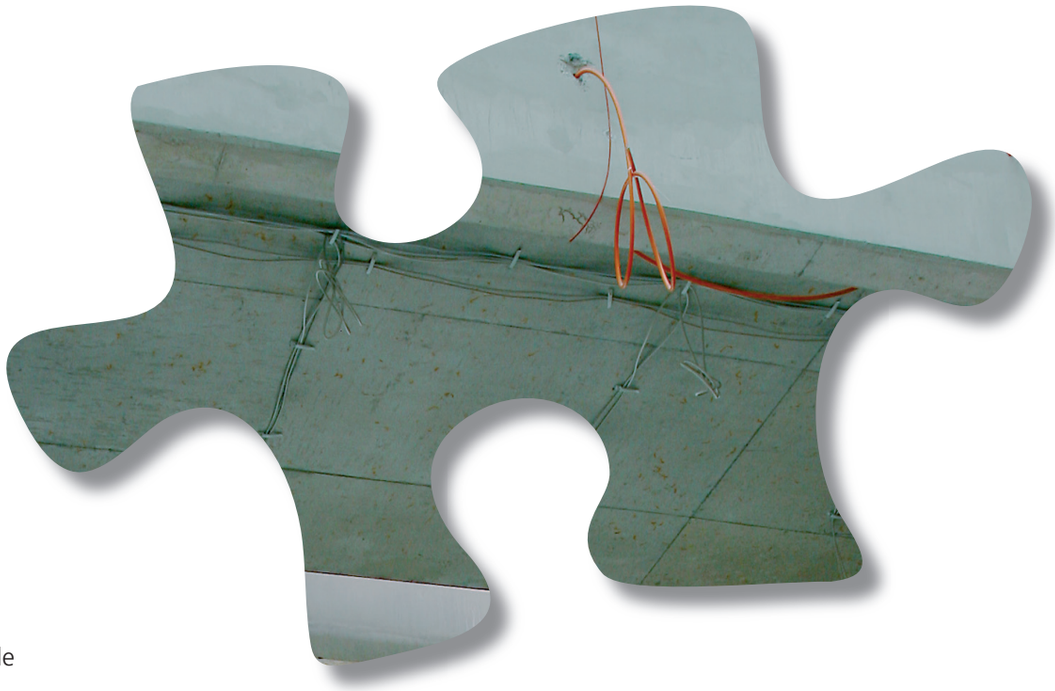
However, the transition coefficients are generally not very well known; they must therefore be determined by in vivo measurements and the subsequent solution of an inverse problem, in combination with computer simulation. The necessary direct measurement results from animal testing are available in the literature. However, the complete three-dimensional model is not appropriate for real parameter identification due to the required computing time. Hence, an additional asymptotic one-dimensional model has been developed and implemented which allows for efficient parameter identification. During the evaluation, the ITWM was especially able to prove a considerable scaling error of the measurement results taken from literature. If the respective financial support will be found, the research cooperation can be continued with the development of a realistic model based on CT data.

Continuum Mechanical Product and Process Design

This main subject combines the different competences of the department with respect to the modeling and simulation of transport processes in order to drive forward the design and optimization of products and production processes, mainly in the form of industrial cooperation projects. Hence, activities are connected to almost every field of continuum mechanics, e. g., flow dynamics, heat conduction, diffusion, radiative transfer, structure mechanics, and acoustics. Our special competence is the solution of coupled problems (multiphysics) by commercial software tools (e. g., FLUENT©, FEMLAB©, ANSYS©, MATLAB®), our own individual software, and hybrid software solutions.

A second focus of our research work refers to projects requiring a model reduction due to their complexity, especially with respect to optimization problems. In particular, asymptotic methods are applied here. One example is the ITWM's participation in the European research project InMAR, which deals with questions of adaptronic vibration reduction. A further example is the cooperation with the company Stryker/Leibinger: on the basis of a continuous cooperation contract, we offer scientific and technical consulting in the field of medical technology with respect to different short-term projects. Here, the work is mainly focused on surgery navigation systems.

The field of Simulated Reality (blending of simulation, optimization, and virtual reality) will be presented in the following by the project "Acoustic Simulated Reality". Our long-term objective with respect to "Simulated Reality" is the development of software tools for the design and optimization of very different products and processes. In this respect, the acoustic aspect of the following project is only one example.



Contact:

Dr. Jan Mohring
☎ +49 (0) 6 31/2 05-38 86
mohring@itwm.fraunhofer.de

Acoustic simulated reality

This research project in cooperation with the group "Computer Graphics" (Prof. Dr. Hans Hagen) of the Department "Computer Science" of the University Kaiserslautern and supported by the "Stiftung Rheinland-Pfalz für Innovation", deals with the development of a system of virtual reality representation by which a room to be planned can previously be entered optically as well as acoustically. Supplied with a space mouse and 3d glasses, a test person can immerse himself/herself into a scene projected before him/her onto the power wall. A high-quality surround system provides the sound field synthesis. The project is mainly focused on the physically correct computation of the sound field in the virtual room and the intuitive visualization of acoustic quality criteria.

A series of criteria (reverberation time, distinctness, localization quality) have been developed in sound engineering in order to evaluate the acoustic properties of a room. The software programs for the simulation of room acoustics which are available on the market can provide a computation and visualization of a certain quality. However, the client of an engineering service – e. g., a local public builder – or a student of architecture are mostly lacking experience with these parameters, thus finding themselves hardly capable of following the arguments of an acoustic engineer. The virtual reality system (VR) will also enable clients without sufficient experience to weigh up the requirements with respect to acoustics, illumination, and aesthetics of, e. g., a concert hall. Once the hardware and software basis will have been developed, numerous further applications can be found (for example, audio-visual rendering of fly-around, noise exposure in a machine shop, traffic noise protection measures). In contrast to already existing methods, the approach which we are proposing is characterized by the fact that low frequencies, which are important for industrial applications, are accounted for wave-acoustically. Besides, it offers a high-quality natural visualization, real-time movement of the listener in the virtual room, realization of the principle of error-oriented adaptivity with respect to all simulation aspects, and the intuitive visualization of complex quality criteria.

During the current project year, the research work has been focused on the development of the required hardware and the specification of the software components. The next steps will concentrate on the subjects of the simulation of room acoustics (high, medium, and low frequency and their coupling), real-time rendering (visual and acoustic), and visualization, i. e. on the development of the software basis. It is our objective to develop a first prototype of hardware and software up to the end of 2006.

Room for Acoustic Simulated Reality

Markus von Nida, Dr. Norbert Siedow, Dr. Marco Günther, Dr. Dietmar Hietel, Dr. Hartmut Hensel,
Dr. Raimund Wegener, Nicole Marheineke, Ferdinand Olawsky, Dr. Arkadiusz Wawrenczuk, Dr. Jan Mohring,
Sergiy Pereverzyev, Satyananda Panda, Dr. Teodor Grosan, Sergey Antonov,
Dr. Robert Feßler, Aleksander Grm, Eka Budiarto, Jevgenijs Jegorovs, Dr. Sudarshan Tiwari

Flows and Complex Structures

The department works on the modeling and simulation of fluid dynamical and structural mechanical processes for the optimization of materials and components. An approach that becomes increasingly important for an integrated material and product design is the integral consideration of all the relevant processes and phenomena together. The efficient solution of the occurring multiscale and multiphysical problems is one of the main competences of the closely connected subjects of

- hydrodynamics
- complex fluids
- microstructure simulation and virtual material design
- structural optimization in mechanics and acoustics.

Among our clients are companies producing technical textiles and composite materials, metal and plastic processing industries, especially foundries, as well as end-users such as producers of filters and system suppliers for the automobile industry.

The past year was characterized by reinforced research and development in direct cooperation with and for industrial clients, resulting in respectively high returns. Apart from a close bilateral cooperation with companies, contacts with clients were extended and intensified by several industrial workshops ("Integrated Process Simulation for the Optimization of Castings", "Simulation and Design of Filters and Filter Media", and "Innovative Methods and Materials in Automobile Acoustics").

In the field of basic and preliminary research, we have counteracted the drastic effects of decreasing public funding of research projects by a larger number of PhD projects – by now, the department has as many PhD students as scientists – and a close cooperation with university research groups working on similar subjects. Apart from the traditionally intensive cooperation with different departments of the Technical University of Kaiserslautern, long-term cooperation has meanwhile been established with several international scientists, resulting in visits of different duration.

Dr. Konrad Steiner
☎ +49 (0) 6 31/3 03-18 20
steiner@itwm.fraunhofer.de

Hydrodynamics

The subject of "Hydrodynamics" comprises the modeling and simulation of complicated flow processes for industrial and ecological applications with a special focus on coupling, multiphysical, and multiscale phenomena. Our activities particularly include the development of algorithms and software for

- the coupling of freely flowing fluids with flows through porous media (e. g., in oil filters, on the surface and in the soil, flow through perforated walls)
- the simulation of floodwater in urban areas
- flows through deformable porous media on the macroscale (poroelasticity) and on the microscale (fluid-structure interaction),

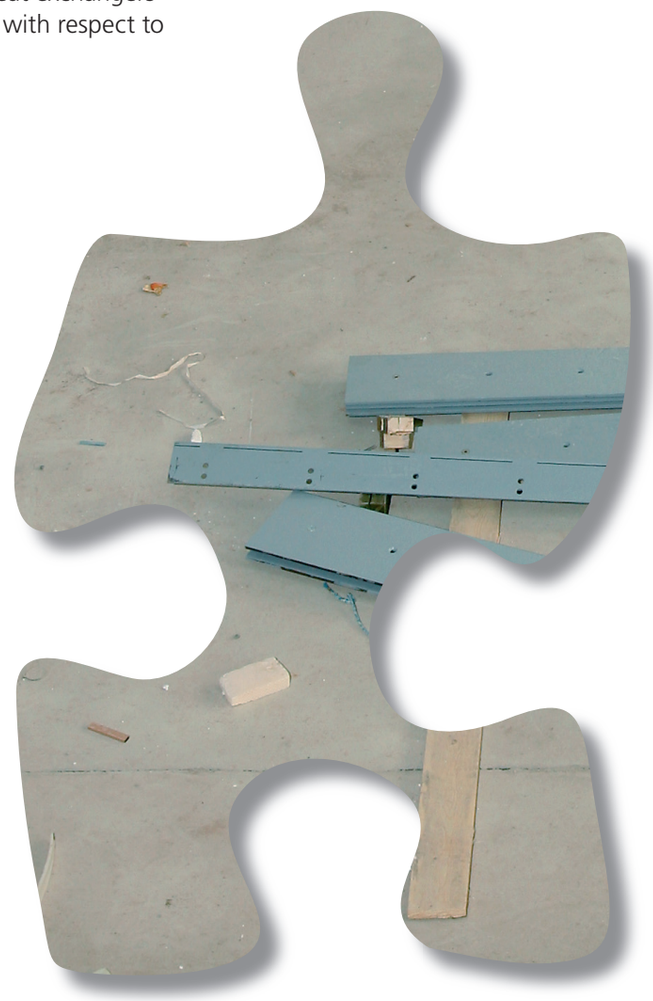
as well as the simulation, analysis, and optimization of

- heat exchangers
- machines for glass wool production
- oil filters, etc.

Stability and efficiency of implemented algorithms are results of our research in the fields of finite volume and lattice Boltzmann methods, optimal iterative methods, and problem-adapted preconditioning.

In the field of floodwater simulation, shallow water equations are used for the simulation of the runoff behavior on the surface and in the sewer network and the neighboring watersheds. Contributions can thus be made with respect to the evaluation of inundation risks and damage potentials and to the dimensioning of sewer systems. Our special competence is the development of digital elevation models for urban areas and the coupling of surface flows and flows in the sewer network.

The optimization of heat exchangers must account for two opposing requirements: the criteria of maximum heat exchange and minimum pressure loss. Detailed numerical simulations of the non-isothermal flow processes allow for the design of heat exchangers with optimum qualities with respect to energy.



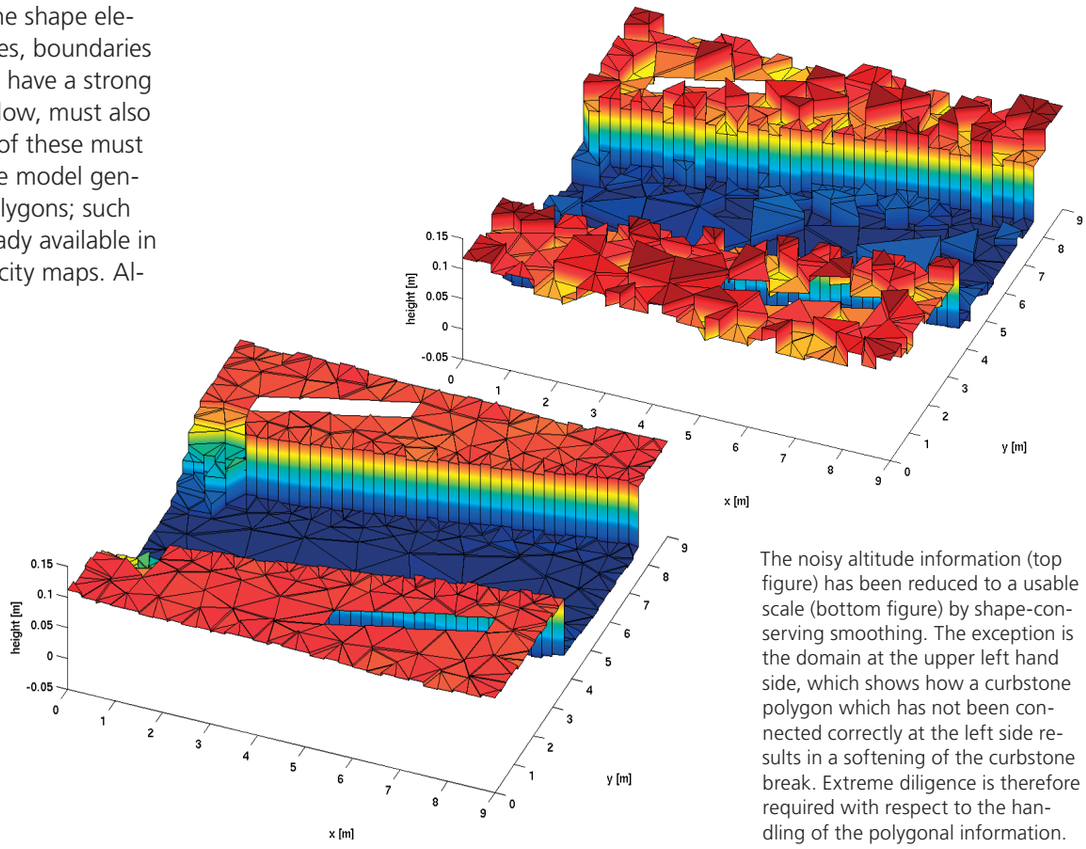
Contact:

PD Dr. Oleg Iliev
☎ +49 (0) 6 31/3 03-18 12
iliev@itwm.fraunhofer.de

Floodwater simulation in urban areas

The conclusion of the BMBF/Eureka project RisUrSim (Risk Management in Urban Areas – Simulation and Optimization), funded by the Federal Ministry of Education and Research (BMBF) and the European Union, resulted in the development of a software for the simulation of the processes which are relevant for a coupled computation of the runoff behavior on the urban surface and in the sewer network. The software is sup-posed to be applied to the estimation of inundation risks in urban settlement areas. It has the unique feature of a bidirectional coupling of surface and sewer network, which requires new modeling approaches and a very detailed model representation of the surface. Decisive progress has been made here during the past year. The relief description in urban areas does not only require altitude information which is as exact as possible; the line shape elements such as curbstones, boundaries of buildings, etc., which have a strong influence of the water flow, must also be accounted for. Data of these must be made available to the model generator in the form of polygons; such data are frequently already available in a usable digital form in city maps. Altitude information can meanwhile be gathered by airborne measurements, such as laser scanning, with a good exactness also for urban areas (a maximum error of 10 to 15 cm in vertical direction); the required 3d resolution of more than one spot per square meter is guaranteed. Tests carried out with such a data record have shown that standard data processing results in a residual corrugation of the data which exceeds the exactness required for modeling curbstones. However, the smoothing algorithms developed at the ITWM allow for a reduction of the residual corrugation in such a way that the difference in altitude between sidewalk and street can be resolved. This step is successful without softening the line shape structures and can be taken by the user without any complicated data preparation. The figures show the functionalities by a synthetic example.

Such processes are currently applied to a real high-quality data record at the institute. First results show that this data record, after having gone through the processing discussed above, will allow for the development of high-resolution surface models yielding an increase of exactness with respect to runoff modeling. The new technology will also be applied within the new BMBF (Federal Ministry of Education and Research) project 3ZM-GRIMEX, which deals with a coupled computation of flow processes for the example of Dresden.



The noisy altitude information (top figure) has been reduced to a usable scale (bottom figure) by shape-conserving smoothing. The exception is the domain at the upper left hand side, which shows how a curbstone polygon which has not been connected correctly at the left side results in a softening of the curbstone break. Extreme diligence is therefore required with respect to the handling of the polygonal information.

Complex Fluids

The main subject "Complex Fluids" deals with flows of industrially relevant fluids whose flow behavior strongly differs from that of ordinary fluids. Among these are, e. g., fluids whose viscosity varies with respect to space depending on the flow pattern, or flows which can behave viscously as well as plastically and elastically. Especially interesting for application are granular media, polymer fluids, colloidal fluids, fiber-reinforced plastics and glass melts, but also many biological fluids.

The possibilities of simulation available through commercial software are insufficient for many industrial applications of complex fluids, because either the mathematical-physical models or the numerical methods which have been applied are not adapted to the application. Within the subject "Complex Fluids", special solutions are developed for these cases. In the last few years, for example, a software module for the computation of fiber orientation during the injection molding of fiber-reinforced thermoplastics has been devised. This module can be coupled to commercial software packages via a software interface.

For the optimization of processes such as injection molding, it is important to be able to simulate the flow of rheologically complex polymer melts in complex geometries. Already a few years ago, the ITWM has developed an industrially applicable code on the basis of the Lattice-Boltzmann method, which is very efficient for the simulation of flows of simple fluids in complex structures. This method has now been extended to flows of polymer melts in the framework of a project funded by the German Research Foundation (DFG).

Another application example is the development of a software solution for the simulation of core shooting, which is used during the production of foundry cores.

Contact:

PD Dr. Arnulf Latz
☎ +49 (0) 6 31/3 03-18 25
latz@itwm.fraunhofer.de

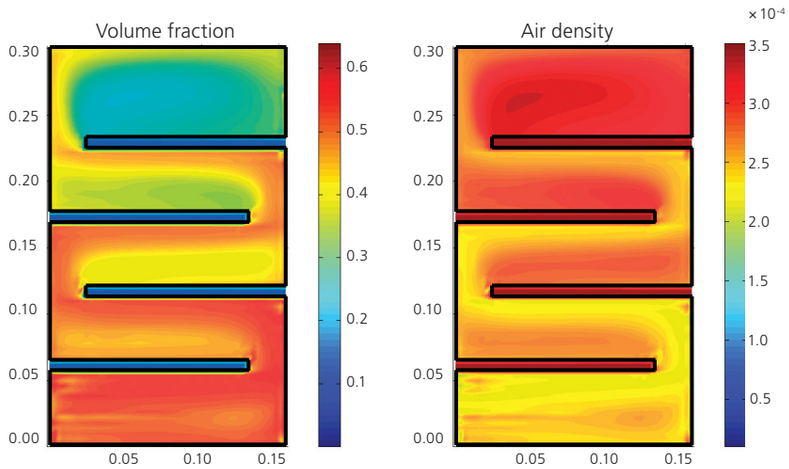
Simulation of core shooting during the production of foundry cores

Production processes where granular media are processed play an economically important part in industrial branches which are as different as building material production, pharmaceutical-chemical industries, and food production. Although there is considerable experience in handling such materials, the complex flow behavior of powders and grains makes it difficult to estimate which behavior to expect in new situations. Simulations which account for rheology as realistically as possible can help here. In close cooperation with the company MAGMA, the competence of the Fraunhofer ITWM with respect to the simulation of granular flow is therefore transferred to the core shooting of sand molds. These are applied by foundries for the production of complex foundry cores. During the so-called core shooting, a sand-air mixture, which consists of approximately 30 to 40 per cent of sand at the beginning, is shot into a model of the core in order to produce a compact sand negative.

The sand core must not show any inhomogeneities with respect to the porosity of the granular structure, otherwise unjustifiable defects of the cast part might occur. In order to meet these requirements, the blank mold must be supplied with vents which guarantee that no inclusions of air can occur even in areas where the air is compressed massively due to the high sand pressure. The software developed by MAGMA and the ITWM handles the granular medium as a compressible sand-air mixture in order to be able to detect regions of high air pressure. Modern kinetic theories help to derive a hydro-dynamic description of the sand dynamics, which, however, differs considerably from the dynamics of ordinary fluids. The differences are due to the dissipation of energy during the collision of sand grains. Granular flows hence not only come to a rest, they are even compressed and become increasingly viscous, as glasses do.

An essential concept for the description of the transition from fast flowing sand to sand at rest is the granular temperature, which quantifies the fast fluctuations of the velocities of the individual grains, in the same way as the ordinary temperature does for the fluctuations of the molecules. In order to describe also the transition from fluid to solid behavior correctly, the mathematical description comprises the most recent research results with respect to the glass-like solidification of granular materials.

The figure shows a snapshot of a filling simulation during which sand is blown into a box at high velocity from the bottom left hand side. We can clearly see that in regions of high air density, the volume fraction of sand has decreased.



Snapshot of a filling simulation: sand is shot into the box from the bottom left hand side, leaving it at the top of the right hand side. The left figure shows the volume fraction of sand, the right figure describes the relative air density.

Microstructure Simulation and Virtual Material Design

The field "Microstructure Simulation and Virtual Material Design" mainly deals with the modeling and improvement of porous media and composite materials, as well as with the computation of their properties. A special focus is the development of individual software, which facilitates the research at the ITWM and is sold to the institute's partners. A further subject is the efficient storage and movement of free surfaces by the Level Set Method.

Important material classes are technical textiles, sintered structures, membranes, and even the human lungs. Apart from generated structures – new are curved fibers, membranes, and tissues –, the method also uses three-dimensional tomographic images as input data for the computation of properties.

Flow and filtration properties are computed for these structures. In 2004, efficient solvers were developed with respect to material strength, electrostatics, and thermal conductivity. The computations are validated according to measurements prior to the development of optimized structures on the computer.

Tools from this area are GEODICT – the structure generator, simulator, and designer – and FILTERDICT for the filtration simulation and visualization. Besides, SINTERDICT handles the determination of the initial, intermediate, and final structures during the sintering process. Objectives are high-quality surface meshes which can be used by partner institutes within a Fraunhofer-internal research project. Within this project, as well as within the Fraunhofer cooperation project "Numerical Simulation", we are explicitly cooperating with other Fraunhofer institutes.

The NETIAM project (*www.netiam.net*) is a close cooperation with European partners for the consultation of the European Commission about mathematical subjects important for future developments. In this respect, a workshop was organized in Kaiserslautern with the subject of "Challenges in visualization, simulation, and design for virtual porous materials".

Contact:

Andreas Wiegmann, PhD
☎ +49 (0) 6 31/3 03-18 24
wiegmann@itwm.fraunhofer.de

FILTERDICT – filtration simulation in microstructures

Subsequently to a demand analysis carried out within a Fraunhofer-internal market study, and initiated by a project supported by the "Stiftung Rheinland-Pfalz für Innovation", one of the subjects in the field of "Microstructure Simulation and Virtual Material Design" is the development of the parallel simulation software FILTERDICT. Current projects in cooperation with suppliers of the automobile industry – mainly in the field of air filtration – have contributed to the determination of the catalogue of requirements which the software ought to meet.

Each simulation starts with a geometry description of the filter medium, which can, for example, be based on tomographic data. However, especially in the case of non-woven structures, such as layered air filter media, the virtual generation by the structure generator GeoDict provides a handy solution.

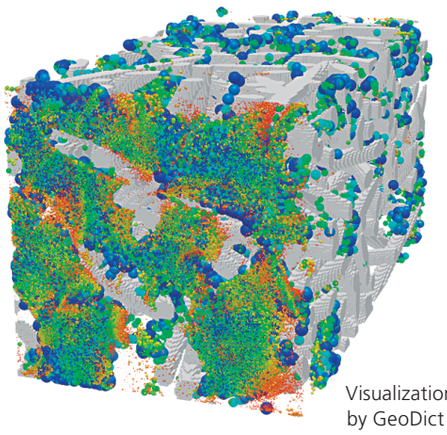
The center of the filtration simulation is represented by the computation of the flow field within the filter geometry, which is based on the solution of the Navier-Stokes equations, and the subsequent determination of the particle paths. The latter are described by a model which not only accounts for the Brownian motion, but also for the particle mass and the friction between particle and fluid as transport mechanisms. In the case of a collision with the filter medium, the particle can be sieved or be taken up by adhesion. If the particle possesses sufficient kinetic energy, it rebounds by energy dissipation.

The simulation model is very flexible, so that the most different physical situations can be simulated. A detailed particle model, e. g., allows for the simulation of standard test dusts as well as for the handling of soot.

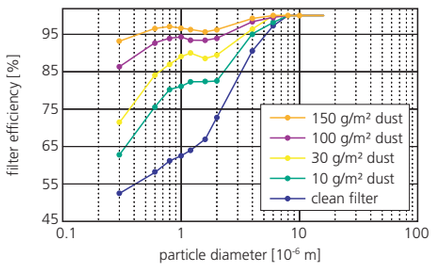
The simulation of the filter efficiency and service life is important for application and validation. Thousands of particles are propagated through the medium for the computation of filter efficiency, in order to determine the relation of adhered and sieved particles. Exact statistics can be generated here, telling the user for example which layer of the medium has preferably taken up which type of particle by adhesion.

The simulation of the service life of filters is carried out in the following way: after a certain amount of particles have propagated through the filter, the "dirty" geometry will again be subject to a flow. The particles will now begin to influence the flow field. These alternating flow and filtration steps will be continued until a given pressure increase is reached. A detailed statistics is also generated here, so that the user will receive information about adhesion with respect to the individual layers. In addition, the service life simulation also provides output with respect to the adhesion behavior subject to time, which is decisive information for the construction of gradient media.

The simulation of real media usually yields extremely large amounts of data which require the use of a parallel computer. However, FILTERDICT is also available as an additional module of GeoDict, which is apt for in-house application at the media developing company, with considerable performance depending on the computer system.



Visualization of particle adhesion by GeoDict



Measured and simulated filter efficiency

The LEVELDICT library for moving surfaces

LEVELDICT is a library for the solution of problems with moving boundaries, which is based on the Level Set Method. The software consists of modules for different industrial applications and is very efficient due to the use of the Narrow Band Method.

The library has three basic modules:

- Initialization: computation of the level set function ϕ on the underlying Cartesian grid on the basis of a surface triangulation
- Contouring: construction of a triangulation of the surface S, which is given by the zero level sets of ϕ, by the Marching Cube Method
- Propagation: movement of the surface S by the solution of the level set equation

$$\phi_t = F|\nabla\phi|$$

where F is the velocity in the direction of the surface normal (propagation velocity). At the surface, F is determined by extrapolation of the velocity field by the Least Squares Method and then constructed on the grid points in a neighborhood of S through a constant continuation of the velocity.

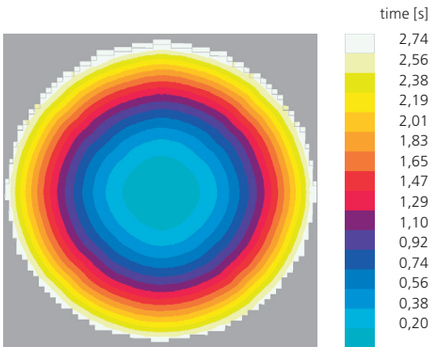
If coupled with SIGMASOFT, a software package for the simulation of plastic fluids, the LEVELDICT library takes over the following tasks:

- Construction of the surface (triangulation) on the basis of the geometry data provided by SIGMASOFT (volume fraction of the fluid) and computation of the level set function ϕ for the underlying non-equidistant grid, which is, however, Cartesian
- Estimation of the velocity field and continuation of a normal velocity towards a neighborhood (see above); movement of the free surfaces according to the level set equation
- Estimation of the volume fraction and of the normal according to the level set function and reconstruction of the free surface for the next time step

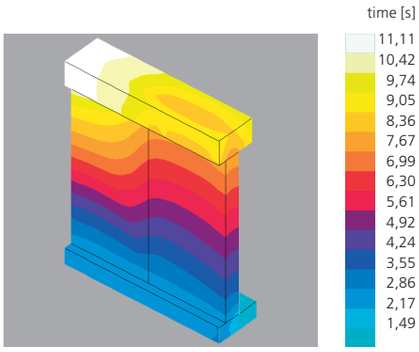
The library has been tested for different geometries with obstacles. The figure on the left side shows the simulation of a filling process for a sphere symmetric plastic mold at different times. The figure on the right side is the filling process of a mold which has different thicknesses along its length.

The LEVELDICT modules are currently used for many different applications, partly also as pre-processors. The initialization module allows surface information to be converted into volume data required by the software packages SINTERDICT, SUFIS, and SIGMASOFT.

Contouring generates surface triangulations on the basis of volume information, which are used by OptCast/TopLevel, EJIIM, and the structure generator GEODICT. Besides, the library processes and exports the stereo-lithography format (STL), which is considered as standard industrial format and used in many applications. There is also a user-friendly user interface called LEVELSPLIT, which divides STL data into their correlation components. It is used within SuFis and TopLevel/OptCast projects.



The simulation of a filling process for the model "circular area" at different times



The simulation of a filling process for the model "jump in plate thickness" at different times

Structural Optimization in Mechanics and Acoustics

The actual problem in the field of construction and development is not the analysis with respect to material load and operational behavior, but, moreover, the shape modification and optimization of components and systems in order to reduce the material load and increase the durability. Software tools automating this problem of structural optimization have been developed within the last ten years and are increasingly applied in industry. The main activities of the ITWM in this respect refer to the following areas:

- Analysis of already existing software for the structural optimization of cast parts
- Development of structural optimization tools based on mathematical and highly efficient algorithms, especially for foundries
- Development of structure optimization tools simultaneously accounting for the production process (casting process) and the consumable load; for example, residual stresses are computed on the basis of the casting process and superposed upon the operational load.
- Analysis of the actual state of components and systems for the determination of the optimization potential
- Optimization of highly complex structures, such as nonwovens or porous composites, with respect to (flow) mechanical, acoustic, and thermal properties

Topology or shape optimization is carried out by an iterative process, during which the shape is improved successively on the basis of an initial design or a given optimization domain. Each iteration requires a structural or sensitivity analysis, which is done on the basis of the Finite Element Method. In order to accelerate the iteration process, the special and highly efficient FEM method DDFEM has been developed in cooperation with the CC HPC (see page 99) and applied to problems of industrial application, as they occur, e. g., within the projects “OptCast” and “Engine block”.

Contact:

PD Dr. Heiko Andrä
☎ +49 (0) 6 31/3 03-18 22
andrae@itwm.fraunhofer.de

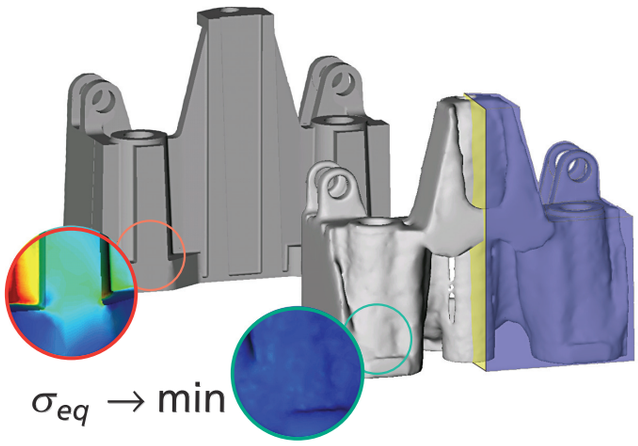
Adequate structural optimization methods for foundries

The project "OptCast", which was funded by the Ministry of Economy of Rhineland-Palatinate and the EU, was terminated successfully in the year 2004. In cooperation with the five project partners (HegerGuss, Gienanth, Römheld & Moelle, Müllers Büro, and Hg.zwo), a CAE test chain was assembled, on the basis of which the topology and shape optimization of benchmark components (typical cast parts from the three cooperating foundries) was carried out and analyzed. A first result of the analysis was the determination of a catalogue of requirements with respect to structural optimization tools for foundries, in order to develop especially tailored software tools for foundries in the future. At the same time, the foundries received proposals of improved or optimized versions of components as a side effect.

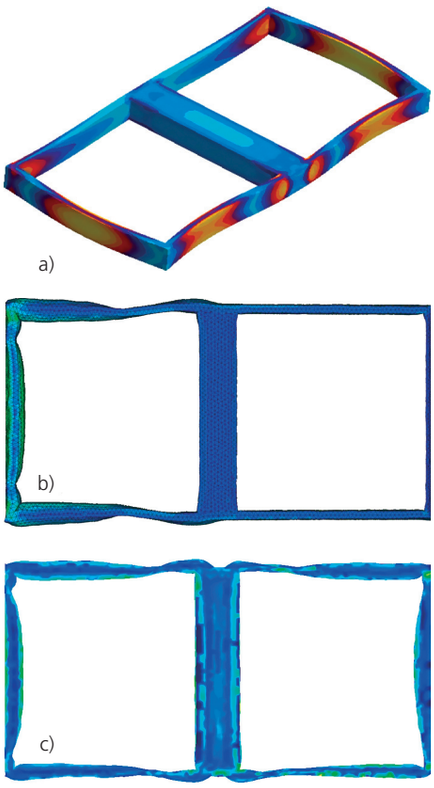
On the basis of the catalogue of requirements, the ITWM has developed algorithms and prototypical methods which are supposed to allow for a future in-house optimization of components and casting processes by foundries and engineering companies:

- The FE preprocessor GiD® was expanded with respect to the specification of topology optimization problems of cast parts.
- The specialized FE analysis tool DD-FEM was developed for the application within the optimization method (see page 99).
- The casting simulation software MAGMASOFT® was integrated into the structural optimization process.
- A new mathematically based topology optimization method was implemented which uses the topological gradient and the level set method.

These tools help to simplify and accelerate the optimization process from the user's point of view. In contrast to similar heuristic methods, the results are based on mathematical methods, thus being essentially more reliable.



Topology optimization for the example of the front plate of an injection molding device: design space (left), von-Mises equivalent stress at the optimized structure (right)

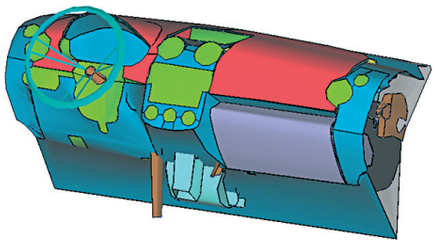


Von-Mises equivalent stress:
a) residual stresses (original construction)
b) optimized version not accounting for residual stresses
c) optimized version accounting for residual stresses

Acoustic simulation of an automobile cockpit

The noise level in the interior of an automobile is in large parts determined by the design of the cockpit. The cockpit separates the passenger compartment from the engine compartment, thus being able to shield the noise from the motor more or less strongly. If we take into account exclusively the acoustic properties, the component should be closed as completely as possible, it should thus be constructed as soundproof. In practice, however, this can only be realized with restrictions due to reasons of expenses, because the steering column and the heating and ventilation systems must be led through the bulkhead, thus causing acoustical leakages. The design of the cockpit therefore is a compromise between the different requirements (price, weight, selection of materials, etc.). Hence, the task of acoustic simulation is to find the acoustically optimum cockpit under these general conditions.

For medium and high frequencies, the noise level can be computed by the Statistical Energy Analysis (SEA). At the ITWM, the SEA software tool AutoSEA2003® is available. The transfer of the CAD cockpit geometry to a respective AutoSEA2003 model was realized. The SEA simulation indicated which acoustical leakages are still on the verge of acceptability and how far the noise from the engine can be shielded by additional acoustic absorbers in the interior of the cockpit.

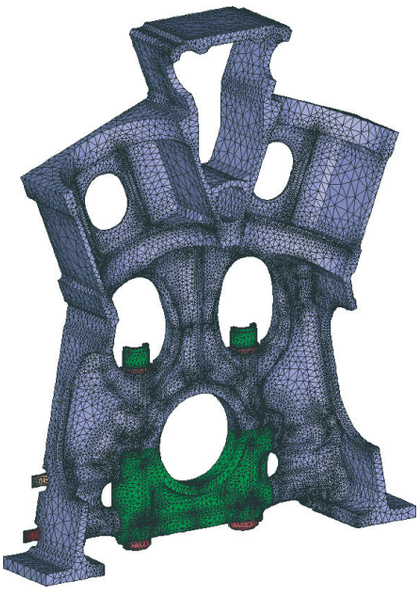


3d view of the simulated cockpit

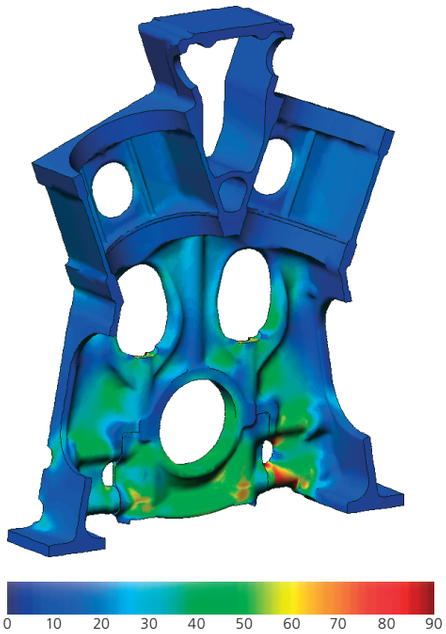
Computational proof of the material strength of cast parts

Services for its customers become increasingly important for a medium-sized such as the company Zimmermann Formtechnik GmbH. These are, for example, a computational proof with respect to the material strength of cast parts and proposals with respect to construction improvements. In this respect, the Fraunhofer ITWM offers as a special service the computation of local stress distributions and of deformations during operation. Additionally, automatic optimization methods allow for a distinct improvement of critical construction areas.

As a concrete example, a construction of welded steel of a motor block was substituted by a cast part. Shape optimization reduced the local material loads in the critical area. The exact computation of the local stress distributions allows for a reduction of the material in those areas which are subject to lesser loads. The weight as well as the production costs of the component are reduced hereby – two decisive advantages with respect to other competitors.



Finite element mesh of a segment of a Diesel engine



Von-Mises equivalent stress of the engine segment in the case of maximum gas pressure in the cylinder and most critical rotation angle of the crankshaft

The project is supported by the Land Rhineland-Palatinate and the EU in the frame-work of "Mathematische Forschungsplattform für regionale KMU"

Dariusz Niedziela, Alfonso Caiazzo, Hanna Naumovich, Stefan Rief, PD Dr. Arnulf Latz, Dr. Norman Ettrich, Ashok Kumar Vaikuntam, Dr. Volker Schulz, Dr. Vita Rutka, Inga Shklyar, Sabine Muntz, Emanuel Teichmann

Models and Algorithms in Image Processing

The department MODELS AND ALGORITHMS IN IMAGE PROCESSING develops customized solutions in the field of image and signal processing in close cooperation with partners from industry and research institutions. The work is particularly focused on

- surface inspection
- signal analysis for railway systems
- analysis of 3d microstructures
- image and sequence analysis.

We are adept in the development of efficient complex algorithms and their integration into industrial production processes. On the basis of the research work of our department and the cooperation with other research groups the range of our services is continuously expanded and improved.

We can look back on a very successful business year 2004. The order situation in the field of surface inspection systems. Within the last year, those systems already in use were developed further, and new systems were put into operation. In the year 2005, we continue working on several projects for the inspection of textured surfaces (e. g., leather, paper, fiber plates, and metal cast parts).

The development of the existing autonomously working monitoring systems for railway tracks has been continued. For the year to come, we are planning a modernization of the software, especially with respect to a better orientation towards international markets.

The domain of 3d image analysis is gaining importance due to improved technical possibilities with respect to image rendering. Our work concentrates on the determination of geometric features of material microstructures. MAVI is a commercial software package for the analysis of 3d images which has been developed at our institute. At the moment, the beta test phase is running; the full version will be introduced on the market at the beginning of 2005.

Within the main subject "Image and Sequence Analysis", the further development of the image search engine for databases and video sequences, which has been built up in cooperation with our partners, has been continuously pushed forward. In the framework of the "Mathematische Forschungsplattform für regionale KMU", supported by the EU and the *Land* Rhineland-Palatinate, examinations with respect to stereo image analysis are carried out.

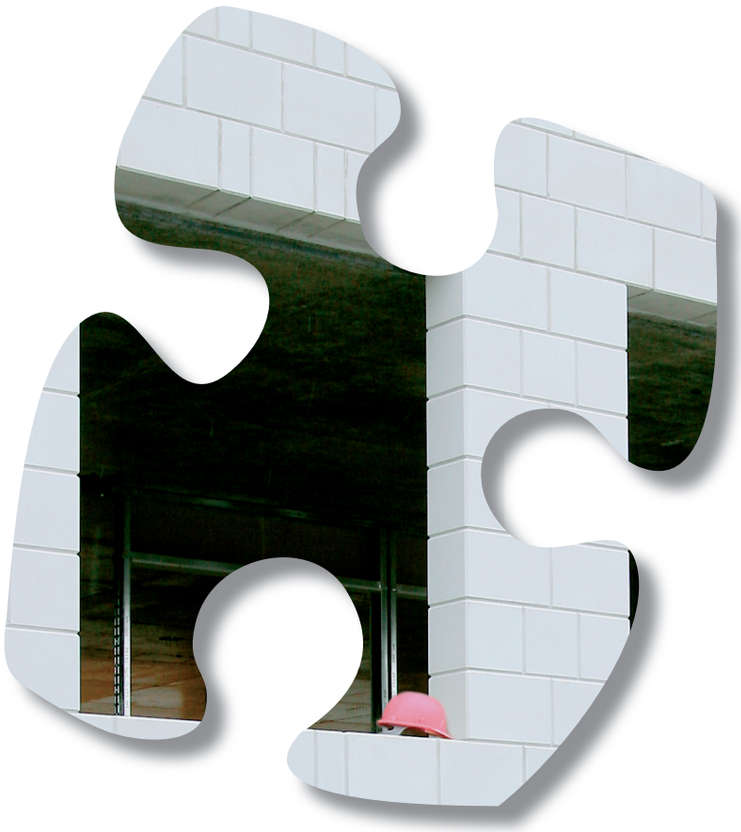
Dr. Ronald Rösch
☎ +49 (0) 6 31/3 03-18 67
roesch@itwm.fraunhofer.de

MASC

In many cases, there is a close relationship between the quality of materials and products and the quality of their surface. Manual quality control is still applied very often and either only allows for the examination of random samples or cannot be carried out during the production process. The methods of the department MODELS AND ALGORITHMS IN IMAGE PROCESSING allow for an online defect detection and classification. Thus, also an early intervention into the production process becomes possible, which can be very important, e. g. in the case of serial defects. Automatic optical surface inspection does not impair the production. Besides, the resulting objectivity guarantees a constant quality of the inspected parts.

Applications vary, both with respect to the examined materials and with respect to the interesting surface properties. In order to meet the requirements of such a large variety of applications, we have developed a modular system (***MASC*** – ***M***odular ***A***lgorithms for ***S***urface ***C***ontrol) consisting of a large number of tools and system components ready for use. These are organized according to a modular structure, thus offering an appropriate basis for fast and flexible solutions for almost every individual problem concerning surface inspection.

In the framework of ***MASC***, inspection systems have been generated for the quality control of textiles and nonwovens, for the defect detection on laminated metal surfaces, and for the classification of colored and structured surfaces such as wood. Further applications can be found, e. g., in the metal producing industry, the plastic producing industry, and with automobile suppliers. The Fraunhofer ITWM is currently developing systems for the automatic quality control of leather and further creating already existing systems for the inspection of paper surfaces, as the following two examples will show.



Contact:

Dipl.-Inform. Markus Rauhut
☎ +49 (0) 6 31/3 03-18 73
rauhut@itwm.fraunhofer.de

Inspection of paper surfaces

In many paper producing companies, quality control is still carried out by especially trained personnel; this is laborious and time-consuming.

The system ***MASC***-SPOT for automatic paper inspection, which has been developed at the Fraunhofer ITWM, has improved the quality of the previously manual inspection by objective measures, simultaneously increasing the inspection velocity. The first version of this system has been revised and adapted to the current state-of-the-art in camera technology and computer hardware. Besides, the system can now detect defects for very different new types of paper. These upgrades allow for higher belt velocities, so that the system can be integrated into the production process even more efficiently. The core of the system is defined by fast image processing algorithms which are able to detect and classify defects on the homogeneous paper surface, e. g., stains and scratches. Input data of the algorithm are digital images of the paper surface, which are provided by cameras mounted above the conveyor belt for the paper sheets. The new high-resolution line scan cameras even allow for the detection of very small defects (resolution: 0.2 mm) which could not be detected before; in spite of increasing amounts of data, the algorithm run times have remained at a constant level.

Image processing

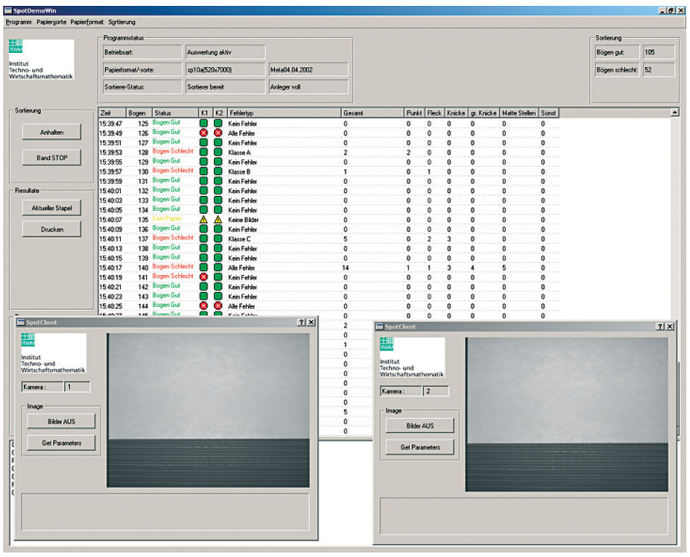
As a first step of the image processing algorithm, the camera image is reduced to the relevant region, i. e. the section of the image showing only the paper sheet. After this process of "boundary recognition", defects are detected in the image and marked by so-called ROIs (Regions of Interest). On the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

Structure of the entire system

The SPOT system is directly integrated into a paper sorting machine. Above the conveyor belt, several cameras are installed which observe the entire width of the paper sheets. Each of these cameras is connected to one of the clients of the SPOT system. These clients run the image processing algorithms. Each client consists of a double processor system where several image processing algorithms run simultaneously. This parallelization is finally responsible for the high system velocity of 250 meters per minute, requiring however the application of high-resolution line scan cameras which allow for very short exposure times (up to 1/20,000 seconds). A central server collects and logs the results of the clients and controls the sorting machine.

The modular structure of the system as a ***MASC*** component allows for an easy adaptation to customer requirements and new technological developments.

User interface of ***MASC***-SPOT



Two line camera images of the paper surface (original size: 8192 x 512 pixels)

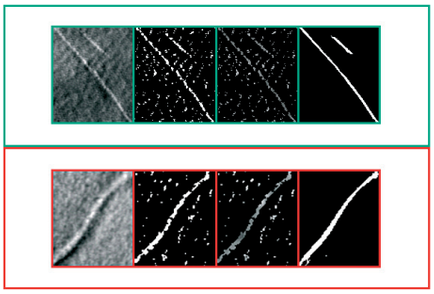
Leather inspection

In cooperation with the Swedish leather manufacturing company ELMO, we have initiated the development of a system for the automatic inspection and grading of raw hides. Up to now, this job has exclusively been carried out by especially trained experts. Depending on their visual appearance, every defect belongs to one of the following four types: insect bites, scratches, warts, and shingles.

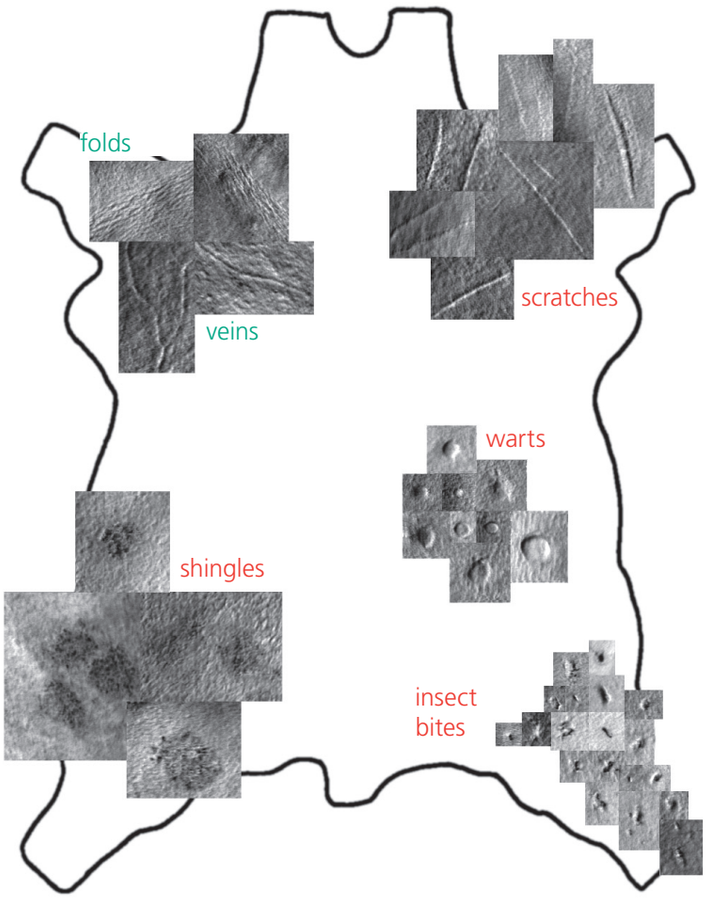
The complexity of this problem results from the very rich and variable structures of leather as a natural product. The system has to be able to distinguish between the natural and desired patterns and the undesirable artifacts which are considered as defects that lower the quality. It is, for example, very difficult from an algorithmic point of view to distinguish between weak and healed scratches and thin veins, because both structures can scarcely be distinguished even visually if only the local image data are available.

A mathematical model accounting for all the different leather patterns and their natural variations would be much too complicated as a basis for a real time system. Instead of modeling the regularities of the visual leather appearance and its deviations, we are directly concentrating on the defects. The special challenge is the development of algorithms which are able to handle the huge amounts of data (approximately 140 million pixels per hide if an 8192 pixel line scan camera is used) and to realize a real time detection and classification simultaneously. Our strategy is to reduce the amount of data at hand as efficiently as possible, so that only the decisive information for the grading remains to be processed.

Systematic preliminary studies have shown the true complexity of the problem. The image acquisition unit (lighting) and the detection procedure (a very low percentage of wrongly identified defects is required) were identified as especially critical system components. Significant progress was made in both areas. We have thus come very close to the objective of proving the feasibility of an automatic leather inspection system. During the next few months, a first pilot system will be constructed and installed at the plant of our customer.



Detection of scratches: the figure shows single process steps. Scratches and veins look very similar; therefore veins are partly identified as scratches (green - correct detection, red – vein, identified as a scratch). During the classification step, the latter must be separated from the real scratches.



Natural leather structures (folds and veins) and typical defects on natural leather

Analysis of Volume Images and Modeling of Microstructures

New materials ought to be lightweight and strong at the same time; their production ought to be simple, and their thermal, acoustic, and mechanical behavior optimal. Material properties are determined considerably by the microstructure. Hence, there is a growing interest in the geometric characterization of the microstructure, especially also of very soft, fragile, or extremely porous materials which cannot be handled by conventional microscopic methods.

The past development of three-dimensional imaging methods, particularly of computer tomography with increasingly better resolutions, larger images, and faster reconstructions is the reason why the acquisition of 3d image data in the laboratory becomes increasingly interesting for many applications. On-line quality control using 3d image data comes into reach. During the past few years, the Fraunhofer ITWM has developed and tested methods for the analysis of 3d images of complex microstructures. ***MAVI*** (***M***odular ***A***lgorithms for ***V***olume ***I***mages) is a platform-independent complete system available for the analysis of volume images, which has been created on the basis of the analysis methods developed at the ITWM.

Apart from the application-specific analysis of very different 3d structures, the combination of stochastic geometry, 3d statistics, and image analysis also allows for the development and fit of geometric models as a basis for the numerical simulation of macroscopic material properties. This approach is not only interesting for virtual material design (see page 37), but also for materials of whose microstructure no volume images are available due to their fineness (nanometer scale).

Contact:

Dr. Katja Schladitz
☎ +49 (0) 6 31/3 03-18 68
schladitz@itwm.fraunhofer.de

MAVI – Modular Algorithms for Volume Images

MAVI is a software system for the processing and analysis of 3d images as they are provided by, e. g., micro-computer tomography (µCT). The system is especially apt for the analysis of material microstructures, for example, of foams, fiber composites, nonwovens, or concrete. However, ***MAVI*** can also be applied immediately for three-dimensional images of other structures, such as bones or snow, due to its modular structure.

The system is based on functions for the characterization of the complex geometry of microstructures. Volume, surface, curvature integrals, and the Euler number are determined for the entire structure or for individual objects. Anisotropies and preferred directions are not only detected, but also quantified. There is an special analysis function for open foams.

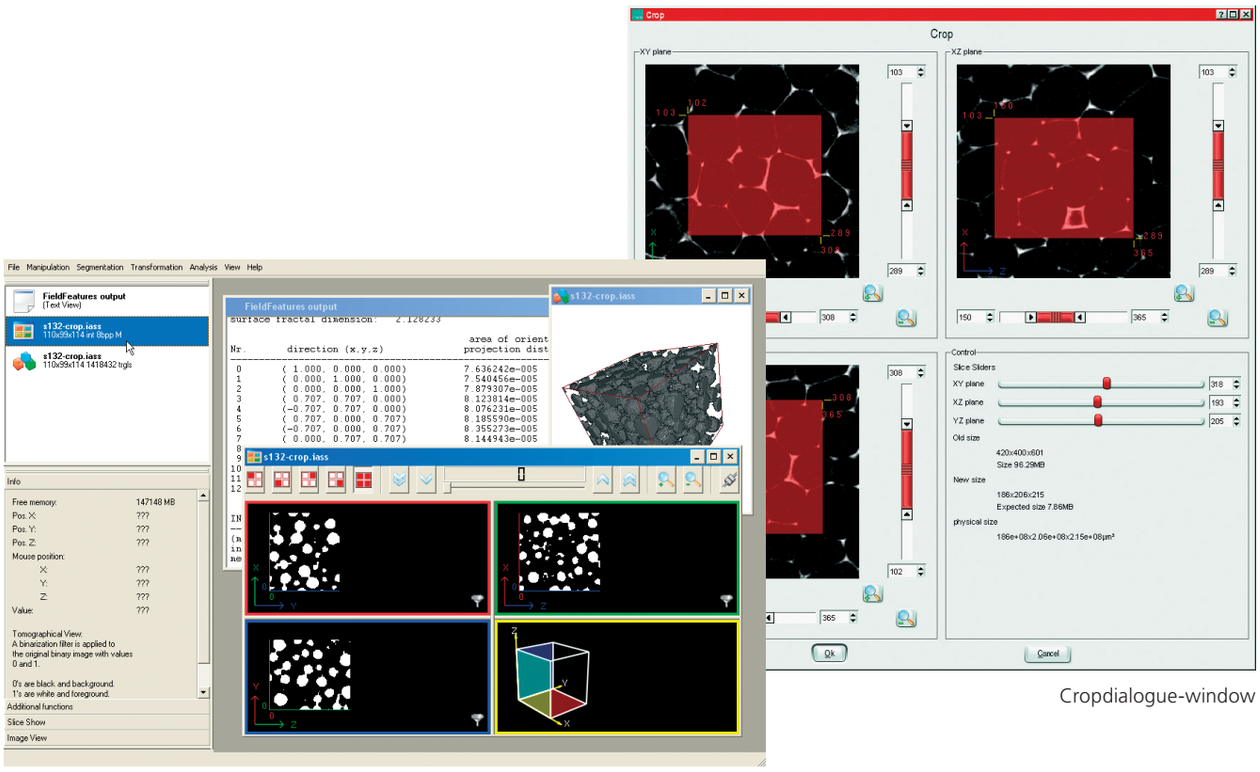
Algorithms for several complex applications which are frequently required, such as the removal of noise particles or the separation of connected objects, have been combined in the form of user-friendly modules.

Moreover, ***MAVI*** also offers the functions which are known from 2d image processing, such as filters, morphological transformations, arithmetic and logic operations, or the Fourier transformation.

The combination of the functions allows for, e. g., the determination of the number and thickness of percolating pores or of the average coordination number of particles, as well as for the image-analytical measurement of tortuosity.

MAVI is platform-independent, is provided with a user-friendly graphic interface, and offers three possibilities of visualization for volume images.

The Fraunhofer ITWM offers the analysis of microstructures also as one of its services. Depending on the material, the ITWM is cooperating with different partners with respect to image acquisition (Fraunhofer IZFP, RJL Micro & Analytic GmbH, Leica Mikrosysteme GmbH, Alfred Wegener Institute for Polar and Marine Research, Hahn-Meitner Institute, European Synchrotron Radiation Facility). The range of examined materials covers metal and polymer foams, ceramic materials, concrete, fiber nonwovens for vacuum cleaner dust bags, and snow.



Cropdialogue-window

MAVI – user interface with different document views

IMVAL: Innovative mineral foam composite applications for lightweight construction

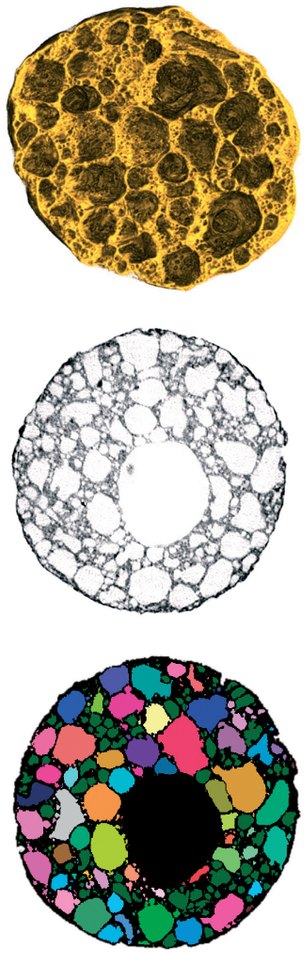
The objective of this cooperation project is the development, production, analysis, and characterization, as well as the application of a new lightweight composite. This composite material is produced by casting liquid plastic or metal around a filling of small and very light mineral foam spheres. The spheres yield a large interface and many cavities, which results in a considerably reduced weight, whereas the deformation properties remain adjustable.

This cellular composite offers particular advantages for lightweight construction, for example in automobile technology, due to its light specific weight, its even foam structure which can be reproduced very well, its good shaping possibilities, and its convenient energy absorptivity. Especially in the case of sandwich constructions, the composite can be applied as core material, providing good stiffness and strength properties. The convenient energy absorptivity of closed foams additionally promises good application possibilities as crash absorbers.

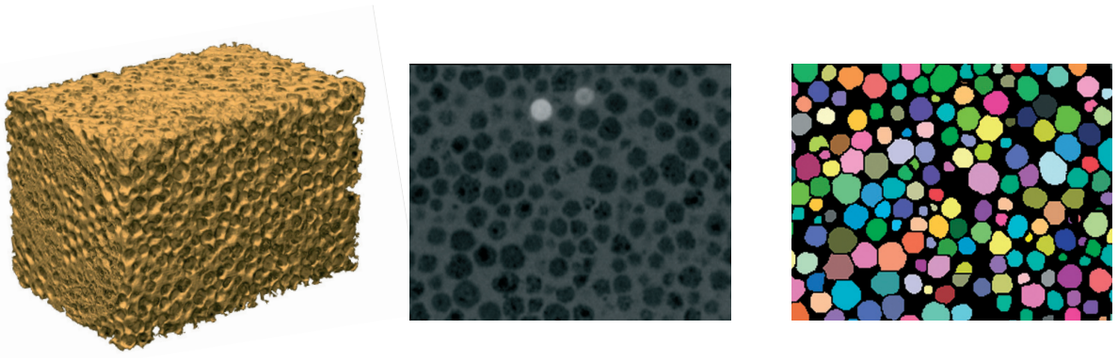
A further advantage is the relatively low material expenses due to the use of recycling products (e. g., bottle glass or filter dust from power plants) for the production of the mineral foam spheres.

Within this cooperation project, the ITWM analyzes volume images of the mineral foam spheres' microstructure and of the microstructure of the resulting composite. Our objective is to gain more exact information about the production process, to examine relations between microstructure and material properties, and, by doing so, to detect possibilities for the improvement of the composite.

The internal pore structure (sizes and shapes) and the state of the grain wall are primarily interesting for the analysis of the mineral foam spheres. The cell walls are not conserved completely; therefore, the pores must first be separated by image analysis. Afterwards, the volume and different shape factors can be determined for each individual pore. We can see that the pore size varies more strongly than expected. The frequently observed apertures in the cell walls were also surprising. Besides, position and size of the inclusions are interesting for the examination of the composite.



Mineral foam sphere of the type KeraPlus
Above: 3d visualization, cross-section
Center: cross-section through a reconstructed tomographic image
Below: identical cross-section with segmented and separated pores



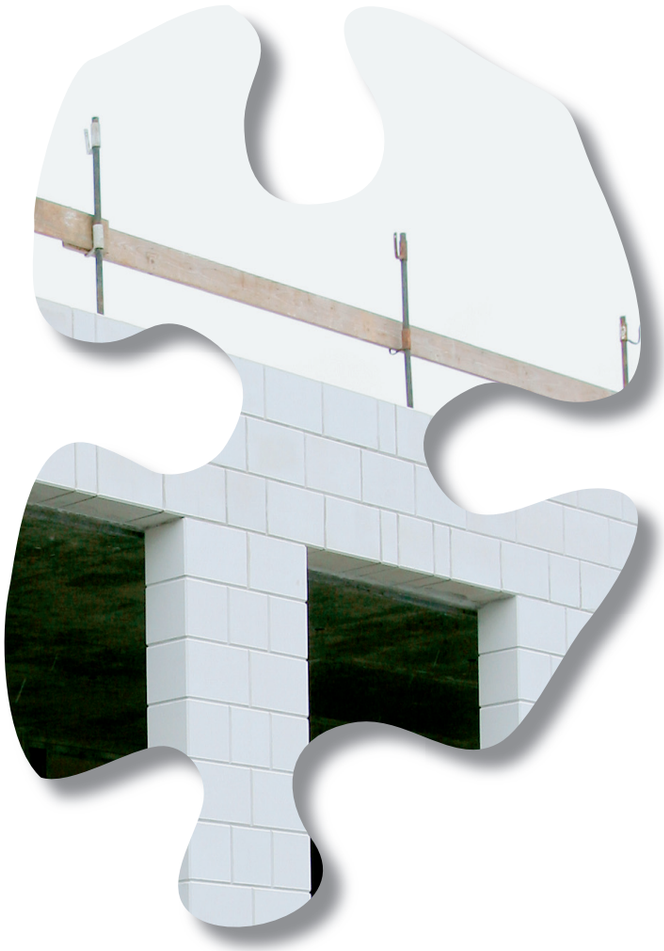
Composite KeraPlus mineral foam spheres in a polyamide matrix
Left: 3d visualization
Center: cross-sectional view of the reconstructed tomographic image
Right: identical view with segmented and separated mineral foam spheres

Signal Analysis for Railway Systems

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

The measurement data also provide information about the type of chassis and brakes, in order to correctly detect the different type-dependent temperature profiles, thus avoiding false alarms.

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



Contact:

Dipl.-Math. Kai Krüger
☎ +49 (0) 6 31/3 03-18 63
krueger@itwm.fraunhofer.de

Chassis monitoring railway sleeper

In the framework of a long-standing co-operation with the company GE Transportation Systems in Bad Dürkheim, the Fraunhofer ITWM maintains the software for the chassis monitoring sleeper (FÜS), which is running in more than 600 systems in Europe.

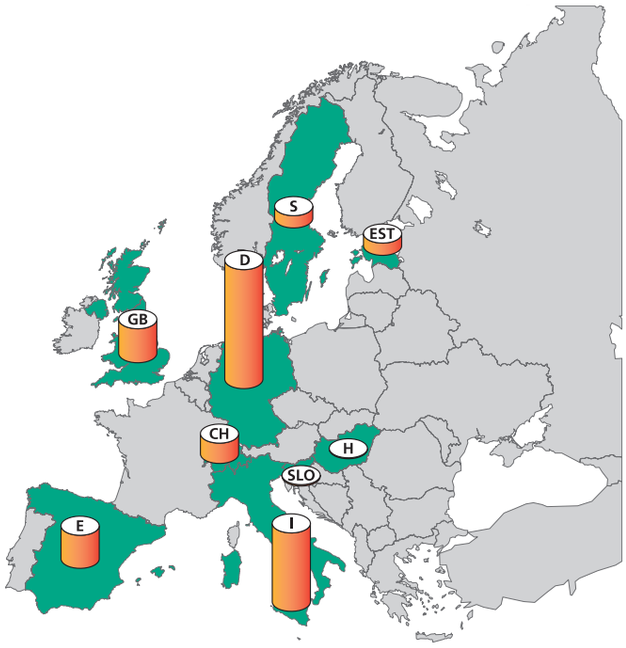
The FÜS is applied by an increasing number of different railway companies throughout Europe; this fact is now generating extension requirements and specific desires from these individual customers. On one hand, each of these requirements must be handled differently, whereas on the other hand, they must be diligently combined in order to converge to one basic software system whose properties are exclusively activated by parameters.

One example is the snow plough circuit, which is applied to those regions of Europe which have large amounts of snow, e. g., Sweden. In these areas, the rails are often covered by snow, which is why locomotives also operate as snow ploughs. Before crossing a FÜS sleeper, the engineer can deactivate the system by pushing a button from the cab for a specific time, so that all the openings of the measuring sleeper are closed and the snow cannot penetrate into it.

Another example is the extension of the so-called vehicle identification (FID), which has been further developed with respect to its parametrization flexibility. For example, all the different types of alarms which may occur during operation, as well as the distance limitation with respect to the next vehicle are considered. Also the temperature limits are parametrized by individual values instead of increasing the range of these limits.

For regions subject to large amounts of snow, e. g., the St.-Gotthard line in Switzerland, a new two-point control has been developed for the already existing winter heating system. This system reacts quickly and stably to strong variations of temperature. The system controls the activation of the heating between two temperature points. Additionally, the controller also avoids an overheating of the system.

FÜS measuring sleeper with control box



FÜS systems in Europe

Image and Sequence Analysis

Most of the currently available image analysis systems work very slowly and are restricted with respect to their application. A new high-performance system has now been developed, based on the funding by the Federal Ministry of Education and Research (BMBF) and in cooperation with partners from the field of contents-based image analysis and parallel online image processing, as well as with committed medium-sized enterprises.

The project is focused on subjects such as the camera-based monitoring of public locations, methods of a similarity-based search for images on the internet, as well as video sequence analysis.

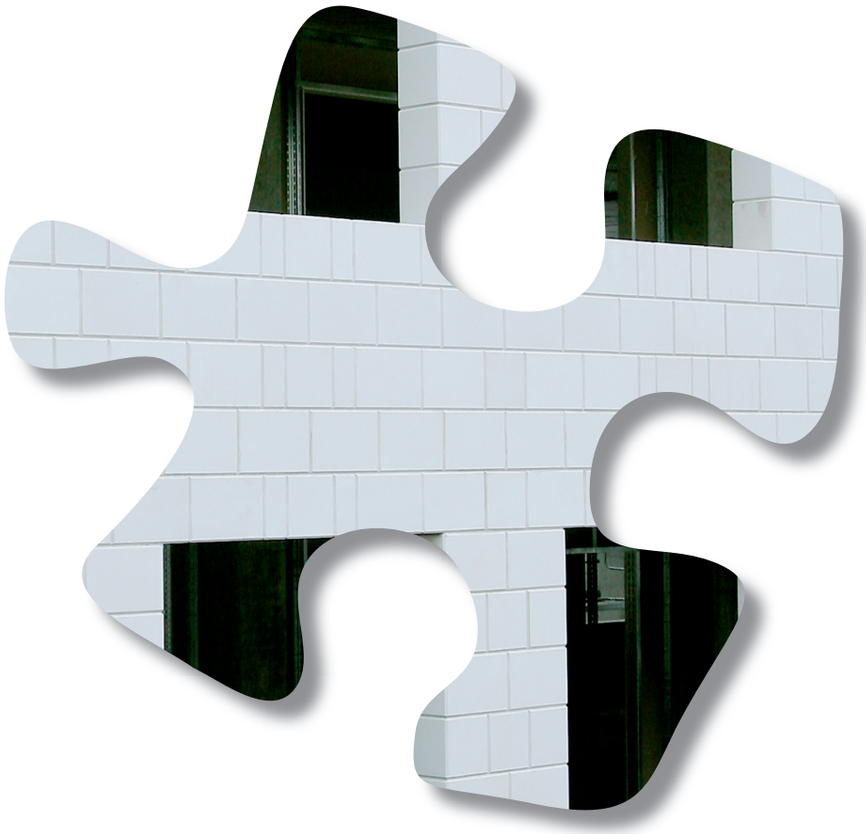
The current subject of security involves the task of detecting and identifying persons showing conspicuous behavior on a public location monitored by web cameras. The solution of this problem requires robust and event-controlled sequence analysis methods on distributed systems which are able to provide online results for the security personnel.

Currently available image search engines in most cases only allow for a search for images of similar labeling. This kind of search scarcely enables the user to find images of similar contents or optic aspects.

Within the project "I-Search", a contents-based image search system has been further developed and combined with the performance of a computer cluster. This method finally allows for a fast semantic image analysis within large image archives.

The combination of well-known methods from video analysis, for example, the detection of key images in image sequences, with a contents-based image search has allowed for a quality improvement of the sequence analysis in media archives.

In cooperation with partners from industry and research, methods of parallel data processing were combined with high-performance algorithms and connected to the current database and internet technologies.



Contact:

Dipl.-Inform. Markus Rauhut
☎ +49 (0) 6 31/3 03-18 73
rauhut@itwm.fraunhofer.de

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

The task of the Fraunhofer ITWM within the project "I-Search"" is the development of a component-based parallel software architecture apt for the operation of a failure proof system consisting of PC clusters and computing grids up to highly complex distributed systems of small high-performance computers on web cameras.

The past year's research work was focused on the integration of the algorithms implemented by our partners into the software architecture developed at the ITWM, as well as on the optimization of the interaction of all the algorithms within the I-Search cluster. Individual tasks were:

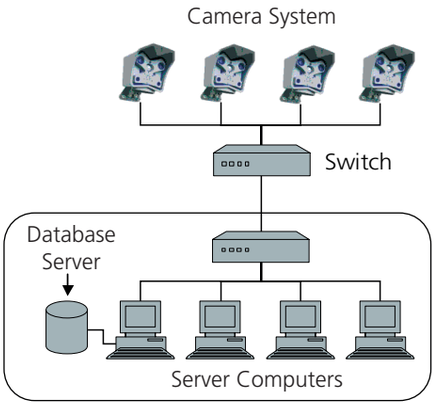
- identification of faces in camera images
- stereo image analysis with modified web cameras
- contents-based search for similar images
- search on image meta data, e. g., date of image acquisition

The core of the I-Search architecture is a distributed run-time platform for component-based applications. The platform realizes an actively replicated group of servers which represents a survival as well as a load interlocking system due to error tolerance and load distribution mechanisms. The architecture is independent from the operating system and uses CORBA technologies as well as TCP/IP for the communication between clusters. In order to reduce communication as well as management expenses, the logical network topology has been designed according to a hierarchic tree structure.

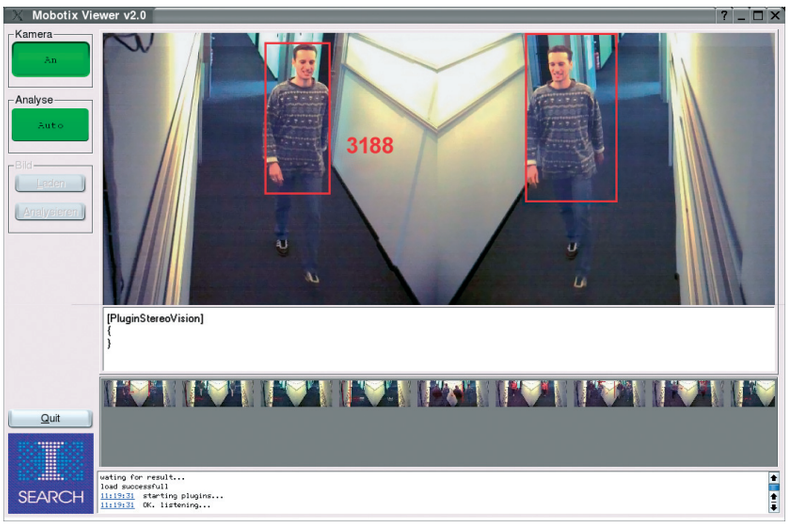
Individual nodes can fulfill different tasks within this infrastructure:

- The "GlobalNode" manages the entire network. It monitors the "SubNetNodes", distributing jobs among them.
- "SubNetNodes" are responsible for the management of a subnet.
- "BridgeNodes" serve as communication adapters with respect to external systems like data bases or cameras
- "WorkerNodes" process the incoming data, i. e. they carry out components.

The algorithms developed by the partners are data processing components for the run-time platform. The architecture controls and checks every data stream in order to realize a fast and failure proof system. User-system interaction takes place via the respective graphical user interfaces which have been developed for the different scenarios.



Infrastructure of the I-Search hardware



User interface for stereo image analysis

Bernd Pobel, Franz Schreiber, Andreas Jablonski, Siana Halim, Monika Muszkieta, Oliver Wirjadi, Mark Maasland, Kristina Kohrt, Kai Taeubner, Markus Rauhut, Falco Hirschenberger, Thomas Redenbach, Andreas Dinges, Stefanie Peters, Steffen Polanski, Michael Godehardt, Dr. Katja Schladitz, Dr. Ronald Rösch, Björn Wagner, Claudia Lautensack, Martin Braun

Adaptive Systems

The activities of the department ADAPTIVE SYSTEMS are mainly focused on the data- and knowledge-based modeling of complex technical and biological systems and processes. The resulting models allow for the simulation and classification of process behavior, the derivation of new knowledge about the respective process, or the prognosis about future process development. Besides, the identified models also represent the basis and main factor with respect to the development of efficient monitoring and control methods.

The main subjects of the department are the following:

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

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

Important developments of the year 2004 within the main subject "CAD for Analog Circuits" were the successful transfer of the know-how about symbolic system analysis and of the Analog-Insydes technology to problems which are not directly connected to the analog circuit approach, such as the analysis of gas pipeline networks or the simulation of electronic hardware accompanying its development. In the field of "Biosignal Processing and Diagnosis Support", the software CENA for nutrition consulting was introduced on the market, and EEG analysis was established as a new subject. In the framework of diverse project activities, the further main subjects concentrated on different aspects of the simulation, identification, and control of nonlinear dynamic component behavior.

In the year 2005, the software products exclusively developed by the department are to be further developed, and the department's competences to be expanded. A decisive contribution will be made here particularly by the large number of graduation and PhD projects.

Dr. Patrick Lang
☎ +49 (0) 6 31/2 05-28 33
lang@itwm.fraunhofer.de

CAD for Analog Circuits

This main subject deals with methods and tools for the modeling, analysis, and sizing of linear and nonlinear analog circuits by symbolic methods. One of these tools is the EDA tool Analog Insydes® (*www.analog-insydes.de*), which has been developed by the department. Our objective is the integration of symbolic methods into the industrial design flow, thus supporting the circuit designers in their daily work. There is a wide range of industrial application possibilities for symbolic methods, from classical circuit understanding to error analysis, and from circuit sizing and optimization to the automated behavioral modeling on the mixed signal or system level.

The mathematical foundations are mixed symbolic/numerical algorithms for linear and nonlinear differential algebraic systems of equations (DAE systems), which can also be applied for the modeling and analysis beyond the microelectronics domain. Examples are the automated modeling of regional and national gas pipeline networks for the optimization of the gas flow, as well as the analysis of complex biochemical reaction networks.

The possibility of an automated modeling of systems from different physical areas opens up new perspectives for the simulation of heterogeneous systems. System simulation is gaining particular importance for industrial hardware development. Although the behavior of the individual components can frequently be represented very well by simulation, currently the mathematical modeling of their interaction still remains a special challenge. A very promising approach for the solution of this problem is the application of symbolic model reduction methods, which are a central research subject within "CAD for Analog Circuits".

User seminars

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

Contact:

Dipl.-Ing. Thomas Halfmann
☎ +49 (0) 6 31/2 05-44 75
halfmann@itwm.fraunhofer.de

System simulation of an electro-chemical measuring device

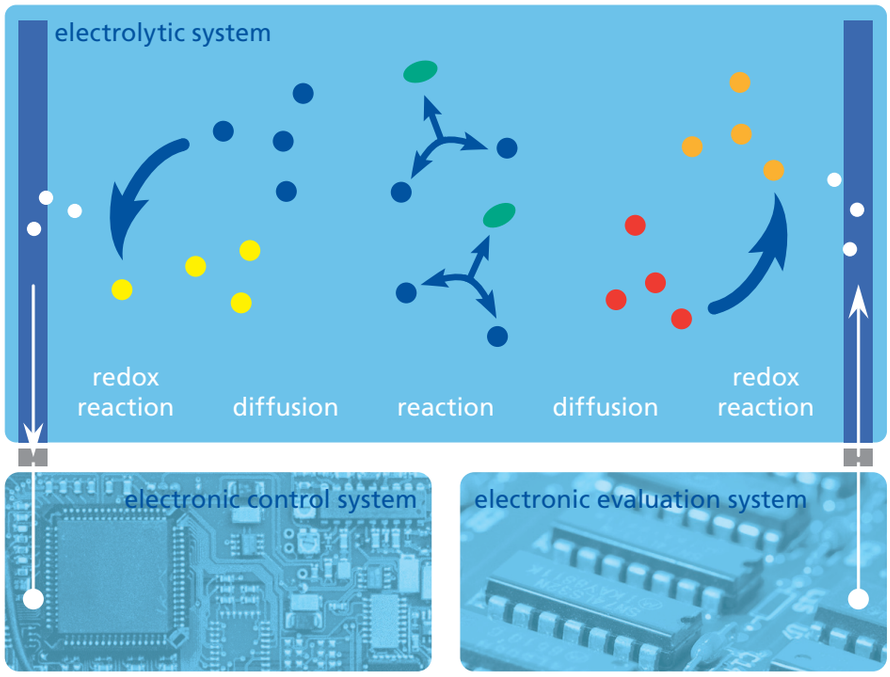
Measuring devices for the analysis of electrolytic processes combine components from different physical areas. On the one hand, we have to deal with an electro-chemical system, usually an electrolytic cell consisting of two or more electrodes and an electrolyte. On the other hand, the electronic system for the control of the electrode voltages and for the evaluation of the electrolytic current must also be accounted for.

The ITWM has developed an integrated simulation platform for such a type of analytic device. On the basis of netlist descriptions, the respective behavioral models for the electronic components were generated in the form of appropriate MATLAB® modules by Analog Insydes®. These were coupled with an individually developed model of the electrolytic cell via MATLAB®/Simulink®. The electrolytic cell is described by a system of partial differential equations which are able to account for diffusive, electrode kinetic (Butler-Volmer kinetics), and enzyme kinetic processes depending on geometric parameters such as shape and size of the reaction chamber and the electrodes. Apart from the heterogeneity of the physical system, the heterogeneity of the different user groups must also be accounted for. It is therefore very important that the simulation platform can be operated easily, which is why a graphical user interface has been developed.

Interval arithmetic

During the analysis of the influence of production-dependent component tolerances on the circuit behavior of analog circuits, the symbolic analysis frequently reaches its limits due to complex formulations. The results of numerical methods, however, do not always account for the entire range of possible parameter deviations.

By interval arithmetic, reliable boundaries can be determined for the circuit behavior, thus closing the gap between symbolic analysis and numerical simulation. In order to yield fast and exact solutions, dedicated methods have been developed which account for the typical structures of the systems of equations for analog circuits, at the same time making sophisticated use of them.



System components of an electrochemical measuring device

Monitoring and Control

This research area concentrates on the development and implementation of mathematical methods for system modeling and for observer and controller design. Main applications are technical systems, e. g., turbine generator shaft lines.

Modeling and simulation

A mathematical substitutional model is a fundamental component of the simulation, control, or monitoring of the behavior of a technical system. Depending on the available system information and the respective interesting system aspects, different modeling and identification methods are applied. If an exact physical model is unavailable, linear and nonlinear identification methods are used with respect to time and frequency. Amongst others we are concentrating on the approximation of complex nonlinear systems by so-called Local Model Networks (LMN), which consist of mostly linear overlapping subsystems.

Observer and controller design

Research in the field of observer and controller design focuses on the development and application of model-based methods. Robust control strategies, such as methods of H_∞-control theory, are primarily applied here. Stability and performance requirements can be fulfilled by this approach, also in the case of model uncertainties and system disturbances. If a given system behavior is to be repeated in cycles, as in the case of robot movements, we can learn from the information received through the previous cycle and subsequently improve the performance; this is called "Iterative Learning Control". An expansion of this method on the basis of LMN models has been developed by our research group.

The application of further control strategies, such as adaptive control, pre-compensation and control, gain scheduling, and model predictive control are complementing the competences of the research group.

Contact:

Dr. Andreas Wirsen
☎ +49 (0) 6 31/2 05-31 26
wirsen@itwm.fraunhofer.de

Systems for the monitoring and analysis of torsional behavior

In the last few years, the software packages TorStor, TorFat, and TorAn have been developed within this research area. In combination with a contactless torque sensor which is exclusively marketed by the Fraunhofer ITWM, they represent differently focused individual systems for the monitoring and analysis of torsional oscillations. The online monitoring systems are applied in the case of rotating shafts. Particularly in the case of a long-term monitoring of turbine generator shaft lines in power plants, they have proved to be very effective in practice. Further possible applications are wind power stations, marine diesel engines, or industrial production plants.

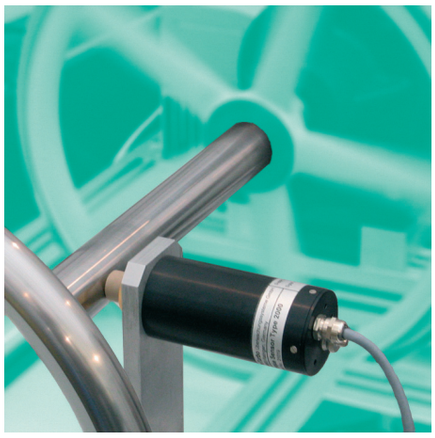
Intelligent Materials for Active Noise Reduction – InMAR

In the framework of the EU project InMAR and in cooperation with 41 well-known institutions from 13 European countries, the Fraunhofer ITWM is working on the development of new, intelligent material systems and their application within active systems for the reduction of noise emitted by technical products and facilities, especially in the fields of building technology, automobile traffic, and railway traffic.

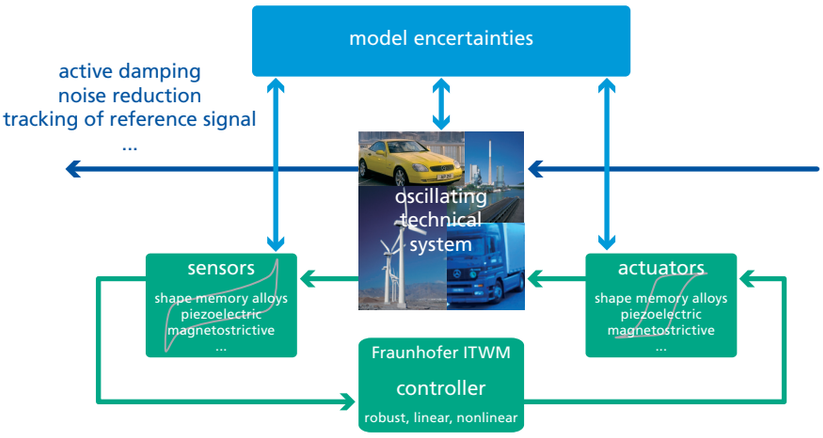
Intelligent material systems, such as piezoceramic actuators, can be deformed well defined by controlling the input energy. In such a way, the stiffness or damping properties of a system can directly be modified. Vice versa, they can also detect system modifications and thus be applied as sensors.

Depending on the strength of the respective voltage, piezoceramic actuators show, for example, a linear or nonlinear transfer behavior. We are analyzing and developing robust concepts of controllers which are able to account for the nonlinear effects, such as hysteresis and saturation, occurring with these actuators at high voltages.

One of our approaches is the use of the method of precompensation and control. The idea of this method is the compensation of the nonlinearities in the form of hysteresis by the previous application of an inverted hysteresis model; the control is executed by a linear robust controller. Alternatively, we are examining the application of a local controller network. According to this method, a robust linear controller is designed for each of the models on the basis of identified local models. Depending on the system state, the controller for the nonlinear real system consists of a linear combination of the individual controllers varying with respect to time.



Mobile sensor test rig



Typical configuration of the control loops considered in the framework of InMAR

Biosignal Processing and Diagnosis Support

The ongoing physical or chemical processes in each living organism produce signals which can be measured by appropriate devices. These signals are almost always time-dependent; sometimes they also depend on the location in space. Examples with respect to the human organism are the electrochemically generated fields of heart and brain, which can be measured as electrocardiogram (ECG) and electroencephalogram (EEG). Both fields are varying with respect to time; additionally, the results of the EEG depend on the position of the measuring electrode on the skull. Further examples for biosignals are the type and velocity of eye movement during sleep, or the time gradient of blood pressure in the circulatory system.

Biosignals carry information about the state of the generating system, a fact which supports medical diagnostics. However, frequently the signal evaluation is very difficult because the generating systems, for example the brain, are very complex and a complete functional model is usually far from being available. In this situation, mathematical support of the medical signal interpretation suggests itself. Data-based methods, such as time series analysis, neural networks, and decision trees are applied here in order to detect relations between occurring diseases and patterns in the measured data. After a statistical validation, such relations can be used for an automatic classification of a biosignal with respect to a specific occurring disease.

The automatic classification can also be done on the basis of knowledge-based methods. Already available medical expert knowledge is formalized mathematically and implemented into a so-called expert system. In this area, the project "Data-based Diagnosis Support in Regulation Thermography", which was supported by the BMBF, has been concluded at the beginning of the year 2004: extensive knowledge about the medical interpretation of so-called regulation thermograms with respect to the occurrence of breast cancer was formalized during the project by fuzzy logic. One of the project's results is a software prototype for the automatic interpretation of thermograms, to be applied within a successive project for the scientific evaluation of regulation thermography, which is currently considered only as complementary medicine.

Contact:

Dr. Hagen Knaf
☎ +49 (0) 6 31/2 05-44 74
knaf@itwm.fraunhofer.de

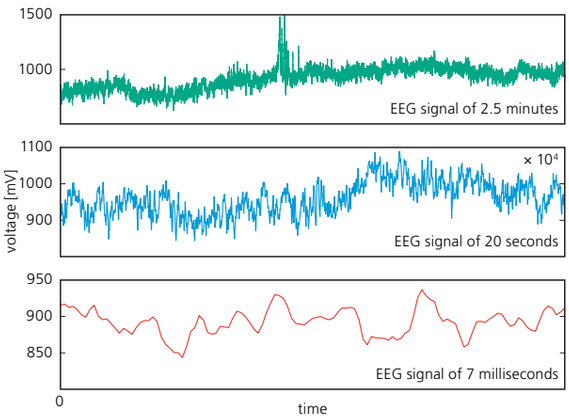
Anharmonic Fourier analysis of the electroencephalogram

The human brain consists of approximately 100 billion interconnected neurons which serve for saving and processing information. The electrochemical processes involved in the information transfer between neurons generate – as a by-product – overlapping electrical fields which can be measured at the skull surface as a time-dependent field. Similar to the electrocardiogram, this field can be measured and recorded by electrodes. Usually, several electrodes are distributed across the skull in order to allow for a spatially differentiated measurement of brain activity. The entire data of such a record is called electroencephalogram (EEG) and belongs to the most complex biosignals applied in medicine.

The so-called brain waves measured by the EEG are classified according to their frequency. Type and strength of the brain waves provide information about the processes taking place within the brain, thus serving as a convenient tool for studying the latter. Besides, the EEG can also be used for diagnostic purposes or as an indicator for external influences to which the body is subject.

The company Rayonex Schwingungstechnik GmbH intends to scientifically validate the efficiency of the bioresonance method, which is not yet accepted in orthodox medicine, by an improved analysis of EEGs. In the year 2004, the company therefore financed the implementation of an algorithm for EEG analysis by the anharmonic Fourier analysis.

In the case of anharmonic Fourier analysis, the already known harmonic analysis is extended by the representation of a signal as a number of possibly damped overlapping oscillations; additionally, arbitrary real oscillation frequencies are allowed instead of integer ones. Since activating and deactivating processes are occurring within the brain, this method appears especially appropriate for EEG analysis. The software prototype for the anharmonic Fourier analysis of EEGs, which has been delivered to the company Rayonex GmbH, has been programmed in MATLAB® and is currently tested at the Hospital for Neurology II of the Otto-von-Guericke University of Magdeburg.



Electroencephalogram on different time scales

CENA – step by step towards healthy nutrition

A healthy and balanced nutrition is very important for the health and personal capabilities of each individual. The software CENA offers decision support with respect to the evaluation and possible modification of the user's usual diet. On the basis of personal data, such as age, size, weight, sex, etc., and a nutrition diary covering at least three days, the user receives an analysis with respect to his/her personal nutrient supply situation. The optimization function of CENA provides proposals for an improvement of the nutrition behavior, simultaneously accounting for personal habits and preferences. The objective is to support a step-by-step learning process towards a healthy nutrition. Additional information is available to the user by a comparison of current and improved nutrient supply in the form of understandable graphic representations and tables, as well as by individually tailored textual information.

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

The version "CENA sana" for the private user can be ordered directly at the ITWM. CENA is structured according to a modular concept and can be adapted to special requirements, e. g., for big customers. The version "CENA aktiv" especially accounts for recreational sports activities.

Prognosis of Material and Product Properties

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

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

Activities of the main subject "Prognosis of Material and Product Properties" can basically be divided into static and dynamic system identification. Within the first area, independent experiment results of a system are modeled. Examples are the prediction and sensitivity analysis of the crash performance of a composite material, or the classification of surface defects of a cast component on the basis of simulated local casting parameters.

The dynamic system identification analyzes and models time-dependent experiment results of a system. Multivariate dynamic systems were identified by delayed feed forward and recurrent neural networks and long-term predictions were successfully carried out for different time-dependent industrial production processes and dynamic mechanical systems.

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

Contact:

Dr. Alex Sarishvili
☎ +49 (0) 6 31/2 05-31 26
sarishvili@itwm.fraunhofer.de

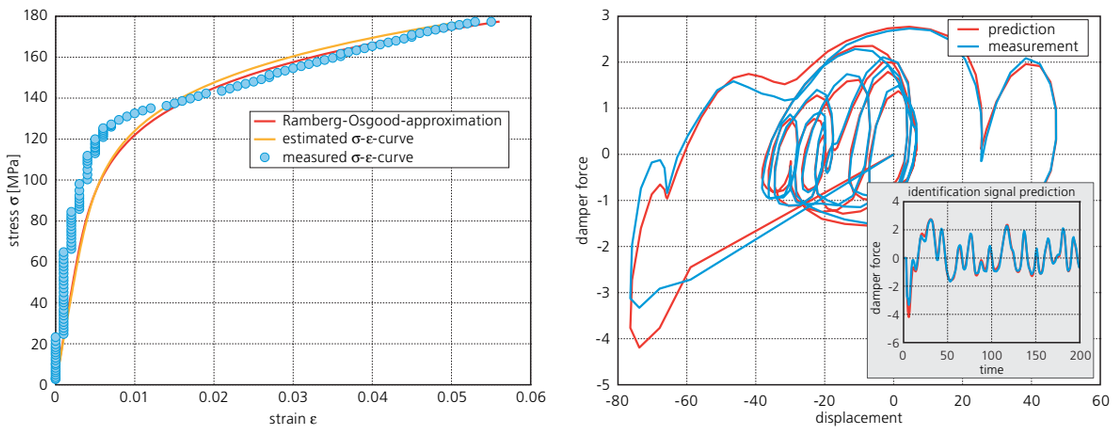
Nonlinear dynamic component models for vehicle simulation

Within the project "Nonlinear Dynamic Component Models for Vehicle Simulation", which is financed by the "Stiftung Rheinland-Pfalz für Innovation", new nonphysical (data-based) and semi-physical models for the simulation of processes influenced by hysteresis are developed in cooperation with the industrial partner LMS Deutschland. During the project, classical and generalized Preisach models are examined with respect to their practical application possibilities, and new parameter approximation methods are applied, if necessary. Besides, recurrent and dynamic feed-forward networks are examined more closely with respect to their ability to simulate certain types of hysteresis. In particular, research is concentrating on integration possibilities of the knowledge about physical processes into a network structure, on new possibilities of hysteretic memory representation within the inner neuron layers, and on the adaptation of the developed models to the real (e. g., data with respect to the spring-assisted shock absorber system of a car) and the simulated data. A more general and medium-range objective of the project is the considerable improvement of the quality and reliability of the multibody simulation of complex mechanical systems in the case of strong external excitation.

A simultaneously developed physical model of a mechanical system with an integrated Mooney-Rivlin material model helps to gain insight into the nature of nonlinear processes and to integrate these into the data-based models; additionally, arbitrary types of hysteresis can be generated for the validation of the developed models.

In the framework of the Fraunhofer-internal "Economy-based Strategic Alliance (WISA) Magnesium", the tensile properties of vehicle dashboard supports, which are produced from magnesium by a special casting technology, were to be determined. After an approximation of the function between input (fracture surface analysis) and output (Ramberg-Osgood curve parameters) variables by a neural network especially adapted to the problem, the so-called sensitivity curves were estimated and visualized. These curves describe the nonlinear variation of the dependence between a certain input variable and the task variable with respect to the variations of the input variable's value. These plots provide information about the problem which input variables must be changed by which order of magnitude in order to yield a high probability of the task variable to behave in the desired way under the considered loading scenarios.

The resulting performance of the neural network – measured by the "mean squared error" of the cross validation and by the interpretive capacity of the sensitivity curves – has supported the strength of our approach, particularly if the scarcity of available data is considered.



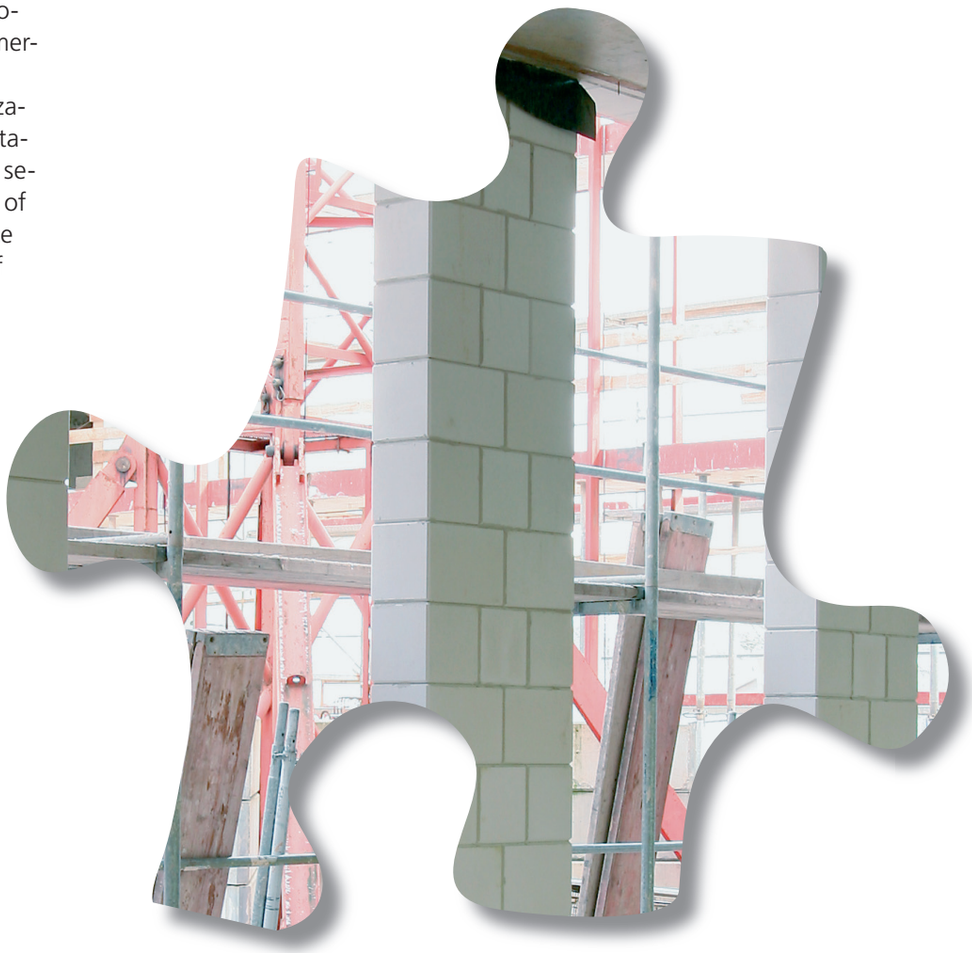
Left: prognosis of the behavior of the magnesium component produced by pressure casting depending on material inhomogeneities due to the casting process
Right: prognosis of the behavior of a spring-assisted vehicle shock absorber system subject to hysteresis

Multiscale Structure Mechanics

This research area primarily deals with the development and application of numerical algorithms for the computation of body mechanical problems concerning materials which show a complicated material structure with different size scales, as well as complicated time-dependent material laws. The research group has special knowledge and competences with respect to asymptotic homogenization methods, the handling of contact problems with micro-rough surfaces, and the consideration of time-dependent processes of homogeneous or composite materials whose (macro-) strength and durability are examined with respect to fatigue, creep, impact load, and wear.

Homogenization becomes necessary for composite materials and porous media as soon as two or more different size scales occur in their micro and macro-structure; these prevent a direct numerical computation or render it far too complicated. Asymptotic homogenization algorithms allow for the computation of macro-stresses and an entire series of average (effective) properties of composite or porous materials on the basis of already known properties of their components and their micro-geometry. The mean properties are stiffness, relaxation parameters, free shrinkage, free swelling, free temperature distortion, strength, durability, and wear.

Examples of technically interesting processes which can be computed by the application of the homogenization method are corrosion, degradation, desiccation, fatigue, and wear of filled resin, concrete, and wood. Concrete applications in the framework of research projects of the department were, for example, the computation of the effective viscoelastic and shrinkage properties of particle-reinforced dental fillings and resins, as well as the computation of contact problems in the case of hip prostheses.



Contact:

Dr. Julia Orlik
☎ +49 (0) 6 31/2 05-27 42
orlik@itwm.fraunhofer.de

Modeling of filled thermosetting resins

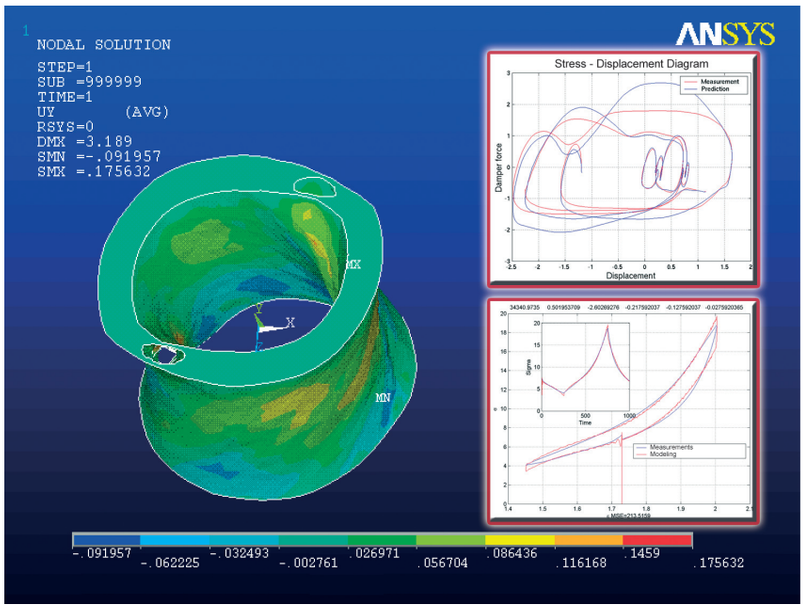
During the first phase of the project "Development of a Basis for Computation and Material Modeling of Filled Thermosetting Resins", which was funded by the German Research Foundation (DFG), homogenization algorithms have been developed for integral viscoelasticity with weakly singular kernels; during the current phase continuing the project, these algorithms are applied numerically. We are using the following approach: first, the spatial dependence is eliminated within the entire system of integro-differential equations by the Finite Element Method (FEM). The infinite dimensional system of integral equations with respect to time is thus reduced to a finite dimensional system, which is subsequently solved by a collocation method modified for singular kernels.

Those parts of the kernel which are nonsingular with respect to the time variable, as well as the out-of-integral coefficients, are discretized with respect to time at the collocation points in order to enable the application of the FEM. Both are used as elastic coefficients for each time step in a purely elastic spatial FE computation by ANSYS©. Each computation yields the global stiffness matrices, which are inserted into the system of equilibrium equations instead of partial spatial derivatives. The FE computation at each collocation point requires a relatively large numerical effort; therefore, a kernel approximation has additionally been carried out by a piecewise polynomial spatial interpolation, resulting in a complete decoupling of time and space dependence. The respective error estimations were done in the framework of an accompanying Master's thesis. The entire algorithm has been integrated into an already developed homogenization routine for viscoelastic composites.

Nonlinear dynamic component models for vehicle simulation

Within a further project, the hysteresis behavior of rubber type bearings subject to a multidimensional load is examined by one-axial stress-strain time series made available by our industrial partner LMS Deutschland. On the one hand, the mechanical models to be identified ought to provide a good representation of the nonlinear elasticity, the plastic effects of load and relief, and of the material memory depending on the load history; on the other hand, however, they should also comprise linear parts, so that the superposition principle can at least partly be applied for load cases. Hence, the quasi-static material behavior was modeled by the nonlinear Mooney-Rivlin law, the load-and-relief effects were linearized, and the memory was described by a linear integral representation via a relaxation kernel. The memory is additionally divided into a global and a local memory, the global memory exclusively accounting for the stress amplitudes of the n last cycles and the local memory for the last n stress values of the current cycle. The models have been validated successfully on the basis of experimental data.

The further steps within the project provide that the mechanical models first are to be applied with respect to the generation of data by commercial FE packages for 3d load cases; finally, they are to be used in combination with the simultaneously developed data-based methods within a gray box model.



Left: rubber cylinder for 3d data generation
Right: approximation of 1d measurement data by the models mentioned above

Dr. Patrick Lang, Dr. Andreas Wirsen, Dr. Julia Orlik, Dr. Alex Sarishvili, Thomas Halfmann, Dr. Hagen Knaf, Jan Hauth, Harriet Bach, Eva Barrena, Dr. Jochen Broz, Alexander Dreyer

Optimization

The department deals with the research and development of models and methods of mathematical optimization for industry and the service sector. The development of innovative software solutions in cooperation with our customers is especially important here. Applied methods range from specialized graph theory and approaches of combinatorial optimization to large scale optimization; they are also combined with commercial solvers (Cplex, Xpress). Further methods of online optimization, multicriteria optimization, and nonlinear and global optimization, as well as logistic simulation and methods of reverse engineering are developed and applied.

The year 2004 was a very positive one for the department OPTIMIZATION. In spite of the negative economic developments and decreasing public funding, we have succeeded in acquiring new customer potentials and maintaining already existing contacts to our customers.

The department is divided into the following main subjects:

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

In addition to a series of industrial cooperation projects within the main subject "Internal Logistics", especially with the companies SAP and psb, contacts to regional SME were intensified by a research lab for production which is financed by the *Land* Rhineland-Palatinate. In the framework of the main subject "Global Logistics and Traffic Planning", cooperation with the company proALPHA Software AG in Weilerbach was continued successfully and subsystems of the product Opti-Trans® for the optimization of patient transports in hospitals were completed together with our partners Sieda GmbH and Comexar Engineering AG. The main subject "Continuous Optimization" has succeeded in acquiring funding from the American National Institute of Health for a four-year project in the field of radiotherapy in cooperation with the Massachusetts General Hospital, a teaching hospital of the renowned Harvard Medical School. By order of the company Siemens AG, Medical Solutions, Department of Oncology Care Systems, we are developing a new planning component for clinical radiotherapy. Together with the department TRANSPORT PROCESSES and within a joint market-oriented research project MAVO SR-PRO in cooperation with the Fraunhofer Institutes SCAI and IGD, components of a reverse engineering process are developed and implemented. Within the main subject "Knowledge Management and e-commerce", a larger project with respect to process management was continued in cooperation with the company Tehalit GmbH in Heltersberg.

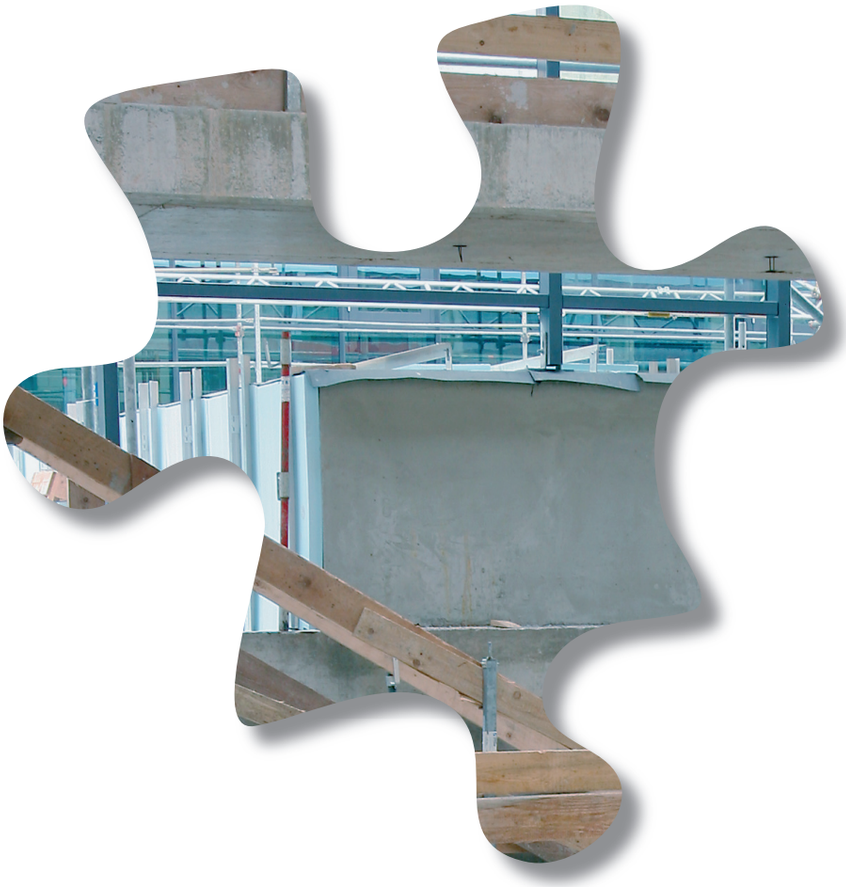
PD Dr. Karl-Heinz Küfer
☎ +49 (0) 6 31/3 03-18 51
kuefer@itwm.fraunhofer.de

Internal Logistics

It often happens that an apparently well-planned industrial plant consisting of the most modern components remains far from its desired performance. The very expensive and technical high-performance individual subsystems are not coordinated sufficiently. Frequently, the reason is not that a company has made savings in the wrong place during the composition phase; rather, the "system view" was insufficient. At an early stage of planning and development, the overall consideration of the entire system and of the interaction of its components due to local and global control is often missing. It turns out that in these cases the mathematical and information technological examinations and solution methods are neglected during the system development.

The activities of the team "Internal Logistics" focus on such a systematic and concise support during the system development as well as during actual operation using integrative application of mathematical optimization, discrete and continuous simulation, artificial intelligence, etc. Typical types of systems within the projects are production systems, mail order companies, automated warehouses, but also rostering and personnel management, security systems, organizational processes. Our services comprise more than the mere simulation and optimization of operational processes: we develop, e. g., the respective control strategies, subsequently testing or refining them on the basis of simulation, we carry out a sensitivity analysis, we examine the behavior of the system at its limit performance, and we develop deadlock prevention measures.

Among the most important industrial partners of the main subject in 2004 are the companies psb GmbH Materialfluss+Logistik (Pirmasens), FSM! GmbH (Kaiserslautern), Horst Zimmermann GmbH (Kaiserslautern), and SAP AG (Walldorf). Scientific cooperation also takes place together with several other Fraunhofer Institutes, for example IML, UMSICHT, and SCAI.



Contact:

Dr.-Ing. habil. Alexander Lavrov
☎ +49 (0) 6 31/3 03-18 84
lavrov@itwm.fraunhofer.de

Integrative solution methods in the fields of material flow and logistics

The processes taking place at a modern, highly automated enterprise are characterized by complicated relations between different actions and methods, a highly dynamic nature of the control decisions to be taken, etc. The scientists working in the team "Internal Logistics" often have to deal with the first signs or the consequences of a methodically restricted and one-sided system planning or organization. Several typical examples from the respective project situations of the past year are mentioned below.

Item distribution in an automated high bay warehouse

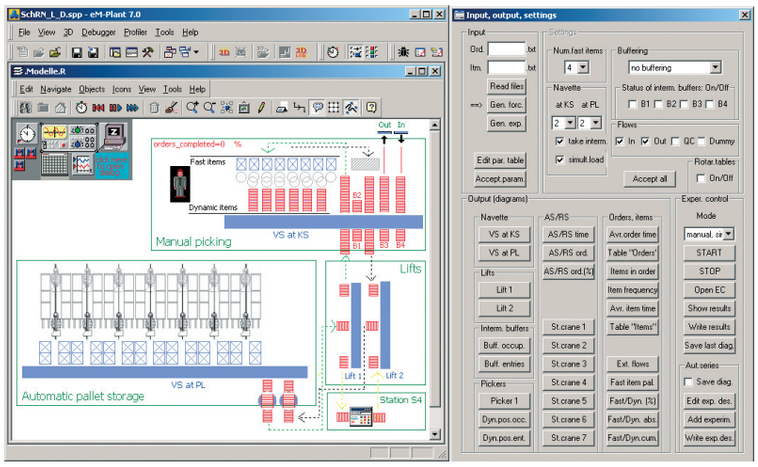
The warehouse was planned with a considerable reserve capacity, the theoretical overall throughput of the stacker cranes being essentially higher than the maximum throughput of other components. Nevertheless, the desired performance could not be reached. It turned out that the resulting short-term queues in front of individual stacker cranes decreased the overall performance due to an inefficient item assignment to the aisles. The proposed analytically based article assignment strategy was subsequently validated and refined using simulation. The decreasing performance was remedied completely.

Control strategies for stacker cranes

Deadlock situations were registered again and again in an automated order-picking system structured in a relatively simple way with respect to pallet flows. The analysis showed that the applied control strategy did not account for the discharge possibilities on the external buffer, which resulted in long waiting times or even deadlock situations in the case of high load situations. A respective adaptation of the strategy has guaranteed local deadlock prevention.

Control strategies for sliding carriages

In one of the projects, the sliding carriage represented a bottleneck. A simple sequential handling of the transport orders was identified as the reason. We proposed a control strategy based on online optimization which allowed for a simultaneous load take-up and discharge and also accounted for the target direction with respect to the determination of the load take-up devices to be used. This strategy has increased the throughput by 12 per cent, which resulted in an increase of overall performance by 24 per cent because the simulation also justified the decision to do without a time-consuming intermediate buffering, which was planned originally.



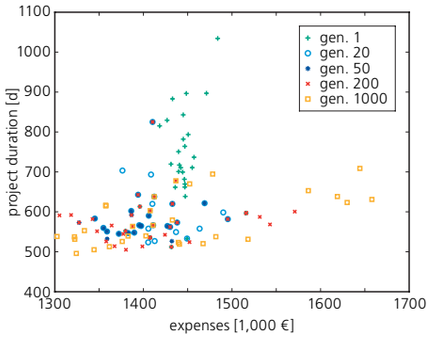
Simulation model of an order-picking system

Research lab “Production Planning for Regional SME”

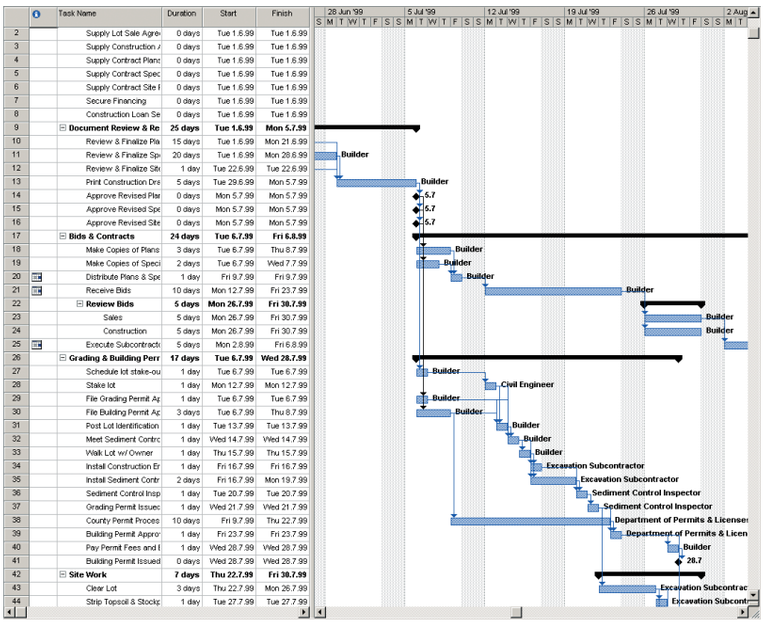
In the framework of the research lab, problems with respect to the planning of project control were examined, e. g. complex production processes or construction projects. In cooperation with several SME partners, especially with the FSM! GmbH and Horst Zimmermann GmbH, we evaluated requirements for a planning software to be developed. Results of a market analysis showed in particular that the market for planning software with respect to construction projects is dominated by a large number of business solutions for the construction industry, which leave different aspects to be desired with respect to the scheduling of working processes. In particular, a real optimization component is usually missing; instead, the planning follows simple disposition rules.

From a practical point of view, a planning tool ought to support, e. g., the application of standard work packages, and account for sequence restrictions, resource requirements, set-up times, and (un-)interruptible activities. Above all, the integration into an already existing software environment (especially the business administration software of the respective branch) is also very important. Besides, practical application requires the support of project monitoring and the availability of a simple and practically real-time rescheduling of activities. We also consider a mobile use of the system, for example the access to project plans on building sites and the feedback to the planning software about the working progress and, if necessary, about problems occurring at the construction site.

The optimization component of the scheduling ought to support different objectives, for example the minimization of expenses, the minimization of the project duration, and the minimization of delays. Within the project, a prototype is developed which is based on a multicriteria optimization using evolutionary algorithms. First results of the application of these planning methods show a considerable potential of saving expenses, time, etc. in comparison with the previously applied disposition rules.



Optimized solutions of an evolutionary algorithm with respect to project duration and expenses



Project plan represented by *Microsoft Project*

Global Logistics and Traffic

This area deals with the development of discrete optimization models and algorithms to support strategic, tactical and operational planning problems arising in logistics. Strategic network design focuses on the optimization of long-term investment decisions, such as the construction of new production plants and distribution centers. On the tactical planning level, based on the network configuration, rough supply, production, and distribution plans are developed for the various facilities of the network. These plans form the basis of short-term planning which deals with managing daily operations. This includes, for example, the determination of the sequence in which orders should be manufactured, or the routing of the produced goods for a timely delivery to the end customers. Planning problems are supported throughout different branches – from producing companies to health care – by especially tailored optimization methods.

The projects in the field of "Traffic" refer to public transport planning. Building new railway stations deals with the expansion of the station network along existing tracks at the lowest possible cost, a task that railway companies undertake at the strategic planning level. A large number of different scenarios are tested on the computer to find an optimal solution taking into account the impact on demand and economic efficiency. On the tactical planning level, the management of secure connections supports public transport organizations in the coordination of the schedules of the associated transport companies. The network-wide interdependencies of the connections are difficult to capture by the dispatcher, thus offering possibilities for the application of mathematical optimization methods. The speedup of local public transport in cities comprises measures for a preferential handling of public transport vehicles at traffic lights. On the operational planning level, the traffic light control system should handle deviations caused by public transport speedup with minimal disturbance in the traffic flow. Analysis tools have been developed to compress the flood of protocol data in the form of usable information, thus allowing for the optimization of the system.

Contact:

Dr. Teresa Melo
☎ +49 (0) 6 31/3 03-18 81
melo@itwm.fraunhofer.de

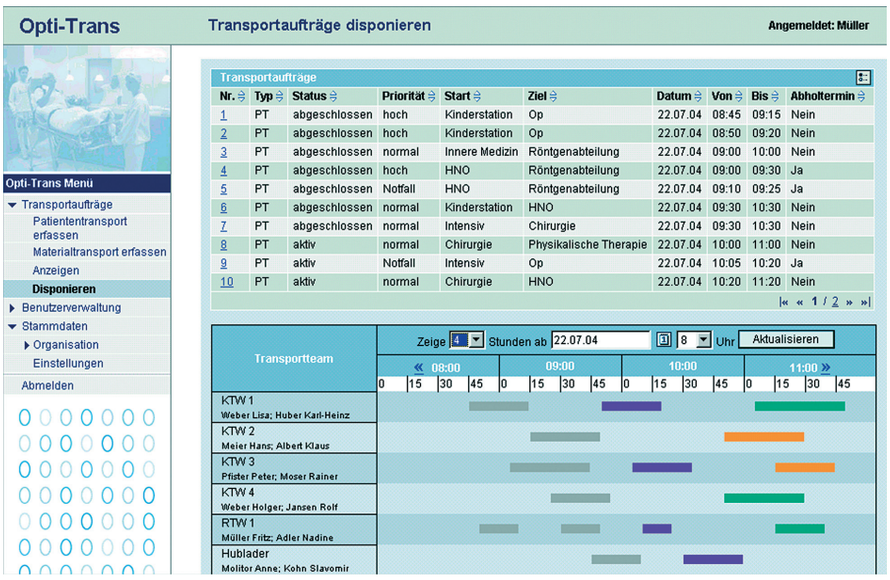
Optimized transport planning in hospitals

Transportation on demand is concerned with the transportation of persons or goods between specific origins and destinations at the request of users. One example stems from the field of health care, e. g. when patients are transported between nursing wards and service units (e. g. treatment rooms) on a hospital campus by ambulances or personnel providing services on foot by pushing beds or wheelchairs.

Usually, a nursing ward or a treatment unit books a transport request to the dispatcher, specifying all data about the request (priority, origin and destination, desired time of departure or arrival, patient mobility, etc.). The transports are handled by personnel of the transport department who either provide services on foot or drive ambulances. On the basis of booked transports, the dispatcher must decide about the clustering of different requests, the routing and the scheduling. Clustering refers to creating groups of requests to be served by the same transport team due to their spatial and temporal proximity. For each group of requests, routing consists of deciding the sequence in which the associated pickup and delivery locations should be visited by the assigned team. Finally, scheduling corresponds to specifying the exact time at which each location in a route should be visited. All these decisions are obviously strongly intertwined and a proper management of the systems calls for their simultaneous optimization. However, only a small percentage of requests is already known on the previous day (approximately 20–30 per cent), thus bestowing a temporary nature to these decisions at the beginning of a working day. Short-notice and on-the-day bookings are placed as a result of emergencies and new admissions. Hence, the problem has a strong online component requiring continuous modification in real-time of previously planned routes.

The objective of this dial-a-ride problem is to construct routes in such a way that transport costs are minimized and at the same time service quality is maximized (e. g. by short waiting times for patients). To solve this problem, feasible routes are first determined by a constructive heuristic. Subsequently, a heuristic based on tabu search is applied to find a better solution by changing the sequence in which requests are served in a route and by swapping requests between two routes. Studies in several hospitals have shown that the application of this method shortens the waiting times for the patients by 15 to 20 per cent. The method is part of the optimization component of Opti-Trans®, a software tool for real-time planning of transports which has been developed in cooperation with the companies SIEDA GmbH (Kaiserslautern) and COMEXAR Engineering AG (Switzerland).

Further information is available at *www.opti-trans.com*.



Assignment of transport requests to transport teams with Opti-Trans®. The color of each bar in the time diagram refers to the status of the corresponding request: gray – completed, orange – assigned, green – dispatched, purple – being executed.

Continuous Optimization

If a complex structure is to be developed – for example, the design of a product, a production process, or the planning of a therapy method –, a decision maker has to select a setting which is acceptable for him/her, or, in the ideal case, an objectively optimal setting, from a large number of configuration possibilities. Mathematically speaking, a complex structure is determined by firm, unchangeable conditions and by selectable parameters which can be influenced by the decision maker.

By a systematic iterative and interactive manipulation of the parameters, effects on the structure to be developed can be examined in the framework of an empirical amelioration process (forward engineering). This approach meets its natural limits if the number of selectable parameters is large and the quality evaluation requires considerable effort or is confusing. It is very helpful in this case to determine simple evaluation criteria (measures with respect to quality or costs) for a supporting simplified evaluation of the structure, and to allow for an automatic determination of the parameters by an optimization process. Based on such quality measures meaningful for the decision maker, a reverse engineering process determines optimal parameter configurations. Generally, there are several at least partly conflicting evaluation criteria; the classical case is the conflict between cost and quality. Hence, the resulting optimization problem of reverse engineering typically is a multi-criteria, high-dimensionally restricted optimization problem whose solution represents a set of so-called Pareto solutions. Pareto solutions are characterized by the fact that all the relevant evaluation criteria cannot be improved simultaneously without at least worsening one of them.

In order to give the decision maker access to the wide range of solutions made available by the Pareto concept, an interactive navigation tool adapted to the respective problem is required. This tool ought to offer suggestive help to the decision maker with respect to the search for interesting solution alternatives. The main problem concerning the design of reverse engineering solutions is the handling of the high-dimensional practical problems. Mathematical challenges are the close coupling of simulation, representation, and optimization algorithms on hierarchical adaptive data structures, the approximation of the Pareto solutions by a system of representatives as small as possible, and the real-time online approximation of the Pareto continuum on the basis of optimal selection routines.

Contact:

PD Dr. Karl-Heinz Küfer
☎ +49 (0) 6 31/3 03-18 51
kuefer@itwm.fraunhofer.de

Radiotherapy planning

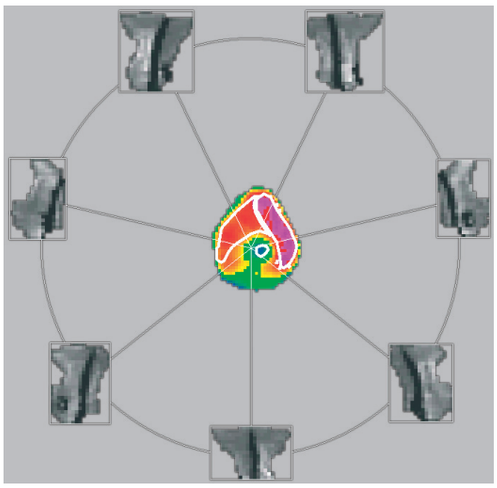
In recent years the main subject ‚Continuous Optimization' acquired expert knowledge in handling large scale reverse engineering problems through projects supported by public funding. This knowledge has been successfully transferred to industrial projects.

An exemplary modelling and treatment of reverse engineering problems is being developed in a series of projects in the field of radiotherapy planning. In 2004, a public project funded by the Dr. Mildred Scheel Foundation for Cancer Research – German Cancer Aid was concluded and a four-year project in cooperation with the Massachusetts General Hospital in Boston (USA) and funded by the American National Institute of Health was initiated. Furthermore, a large industrial cooperation project with Siemens Medical Solutions, department of Oncology Care Systems was started with the goal of developing a novel radiotherapy planning component for the Siemens radiotherapy planning product line.

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

Here, the structure to be optimized is the dose distribution in the patient's body. The required therapeutical doses for the tumor tissue and tolerance doses for the healthy tissue are based on statistical sources and medical experience. The optimization parameters are the irradiation geometry and the fluence distributions.

The huge dimensions of the radiotherapy planning problems pose a challenge for the design of an algorithmic solution strategy. The discretization of the 3d volume structure into several 100,000 volume elements, the several thousand parameters to be optimized, and the usually five to ten quality indicators constitute a large scale problem that is solved by a specifically developed solver from the Fraunhofer ITWM.



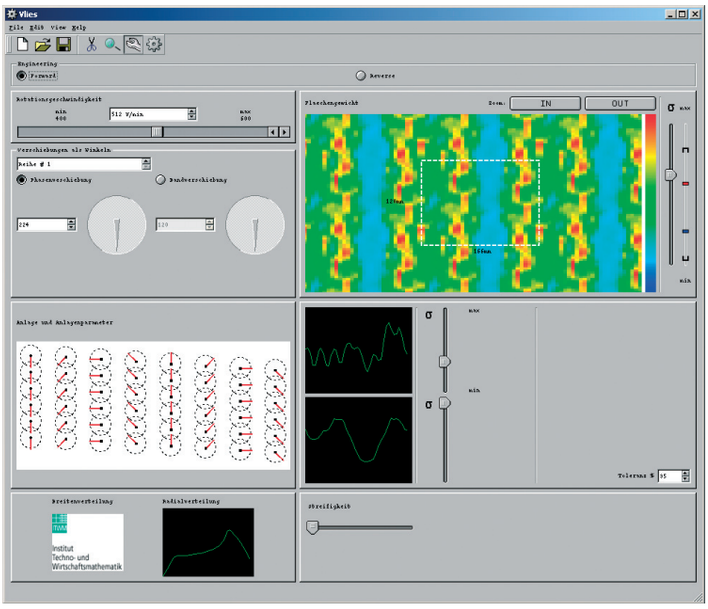
Irradiation geometry and fluence distributions for a head-neck tumor

Gemstone production

The search for utilizable volumes which are as large as possible in the case of colored raw gemstones is a classical design centering problem and can be formulated as a single-criterion, semi-infinite, high-dimensional optimization problem. Within a series of feasibility studies by order of the company ParTu Lapidaries in Idar-Oberstein (Kirschweiler), computations were carried out on the basis of test data records. They were supposed to embed a round form of brilliant optimally into a raw gemstone with respect to the quality indicator "volume" and to examine whether the current manufacturing process during the production of colored gemstones could be substituted by an automatic industrial production process. An especially interesting problem of the year 2004 was the handling and evaluation of the polishing process; the amount of material removed ranges on a sub-micrometer scale.

MAVO SR-PRO

In the framework of a joint market-oriented research project MAVO SR-PRO with the topic of simulated reality, supported by the Fraunhofer-Gesellschaft and in close cooperation of the Fraunhofer Institutes ITWM, SCAI, and IGD, the design of production processes and products by simulation, reverse engineering, and virtual reality has been defined as a central task of the future. Basic concepts of reverse engineering are further developed and tested by demonstrators for two applications: the production process of nonwovens, lead-managed by the department TRANSPORT PROCESSES, and crash analysis, lead-managed by the SCAI. The tasks of the department OPTIMIZATION are the development of multi-criteria optimization concepts for the production of nonwovens, based on the simulation components of the department TRANSPORT PROCESSES, and the definition of optimization modules for generic multi-criteria reverse engineering which are not application-specific.



User interface of a software tool for forward and reverse engineering of the rotatory productions of nonwovens, developed by the departments TRANSPORT PROCESSES and OPTIMIZATION

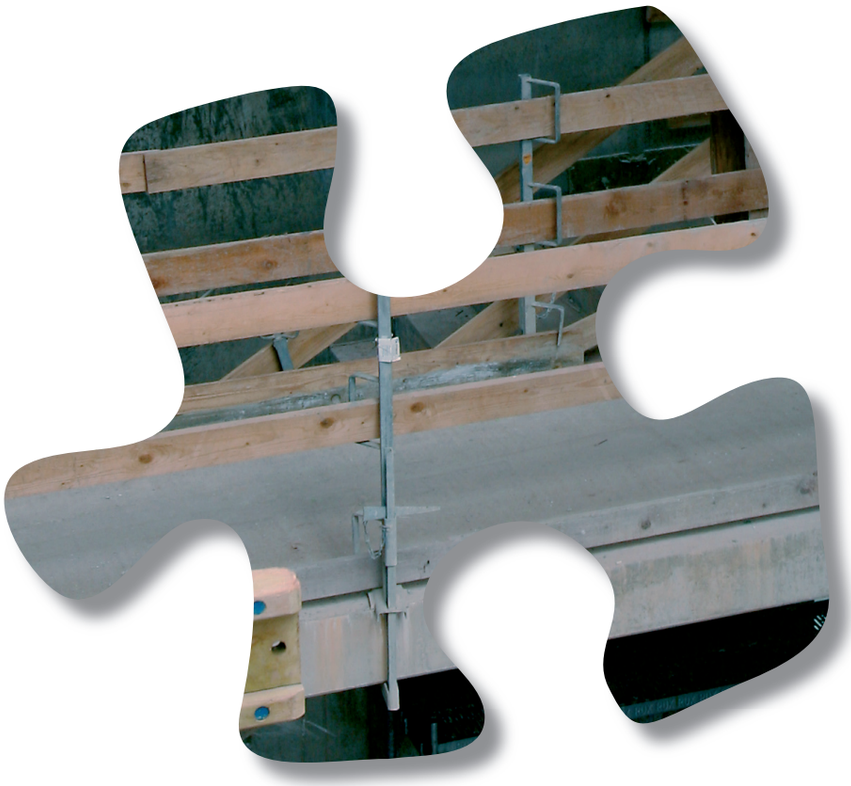
Knowledge Management and E-commerce

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

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

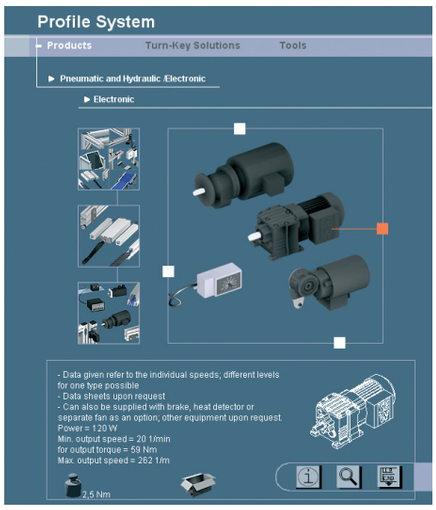
Different types of criteria – quantitative or qualitative, objective or subjective, active or passive, dependent or independent, deterministic or statistical – can be considered simultaneously; each user can navigate in the decision space according to his/her special strategy and accounting for current restrictions. Both domains of this main subject include aspects of knowCube®.

Special fields of application are virtual product design, logistics, marketing, and the sales sector. The composition of multi-criteria methods and concepts of SixSigma quality philosophy is increasingly gaining importance.



Contact:

Dipl.-Math. Hans Trinkaus
☎ +49 (0) 6 31/3 03-18 55
trinkaus@itwm.fraunhofer.de



Navigation within a product system

Electronic Product Consultant

Virtual consulting on the internet: extensive and context-dependent knowledge with respect to product systems in need of explanation is continuously available to the customer online in current versions. Graphic and partly animated representations of technical components support the understanding of product functionalities and system hierarchies.

With respect to e-commerce, an interactive product catalogue consisting of graphic objects has been expanded. The customer can navigate on the internet through complex and technically demanding product systems, select his/her orders, and place them via mouse click.

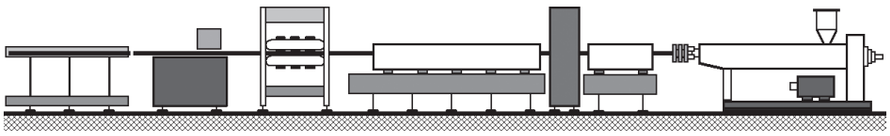
In the year 2004, a multi-language version of the "virtual consulter" has been realized for the company MiniTec GmbH. The software is not only characterized by its intuitive user interface for the customer, it also enables the company to carry out fast and easy updates of product data.

Knowledge management in business processes

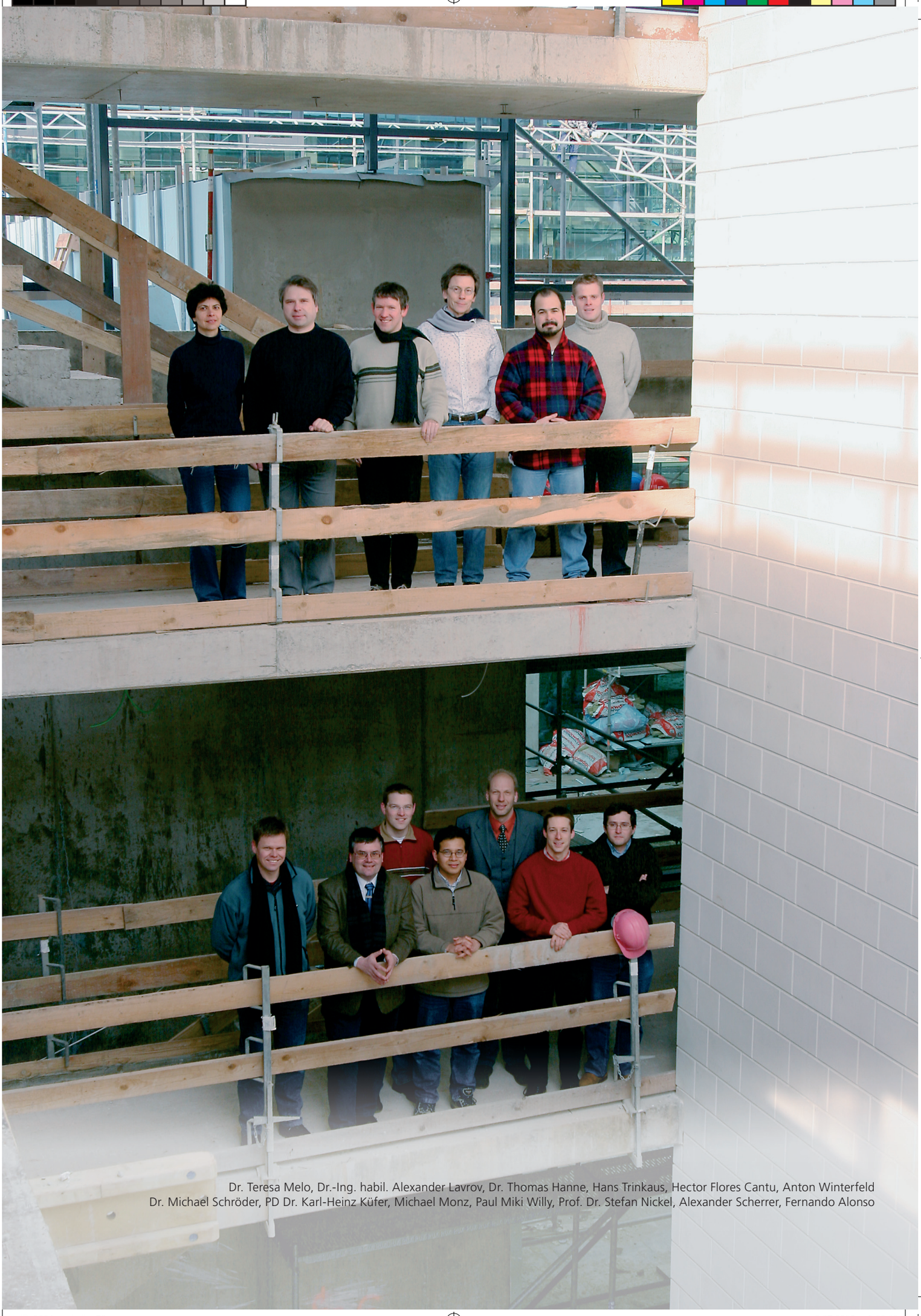
The management of the resource "knowledge" is becoming increasingly important for enterprises of all sizes. It includes the new knowledge resulting from innovation processes, as well as the whole range of diverse capacities and experiences which have once been acquired and collected during the history of a company. Fields of application are, for example, the business processes of product design, product development, production optimization, and production control.

Central tasks of knowledge management are on the one hand the protection of knowledge, with the objective of explicating valuable knowledge and saving it according to a certain structure, and on the other hand, of course, the finding of knowledge, in order to make use of the stored company knowledge for value creation.

A larger industrial cooperation project, initiated in the year 2003, was focused on the creation of a company-specific "process memory". On this basis, the component "process analysis" was developed in 2004. In the following year, the project will deal with the subject of "process control".



Sketch of a complex production line



Dr. Teresa Melo, Dr.-Ing. habil. Alexander Lavrov, Dr. Thomas Hanne, Hans Trinkaus, Hector Flores Cantu, Anton Winterfeld
Dr. Michael Schröder, PD Dr. Karl-Heinz Küfer, Michael Monz, Paul Miki Willy, Prof. Dr. Stefan Nickel, Alexander Scherrer, Fernando Alonso

Financial Mathematics

In the year 2004, the department's position acquired during the previous years was consolidated especially in the economic sector by an impressive number of successful industrial cooperation projects with familiar partners, which also proves that our customers are highly satisfied. Besides, the cooperation with our Swedish partner institute FCC in Gothenburg could be further intensified by common industrial projects, in particular by our project together with one of the four Swedish pension funds. Additionally, several projects in the field of credit risk/Basle II were successfully concluded.

The successful cooperation with the Centre for European Economic Research in Mannheim is also very promising. Within a common project by order of the Federal Ministry of Finances, we have examined the modeling of venture development bonds. Intentions behind this project were the plans of the Federal Ministry of Finances, which took over the G20 presidency in 2004, to initiate the assistance of emerging-market countries by innovative financial products.

The main subjects with respect to research and project work which have been determined during the last few years, i. e.

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

were confirmed again in the year 2004. Most of the funding was acquired in the fields of option pricing, credit risk, and credit derivatives; however, we have also worked on projects concerning interest rate models and portfolio optimization.

Scientific highlights of the year 2004 were the cooperation with Nizar Touzi (Paris) with respect to the Malliavin calculus and its application to American options and with Chris Rogers (Cambridge) with respect to the modeling of dividends. Besides, one of our publications on the pricing of Asian options will be published in the compilation "Best of Willmott 2004" of the Willmott magazine. In the year 2005, cooperation will begin with the Department of Technomathematics of the University of Catania. Besides, further cooperation is planned with partners in Turkey and Bulgaria.

Prof. Dr. Ralf Korn
☎ +49 (0) 6 31/2 05-27 47
korn@itwm.fraunhofer.de

Option Pricing

The main subject "Option Pricing" focuses on the derivation of pricing formulae and the development of numerical algorithms for the computation of the prices and sensitivities of exotic derivatives. Derivatives are, as the name already tells us, derived securities whose actual payment depends on the price development of their underlying goods, e. g., equities or interest rates. The area of option pricing is considered as the most popular area of financial mathematics; in the trading sector of large banks, option trading is also an important item especially in times of unfavorable market conditions. In order to offer their investors attractive products with a limited risk of loss, odds notwithstanding, also during weak periods of the market, banks frequently offer derivatives with a very complex payment structure. These products guarantee that the investor will not suffer a loss (capital guaranteed products), simultaneously limiting the maximum payment of profits on the part of the bank.

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

The demand for such models is reflected by the fact that we were able to intensify our research with respect to equities by further focusing on stochastic volatility (modeling of dividends) and the pricing of exotic derivatives. Besides, we have also been able this year to do a successful evaluation of new option types, such as variance swaps, volatility swaps, and correlation swaps.

Contact:

Prof. Dr. Ralf Korn
☎ +49 (0) 6 31/2 05-27 47
korn@itwm.fraunhofer.de

Pricing and risk management of correlation products

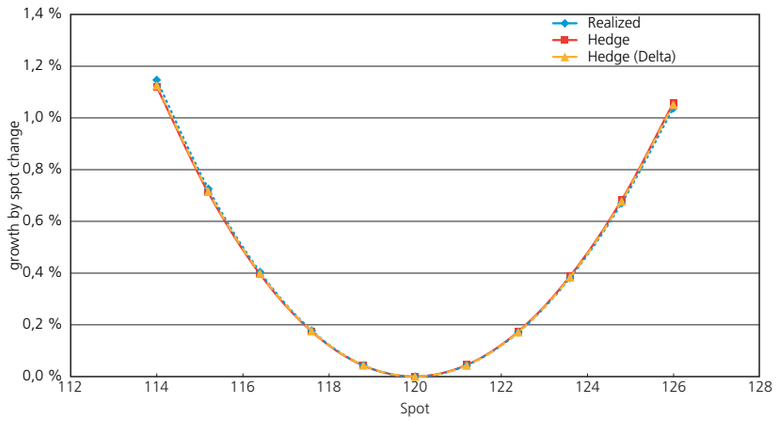
The pricing and the risk management of exotic derivatives are decisive problems of modern financial mathematics. One example is the variance swap. The payoff of a variance swap is the difference between the variance of the equity's return and a previously fixed rate. In the case of a swap, this rate is usually selected at the beginning in such a way that the value of the contract is zero. A variation of the variance swap is the volatility swap; in this case, the payoff depends on the square root of the variance, which exactly corresponds to the volatility of the Black-Scholes model. These contracts are also used in order to protect a hedge portfolio against volatility fluctuations.

If the risk of a portfolio consisting of several equities and equity options is to be hedged, the hedge strategy also depends on the correlation of the assets of the portfolio. So-called covariance swaps and correlation swaps are used in order to hedge the portfolio against fluctuations in the correlation. The payment has the same structure as in the case of the variance swaps: the realized correlation is observed, and the amount which is finally paid is the difference between the realized correlation and a previously fixed rate.

The pricing of variance swaps and covariance swaps works in a very similar way. A self-financing dynamic trading strategy is selected among all the scenarios, leading to the identical payoff as in the case of the option on the date of maturity. Hence, the fair price of the option is exactly the value of this trading strategy at the beginning of the option. In the case of a variance swap, the trading strategy consists of forward contracts, call/put options, and the basic equities. The equities' position is changing permanently, whereas the positions of the other securities are static. In the case of the covariance swap, there is an additional basket option. The difficulty is to select this portfolio in such a way that the performance of the realized variance (covariance) and the performance of the hedge portfolio are as identical as possible. The figure shows how the realized variance changes due to a jump of equities by 120 with respect to different values on the next day and compares these to the performance of our hedge portfolio. We can see excellent correspondence: we have succeeded in balancing the risk of the variance swap by our trading strategy. Results with respect to the covariance swaps were equally satisfying.

All the new routines are available as C++ functions in MS Excel, so that they can comfortably be integrated into existing Office systems.

Performance comparison of the hedge portfolio and of the realized variance after one day

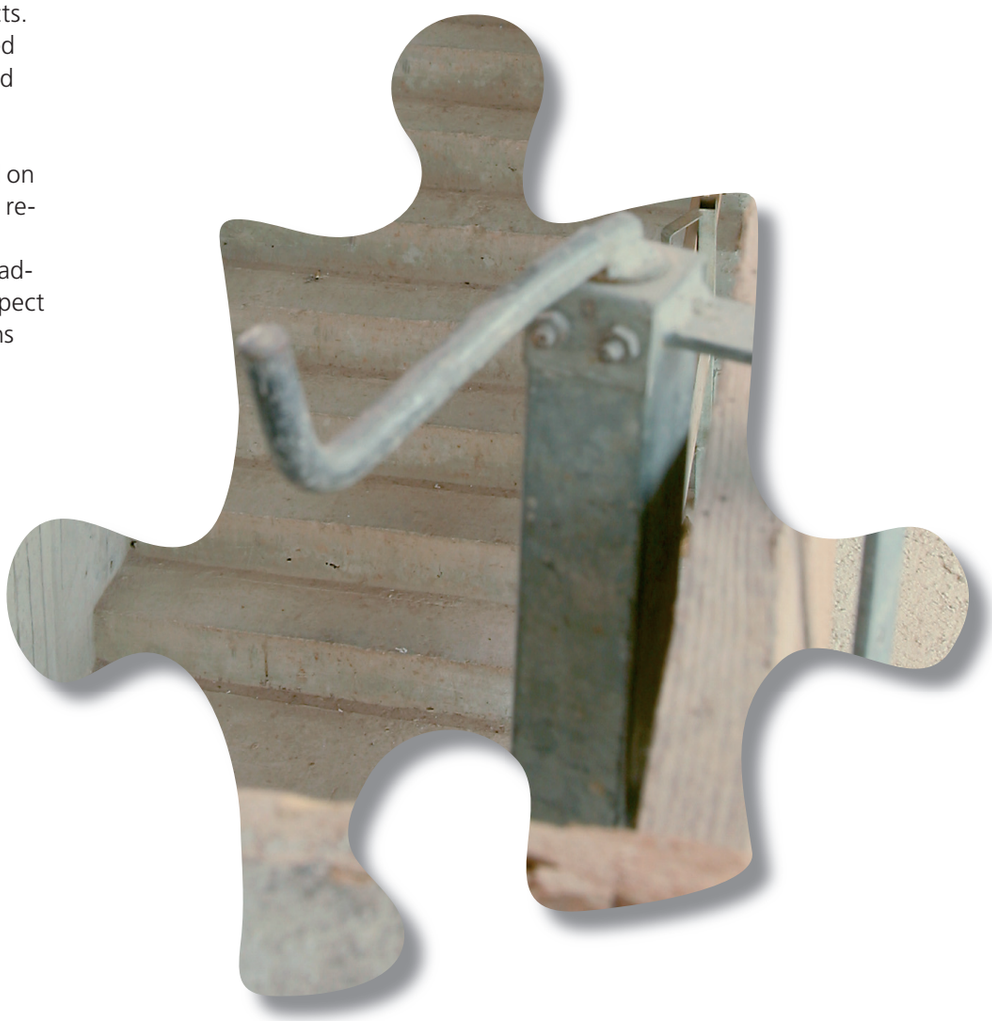


Credit Derivatives

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

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

The main subject of credit derivatives, which was founded in the year 2003, has been expanded in 2004 by several long-term projects.



Contact:

Dr. Ulrich Nögel
☎ +49 (0) 6 31/2 05-47 32
noegel@itwm.fraunhofer.de

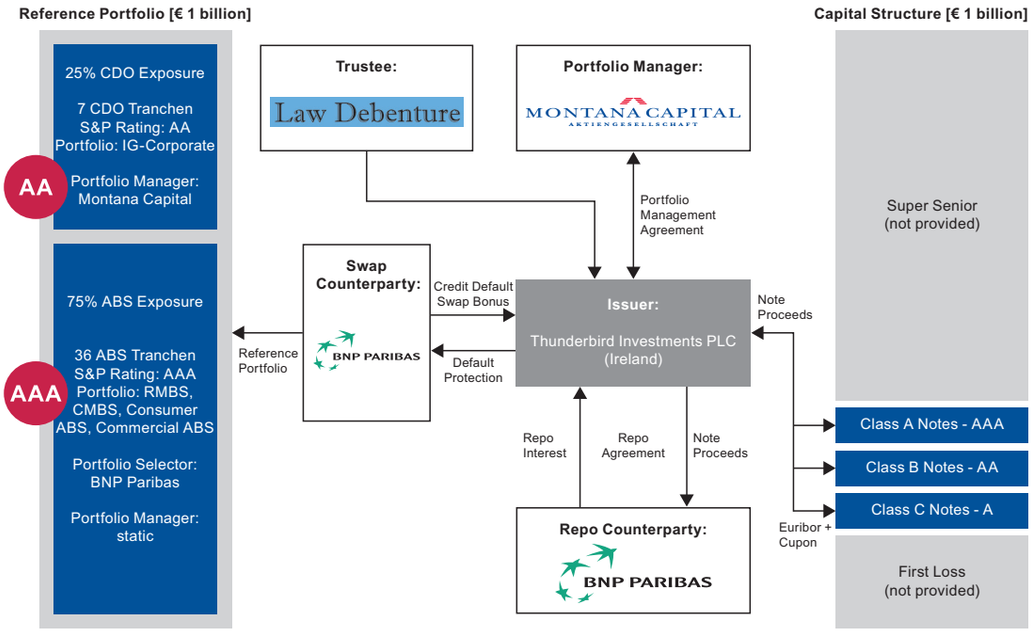
Pricing of basket default swaps

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

However, the problem in pricing and hedging of credit derivatives is that there is no standard model for the default probability of a credit yet. Within several industrial cooperation projects carried out in 2004, the ITWM has dealt with the selection, implementation, and further development of appropriate models.

An example for a strongly standardized product based on only one individual financial instrument subject to a risk of default is the so-called credit default swap (CDS). Meanwhile, the traded CDS have formed a sufficiently liquid market, so that their market prices can be used for the calibration of a credit's probability of default. The credit spread curve resulting from this calibration is the foundation for the pricing of further products. The ITWM tests and develops different methods for the determination of this spread curve (e. g., bootstrap, parameterization, etc.), for the evaluation of historic CDS spread data (e. g., descriptive analysis, test for normality, adaptation of mixing distributions), as well as for the determination and calibration of appropriate stochastic models with respect to these historic data.

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



CDO of ABS (with kind permission of Montana Capital AG)

Interest Rate Models

Interest rate models are one of the five main subjects of the department FINANCIAL MATHEMATICS. The classical Black-Scholes model with respect to option pricing considers the interest rates to be constant, which, however, does not hold in reality. Each individual person can realize that if he/she wants to invest money at a fixed interest rate or to raise a credit. These fluctuations are due to economic developments. However, interest rates do not fluctuate as strongly as equity prices.

Basically, the development of interest rates is important for all financial instruments, because a bond is usually included in the market considered for the pricing of a derivative. However, there are also many interest rate products whose payoff directly depends on the future interest rate development. Besides, the trading volume of these products is very high, so that a model for the future interest rate development is absolutely essential. Unfortunately, one cannot predict the future; hence, the development must be represented by stochastic models. There are plenty of models which all have their advantages and disadvantages, such as spot interest rate models, models based on the Heath-Jarrow-Morton framework, or LIBOR and swap models. "The model" for interest rate modeling simply does not exist; the advantages and disadvantages of each individual model must be reevaluated according to the current problem, and a different model must be selected for each individual problem.

The research work of our department focuses on the evaluation of exotic interest rate products for our project partners from the banking and the public sector, e. g. inflation-linked bonds, constant maturity swaps, or venture development bonds.

Contact:

Dr. Gerald Kroisandt
☎ +49 (0) 6 31/2 05-41 38
kroisandt@itwm.fraunhofer.de

Bundesministerium der Finanzen

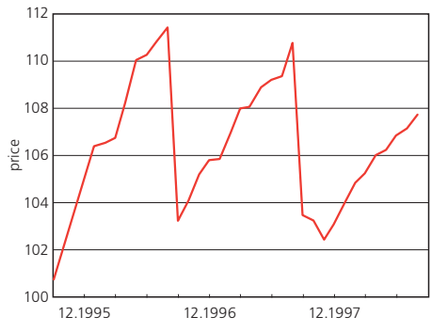
ZEW
Zentrum für Europäische Wirtschaftsforschung GmbH

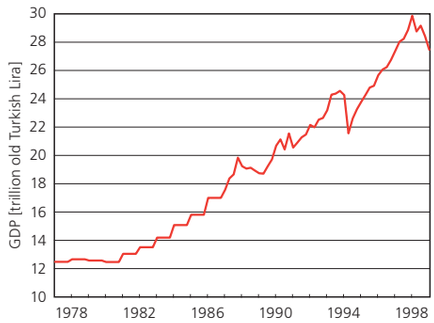
Venture development bonds – innovative financial instruments for the financing of development

The creation of a sufficiently strong economic growth in accord with a respective perspective of development and occupation for the people concerned is a huge challenge not only for emerging-market countries. In view of this task of development policy, the international community has committed itself to reach the UN Millennium Development Goals. The financing of these goals requires thinking about all the financing possibilities, even those which are not included in direct development aid. The International Conference on Financing for Development in Monterrey has therefore also decided to examine innovative financial instruments.

A large number of emerging-market countries do not have any or only a restricted access to financial markets for the external financing of public investments. The idea of innovative financial instruments for the financing of development, the so-called "venture development bonds" (VDB), is mainly intended for emerging-market countries who have a restricted access to capital markets. The least development countries will continue to receive direct development aid in the form of financial subsidies.

The project by order of the Federal Ministry of Finances and in cooperation with the Centre for European Economic Research was intended to examine VDB as possible instruments for the financing of development, and to analyze different versions of this financial innovation from an economic and investment mathematical point of view. Apart from the theoretical development of a number of economically sensible product versions of VDB, their market potential was examined. On the basis of a pricing model for index bonds which we have developed, we simulated VDB price time series based on different historic interest rate and index scenarios. We assume a coupling of the payment flows with the long-term modification of the gross domestic production (GDP) or the short-term GDP rate. On the basis of these simulations, the diversification behavior of international bond portfolios was analyzed. Besides, the study also includes an evaluation of this innovative financing for development from a regulatory and institutional point of view.





Left: simulated price development of a VDB in case of liquidation at par and the coupling of the coupon payment with the short-term development of the gross domestic production (GDP) of Turkey. *Right:* development of the Turkish GDP on which the simulation is based (without inflation)

Many banks focus on the evaluation of the current rating system and a possible new conception with respect to the application of the new Basle Capital Accord (Basle II). Typical problems which require consulting by the department FINANCIAL MATHEMATICS are the conception and evaluation of rating scores, the reevaluation of the components of the rating score, the estimation of probabilities of default (PD), the modeling of loss-given default (LGD), and the evaluation of rating systems.

First, we are searching for statistically significant rating factors with respect to discriminatory power between default and non-default in order to develop a conception of the rating. Discriminatory power and calibration of the estimated probabilities of default are relevant for the evaluation of rating scores. Regression methods, such as the Logit model, are appropriate for the reevaluation of the factors within the score and for the estimation of probabilities of default. Numerous extensions are available here which render the model more flexible with respect to individual aspects. Panel and survival models are used in the case of observations covering several years. Neural networks, classification trees (CART), monotonicity restrictions, and semi-parametric models serve for the model examination and help to find appropriate variable transformations.

This year, we have also dealt with more specific aspects of rating systems: if the used data are not representative, the rating evaluation might become distorted. For this case, we have developed interval estimations for the criteria. Besides, a rating system must be evaluated regularly. Back and stress testing examine the quality of the current system by historic data and estimates the system limits. We have implemented different resampling methods (Monte Carlo, bootstrap, cross validation) for both areas.

Contact:

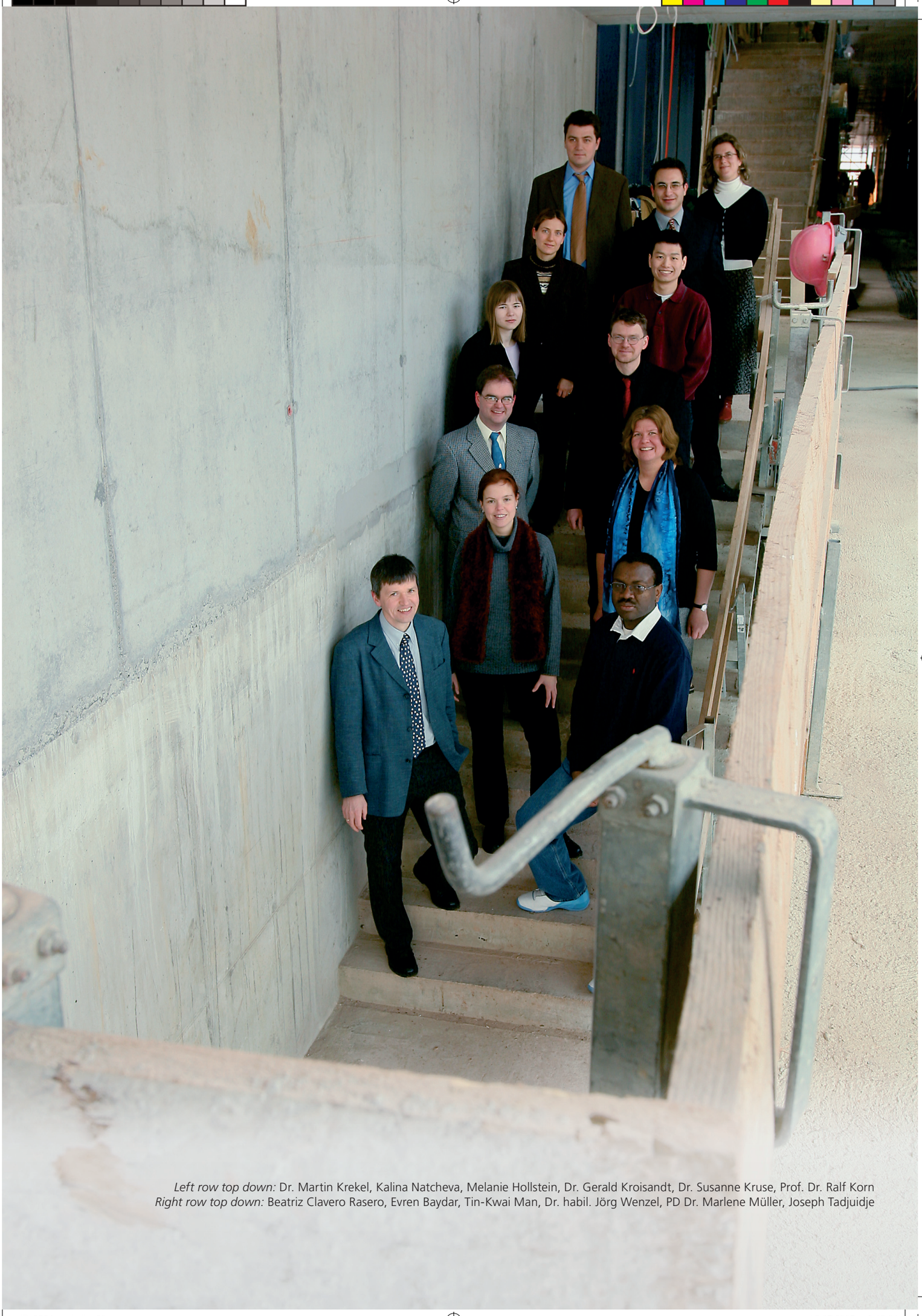
PD Dr. Marlene Müller
☎ +49 (0) 6 31/2 05-41 89
mueller@itwm.fraunhofer.de

Portfolio Optimization

Portfolio optimization is mainly focused on the determination of an optimal investment strategy on a financial market. More precisely: the investor must decide how many shares of which securities to hold when, in order to maximize his/her utility of wealth at the end of the planning period. In contrast to option pricing, where time-continuous models of financial mathematics have been applied in practice for decades now, the more than 40-year-old single period model of Markowitz, including several variations, is still representing the foundation of fund managers' investment decisions. In the meantime, the development of modern, time-continuous portfolio optimization – the main research area of the research group of financial mathematics at the Department of Mathematics of the Technical University of Kaiserslautern – has advanced so far that many algorithms now suggest themselves for practical application and implementation also at the ITWM. A respective project is the development of an online consultation tool, which is to be initiated in 2005 in the framework of the ITWM's activities in Catania within the POKER project. In the year which has passed now, a successful project with respect to portfolio optimization was the development of a simulation tool for asset liability management for the Swedish AP2 fund (in cooperation with the FCC in Gothenburg). Research projects within the main subject were the optimization of bond portfolios (also with respect to bonds subject to default risk), portfolio problems of insurance companies in the case of a crash risk, and the practical application of portfolio optimization methods with respect to transaction costs. A further current project has been the determination of optimal portfolios consisting of index options and inflation bonds.

Contact:

Prof. Dr. Ralf Korn
☎ +49 (0) 6 31/2 05-27 47
korn@itwm.fraunhofer.de



Left row top down: Dr. Martin Krekel, Kalina Natcheva, Melanie Hollstein, Dr. Gerald Kroisandt, Dr. Susanne Kruse, Prof. Dr. Ralf Korn
Right row top down: Beatriz Clavero Rasero, Evren Baydar, Tin-Kwai Man, Dr. habil. Jörg Wenzel, PD Dr. Marlene Müller, Joseph Tadjuidje

Mathematical Methods in Dynamics and Durability

The design and construction of complex mechanical systems and their subsequent testing with respect to durability – this is a traditional cycle to be gone through several times. However, there are restrictions with respect to time and cost, so that it has become absolutely necessary today to reduce the number of required prototypes as far as possible with the help of simulation tools. No matter whether we are talking about the construction of vehicles or aircraft or the design of wind power stations – the savings potential by an early application of appropriate simulation methods is significant everywhere.

The department MATHEMATICAL METHODS IN DYNAMICS AND DURABILITY is active in modeling and simulation of durability and reliability of mechanical systems.

The department was founded in 2003. During the first year of activity, we primarily had to work on getting started: main subjects were the presentation of the department to potential clients and partners, the acquisition of and work on first projects, the writing of proposals for the acquisition of funding, and the preparation of workshops and seminars. In such a way, the department grew from two persons at the beginning of 2004 to an entire number of five scientists and a PhD student in the course of less than one year.

Main subjects are methods of load statistics for the development of durability design targets and the simulation of mechanical systems by finite element and multi-body models. Our objective is to use simulation to improve the quality of the design even before the first prototype is available.

Another main research subject is the combination of durability simulation with the previous simulation of manufacturing processes such as casting or welding.

A three-day seminar on the representation of the entire process chain, including the processing of measurement data and the different simulation methods, was very well received. It will be repeated in June 2005.

Dr. Klaus Dreßler
☎ +49 (0) 6 31/3 03-18 69
dressler@itwm.fraunhofer.de

Load Data Analysis

How long a mechanical system is able to fulfill its tasks without failure, essentially depends on two factors: the strength of the system and the load to which it is subject during operation. In many cases, e. g. for grand vehicles, the loads occurring during operation strongly depend on the user and the general application conditions. It is the task of load data analysis to describe loads and prepare the data in such a way that they can be used for durability design. Components can be designed in such a way that they will not break down prematurely and that they are not overdesigned – the latter being responsible for higher expenses due to a larger amount of required material or an unnecessarily heavy weight. Experiments with prototypes are usually shorter than the actually planned service life during real operation. Here is another important area for the application of load data analysis or synthesis: the definition of experiments and test scenarios, as well as the related shortening of experiments times in order to save costs at the test rigs.

The ITWM is working very intensively on the description of customer behavior and the development of the respective load statistics. Methods are developed and applied in order to acquire the necessary measurement data in appropriate form and to reduce them in such a way that they can be specifically designed for different application scenarios on this basis. The results of these examinations represent the foundation for tests with real prototypes, as well as for computations and simulations.

A methodology which allows to analyze the fatigue potential of complex loading scenarios is the rainflow counting method. During the last 15 years, scientists of the ITWM have essentially contributed to the development of rainflow-based methods, which are meanwhile applied worldwide also within commercial software.

Currently, the application of load data analysis methods is not restricted to the domain of tests any more; the methods are also applied for the evaluation of simulation results. Adequate methods can identify the reasons for the differences between the measurement results from driving experiments and test rig experiments and the simulation results.

Contact:

Dr.-Ing. Gerd Bitsch
☎ +49 (0) 6 31/3 03-18 79
bitsch@itwm.fraunhofer.de

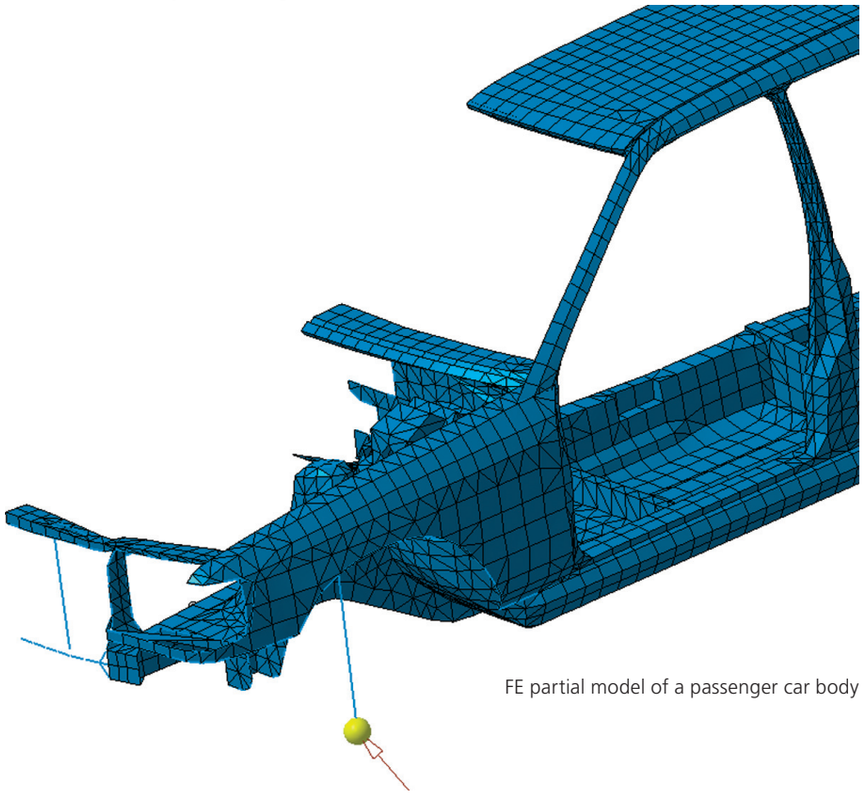
Finite element computations and multi-body simulations

How long does a critical component live under realistic service loading? The answer essentially depends on the problem to which loads the component is subject and which are the resulting loads in the interior of the component. However, in many cases the loads to which a component is subject cannot be measured directly. The measuring points are either inaccessible or the application of the respective sensors is too expensive, or no prototype is available yet at an early stage of development.

Multi-body simulation can help to compute the active forces in the interior of the system by a model reflecting the mechanical system with its masses, inertias, and stiffnesses. For example, measured wheel forces or a given road profile are integrated into a multi-body model of a car; on this basis, the interior loads to which the axle is subject can be computed. The coupling with finite elements subsequently allows for the identification of potential points subject to a risk of default, and for the optimization of the construction in such a way that the components are able to bear operational loads.

Another important main subject of the department's research work is the parameter identification respectively the development of parameter identification methods; the parameters to be identified are to be used as sensible input parameters for models of not yet existing prototypes. Inverse methods in combination with iteration methods allow, for example, the computation of road profiles on the basis of measurement data of already existing vehicles; these profiles can then be used as input for the simulations of future vehicles.

Test rig experiments are very expensive. Numerical simulation can be used to prepare those tests and reduce the complexity and the length of the tests. Can the experiments be carried out at all in the planned form? Is the test rig able to provide the required loads in combination with the device under test? Does a new test rig concept have any advantages compared to the one which has previously been applied? These are problems for which the ITWM is intensively searching answers.



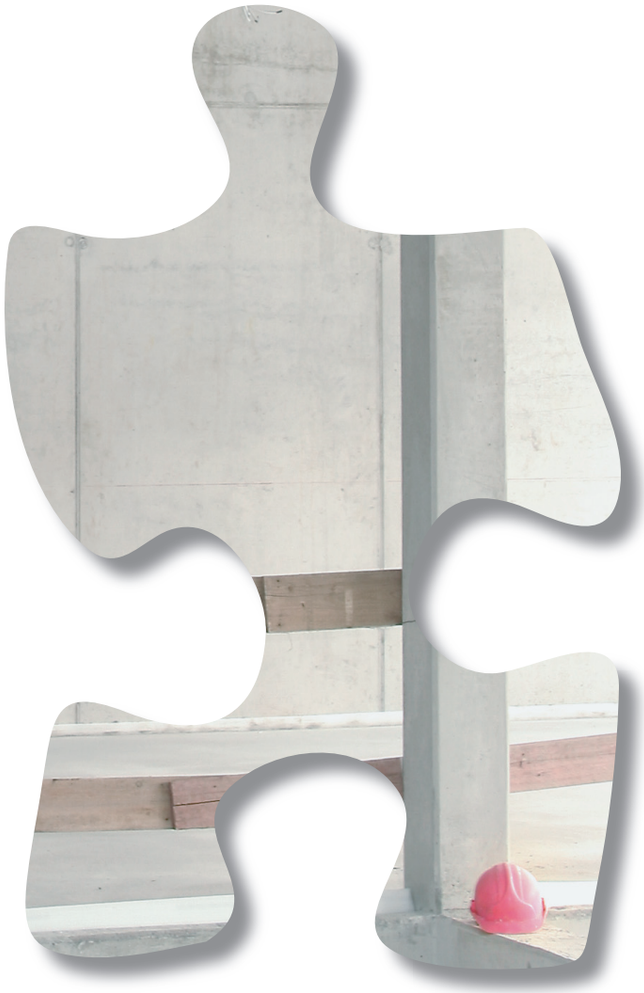
FE partial model of a passenger car body

Casting Simulation

The "virtual casting" by MAGMASOFT® has been a continuous subject of different research and service projects of the ITWM since 1996. Projects have mainly been focused on the one hand on the consulting of foundries with respect to the application of the simulation software during practical operation, and on the other hand on common research and development projects in cooperation with the company MAGMA GmbH in Aachen.

The ITWM consults and supports different regional foundries (e. g. HegerGuss, Römheld & Moelle, Gebr. Gienanth) with respect to the application of casting simulation for the solution of specific problems. Examples are the formation of porosities and the structure of special cast iron alloys, or the functioning of special gate systems for the mold filling of large crankcases. The availability of MAGMASOFT® on the HPC cluster of the ITWM allows for extensive parameter studies or the simulation of complex, fine network geometries of cast parts in very short time, thus representing an important advantage for the foundries. An interactive evaluation of the casting simulation results at a high resolution with respect to time and space is possible with the visualization software PV-4D MAGMAVR, which has been developed at the ITWM. The foundries have especially made use of this possibility with respect to the visualization of the solidification process in the case of complex geometries of the cast parts, and of complex flow processes during the mold filling.

Currently, the development of methods in the field of casting simulation is mainly concentrating on the connection of the simulations with respect to manufacturing and functions. The ITWM participated in the WISA (economically oriented strategic alliance) Study "Magnesium Lightweight Construction", carried out by the Fraunhofer-Gesellschaft and concluded in 2004, with a contribution with respect to the local mechanical properties of magnesium parts produced by pressure casting. Material properties caused by the production process are also important for the durability computation of iron cast parts and for subsequent steps (e. g. the computation of service life). First steps for the integration of the results of a casting simulation into stress computations for the structure optimization of iron cast parts have been taken in the framework of the publicly funded research project OptCast. A workshop on "Integrated Process Simulation for the Optimization of Cast Components" in April 2004 gave a survey of the ITWM's activities in this area to the participants from the fields of foundry technology, mold construction, automobile construction, and supply industry.



Contact:

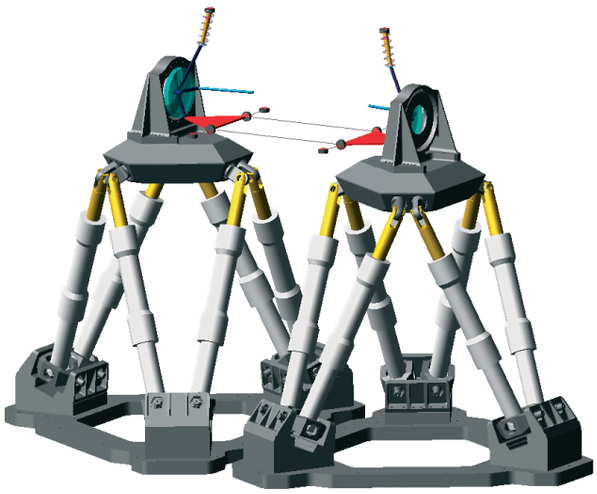
Dr.-Ing. Joachim Linn
☎ +49 (0) 6 31/3 03-18 79
linn@itwm.fraunhofer.de

Simulation of an axle test system by MBS modeling

In automobile industry, safety-relevant components are increasingly analyzed on the computer before their release for serial production; nevertheless, they are always additionally tested by experiments. in order to determine their durability, individual components or entire systems (e. g. knuckles or front axle) are exposed to a load as similar as possible to the real load by hydraulic test rigs. The ensemble of test rig and device under test represents a complex mechanical system whose behavior during the continuous run test must be monitored and controlled very exactly if the desired examination is to be carried out. A computer simulation of the test is supposed to support a better understanding of the test system's behavior in order to shorten the time required for the real testing.

During the testing of vehicle axles, the load is described by the forces and moments occurring at the right and the left hub in the direction of the longitudinal, transverse, and vertical axes of the vehicle. In order to expose the axle during the test to a load identical to the load during a driving maneuver, the test rig requires six degrees of freedom at each side. A new test rig concept for axle testing uses the hexapod configuration, which is able to generate an arbitrary force/moment constellation at the center of the wheel by a system of six identical hydraulic cylinders. An axle test rig is constructed on the basis of two hexapods which is able to generate arbitrary loads at each wheel. The test system is driven via control parameters for the hydraulic valves which generate the desired forces and movements in the individual cylinders. Due to its complex structure including keys, shock absorbers, rubber bearings, etc., the axle shows a nonlinear relation between forces/moments and the displacements and rotations at the hub. Besides, the degrees of freedom are strongly coupled and cannot be set independently from each other. A testing with given loads therefore demands a lot with respect to the monitoring and control of the system. During the test run, the actually occurring forces and moments *F* (actual parameters) are continuously measured at the wheel, compared to the given parameters *T* (target parameters), and fed to a controller generating a control signal v for the hydraulic valves on the basis of these data.

The mechanical system of axle and hexapods is simulated by a multi-body model. The hydraulic system is modeled by a set of (differential) equations and the respective parameters (viscosity, E-modulus …), and the controller used in the real hardware is integrated into the simulation environment via appropriate interfaces. On the basis of measurement data from driving maneuvers and the test rig run, the modeling of all the subsystems is examined and adapted to the real behavior. In such a way, studies with respect to the adaptation of the geometric configuration of the hexapod to the axle or with respect to the improvement of the control mechanism are carried out, and their effects on the testing of individual axles are predicted.



Axle test rig based on two hexapods

Dr.-Ing. Joachim Linn, Janis Bajars, Dr.-Ing. Gerd Bitsch, Dr. Klaus Dreßler, Holger Lang, Dr. Michael Speckert, Thomas Stephan

Competence Center High Performance Computing

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

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

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

The research work of the COMPETENCE CENTER HIGH PERFORMANCE COMPUTING is mainly focused on

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

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

The development of new, strongly parallel computation codes in the fields of molecular dynamics, structure mechanics, and financial mathematics represents three subjects for the COMPETENCE CENTER HIGH PERFORMANCE COMPUTING which will be very important for the future and can be further expanded also in 2005 on the basis of a solid financing.

Dr. Franz-Josef Pfreundt
☎ +49 (0) 6 31/3 03-18 21
pfreundt@itwm.fraunhofer.de

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

Up to now, the internet has mostly been providing information. In the future, it is also supposed to provide computing power. In the same way as today a laptop is connected to the power supply network, we will in the future be connected to world-wide grids, being able to make use of the power of large computers and high-performance software.

Increasing computer networks enable us to use, e. g., free computers in Indonesia during the nighttime there.

The Fraunhofer Grid Alliance (FhGA), consisting of the ITWM and seven other Fraunhofer Institutes, is developing an individual Fraunhofer grid infrastructure. The Fraunhofer Resource Grid (FhRG) is intended for industrial users; therefore, user friendliness is a very important aspect. Existing applications can be integrated easily and processed within the grid. Even large amounts of data can be handled safely with the help of the storage resource broker.

A web portal developed by the Fraunhofer IAO leads the grid user to the applications, and supports him/her in their execution. The workflow system, which is based on Petri networks and has been developed at the Fraunhofer FIRST, allows for the modeling of very complex simulation processes.

The contribution of the Fraunhofer ITWM is a distributed scheduler based on auctions, which is able to select the fastest or cheapest computer for the respective application. The preferences of the users as well as the interests of the computer operators are simultaneously accounted for.

The ITWM participates in different international grid projects: the EU project EGEE is intended to provide to the scientists an infrastructure for problems requiring extraordinary amounts of computing power. Experiences collected during the EGEE project and during the operation of the FhGA infrastructure are also integrated into the research and standardization with respect to grid protocols, for example in the framework of the Global Grid Forum. The ITWM is especially active in the fields of scheduling and operating.

FhRG
Fraunhofer Resource Grid

Contact:

Dr. Franz-Josef Pfreundt
☎ +49 (0) 6 31/3 03-18 21
pfreundt@itwm.fraunhofer.de

Parallelization and Performance Analysis

The combination of a large number of computers in the form of clusters and grids today results in high-performance parallel computers which are able to compute more and more complex problems with continuously growing memory requirements. However, the increasing complexity of processors and memory hierarchies also results in an increasing complexity of the optimal usage of the available system performances. Each specific problem does not only require individually the distribution of computing jobs to the processors; the communication between the nodes and the access to the different memories of the system must also be especially considered.

The main subject "Parallelization and Performance Analysis" deals with the efficient parallelization and code optimization of the institute's own software and our customers' software. Within several projects, existing MPI codes were made considerably faster, applications were parallelized, and also non-parallel codes became very much faster due to optimization. Among our customers are different weather services and several enterprises from the financial sector.

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

The efforts of the ITWM concerning software parallelization and performance analysis are also based on extensive competence and experience due to the operation of the institute's own PC clusters. The four PC clusters, among which there is also a system with 64-bit Opteron processors, together reach a peak performance of more than 900 Gflops. In the year 2003, a system of 128 Pentium 4 processors was among the 500 fastest computers in the world.

Contact:

Dr. Boris Briehl
☎ +49 (0) 6 31/3 03-18 08
briehl@itwm.fraunhofer.de

Performance analysis and prediction

Models of performance prediction are supposed to allow for a realistic estimation and prediction of the runtime and scaling behavior of application software on inaccessible or not yet existing systems. This kind of information supports the users of the software especially with respect to the decision about upgrades or the purchase of new hardware components. In the framework of the joint research project IPACS (Integrated Performance Analysis of Computer Systems), which is funded by the BMBF, we are developing such models of performance prediction. They are based on an abstract characterization of the hardware by low-level benchmarks and of the software by an exact runtime analysis with respect to cache, memory, and network accesses. In such a way, the exactness of the performance prediction for the commercial CFD software packages FLUENT® and StarCD has reached 10 per cent.

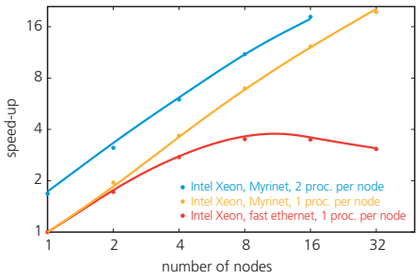
Parallelization framework ParMC

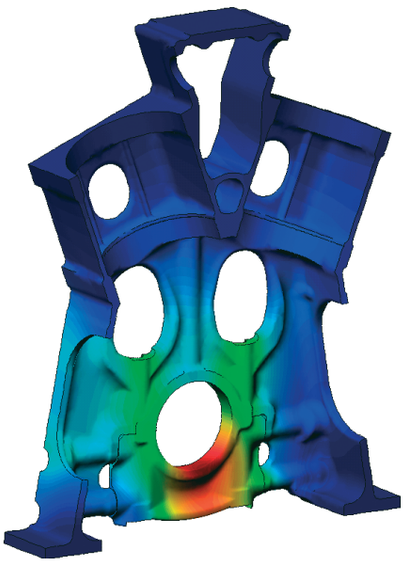
Together with a customer from the financial sector, we have developed a parallelization framework in the form of a manager-worker system, which allows for a parallel computation of many Monte-Carlo simulations for portfolio evaluation on a PC cluster. The application of performance prediction methods guarantees that the performance of the system is utilized optimally and that the response times of the individual computations simultaneously remain short. Another important factor is a high availability which is able to tolerate faults or total failures of individual cluster nodes and, interacting with a redundant design of hardware components, leads to a fault tolerance of the entire system which is as high as possible. On the basis of this system, which is meanwhile running very stable in operation, we are working together with our customer on the expansion of ParMC also with respect to the solution of other problems requiring extensive computing power; we intend to develop a universally applicable parallelization framework.

Shape optimization with DDFEM

DDFEM is a parallel finite element (FE) code for 3d linear elasticity. It calculates deformations and stresses within an elastic body, subject to certain (external) loads. The domain decomposition concept is a basis for parallelization at the FE-discretization stage: the computational domain is divided in subdomains and each subdomain is then independently processed. The large-size linear system of equations, produced by the FE-discretization, is solved also in parallel using the PETSc library. DDFEM uses its own input language to describe the tetrahedral mesh and the boundary conditions for the particular problem. The object-oriented design and the effective parallelization of the code provide its high performance. DDFEM has been used at ITWM both as a standalone solver to investigate the elastic properties of fiber structures and as a FE-solver, iteratively referenced within the shape-optimization loop in the process of structure analysis.

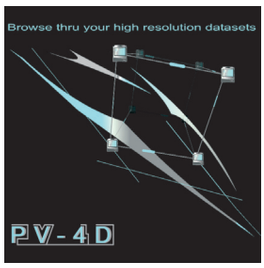
Measured and predicted Speed-Up of FLUENT® on a Xeon cluster with Fast Ethernet and Myrinet for one and two processors per node.





Shape optimization using DDFEM: displacements in a engine block segment. The tetrahedral mesh and the stresses for the same detail can be seen on page 42.

Visualization



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

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

The PV-4D kernel is based on the vector shift algorithm developed at the ITWM, which allows for the mapping of 3d data structures onto the vector units (SSE-I, SSE-II) of the processors. Several units of the rendering kernel thus reach the peak performance of the current Intel/AMD processors. PV-4D is designed as a continuous parallel software system and uses all the available parallelization levels (on chip, SMP, distributed memory) optimally. Lacking performance during visualization always means that more time and thus more money are required on the part of the user. PV-4D therefore applies parallel I/O wherever this is possible.

PV-4D is a complex parallel visualization tool supporting Ethernet, Myrinet, and Infiniband as connecting networks. It is however presented to the user as an easy-to-use Windows or Linux viewer. Today, PV-4D is available as a generic visualization tool and in the form of special adaptations for MAGMASOFT® users, for the seismic industry, and for the visualization of CT data in medicine.

Contact:

Dr. Carsten Lojewski
☎ +49 (0) 6 31/3 03-18 75
lojewski@itwm.fraunhofer.de

Examples

PV-4D *MAGMAVR*

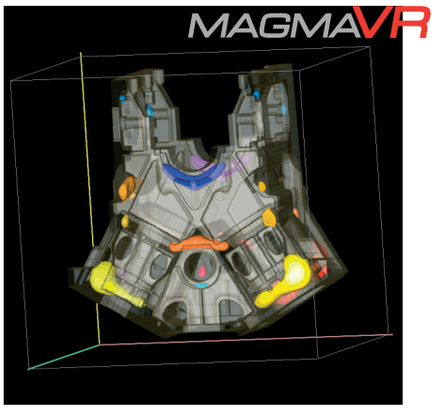
As a first application, the software package ParPac, which has been developed at the ITWM, and the parallel version of MAGMASOFT®, the leading casting simulation package, were supported by PV-4D. The large amounts of data resulting from parallel simulation can now be visualized really interactively for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

PV-4D *MED4D*

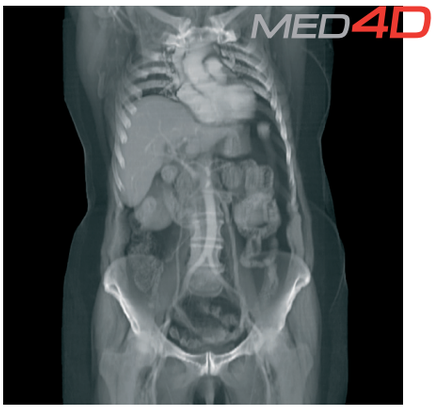
In cooperation with the Medical University Hospital Hannover, a beating heart of a living person was rendered for the first time as a high-resolution moving object in three dimensions in such a way that the user can immerse himself/herself interactively into the object without any temporal delay (50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

PV-4D *SEISMICPRO*

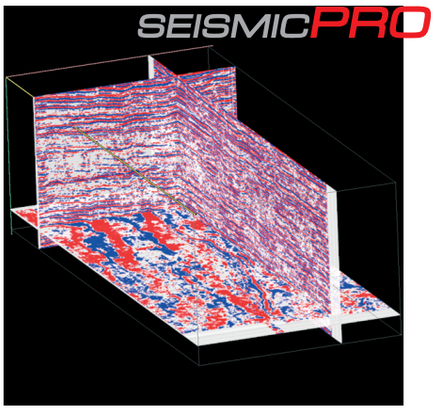
The visualization of extensive seismic data still is a very complex and expensive process in industry which definitely is of decisive importance for the interpretation of reservoirs and thus for the detection and the improved use of oil and gas resources. The specially adapted version of PV-4D supports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



Detection of "hot spots" during solidification: 140 million cells, 100 time steps



Visualization of a CT image: 512 x 512 x 1024 volume elements



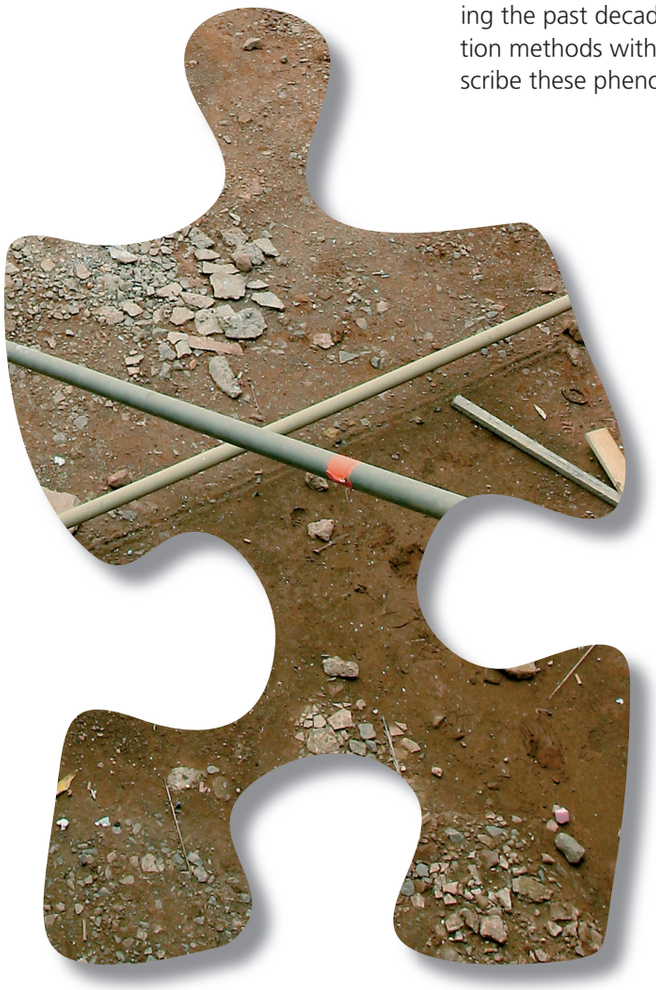
Seismic data record (with kind permission of Rock Solid)

Availability

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

Molecular Materials Design

The virtual experiment on the computer has become an essential tool in many areas of industrial research and development. Mathematical methods in duration and stability analysis, using finite element methods, are nowadays standard, i.e. during the construction phase in the automotive industry. The situation in the field of materials design is, however, different. What does exactly happen during coating processes which are especially important for the semiconductor industry? When do cracks occur? When not? Which oil formulations provide optimal lubrication behavior at low temperatures? Physical and chemical processes at an atomistic scales are to be considered to understand these kind of problems since these effects are beyond the scope of continuum models. During the past decades, computer simulation methods with the capability to describe these phenomena have been developed at universities. These methods have the capability to describe materials in a very detailed way on atomistic scales and may therefore be applied to those problems; however, they require extremely long simulation runs. Due to the rapid development of the computer technology in the direction of parallel cluster architectures on the one hand and the development of multiscale algorithms on the other hand, the computer experiment is now conquering the industrial research in the field of materials design.



The development of multiscale methods, which are very promising candidates for virtual materials experiments, is based at the ITWM on the method of molecular dynamics. For materials design by molecular dynamics methodology to become feasible in the future however, several conditions have to be fulfilled: For the physical modelling, these are a description of the atomic interaction potentials, the definition of observables on atomistic scales which correlate with mesoscopic materials properties, and multiscale methods which bridge the gab between atomistic length and time scales and engineering scales in order to speed up the notoriously high computation demands of atomistic simulations. In particular, efficient numerical algorithms and highly scalable parallelized software tools are necessary in order to solve for industrial problems in the field of materials science. The ITWM faces these new challenging task in the framework of various projects, including in-house research activities.

Contact:

Dr. Peter Klein
☎ +49 (0) 6 31/3 03-18 04
klein@itwm.fraunhofer.de

Massive parallel molecular dynamics kernel

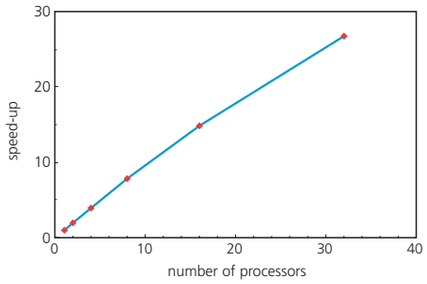
We have developed a massive parallel molecular dynamics kernel as one of our tasks in the MAVO project "MMM Tools" (Multiscale Materials Modeling). This software module forms a platform with plug-and-play interfaces to various other modules, including force modules, to be implemented by our partners in the MAVO-MMM. The resulting applications can then be specialized for the solution of problems in materials science. This approach has proved to be very flexible and extendable.

First tests on the parallel efficiency of the software show al linear scaling behavior of applications with a fairly high performance. Hence, the software may be used for the simulation of large numbers of atoms distributed among many processors, as it is necessary for virtual materials design.

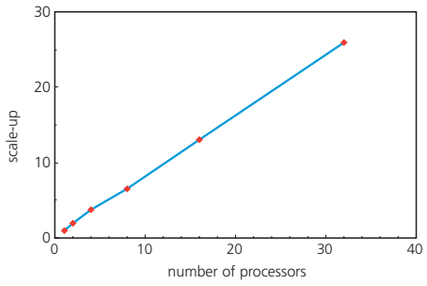
A first analysis of the speed-up was carried out with the help of a Tersoff potential for amorphous SiC; this potential was implemented by our partners in the MAVO-MMM. Scale-up´s were measured using our in-house implementation of the Stillinger-Weber potential. Both potentials are given analytically and belong to the class of simplified potentials used in standard molecular dynamics simulations.

Apart from the pure software development within the MAVO-MMM, the ITWM is also working on general problems in the field of upscaling techniques in order to solve problems in materials science within other projects. Atomistic simulations are interpreted on larger scales and in the context of experiments by methods from statistical mechanics in order to achieve model reductions on coarser scales; however, his is work in progress.

Speed-up
43 520 particles were simulated at ten Kelvin over 1 000 time steps (0.1 femtoseconds per time step). The figure shows the speed-up of one processor with respect to the number of processors. For up to 16 processors, efficiency is almost ideal, i. e. if the number of processors is doubled, the required computing time is reduced by half. Afterwards, the efficiency decreases slightly because a problem of "only" 43 520 particles is too small to be distributed among several processors (Intel-Xeon cluster with Myrinet, communication via MPI).



Scale-up
During this test, the problem was increased with the number of processors, so that each processor continuously had to handle the same number of particles. 4 096 particles were simulated per processor at 1 500 Kelvin over 1 000 time steps (0.1 femtoseconds per time step). We can see that the software is scaling linearly. An ideal efficiency cannot be reached in the case of molecular dynamic codes because strong dependences between the processors result from the atomic interactions; these require communication of data between the processors. This communication is unnecessary in the case of one-processor computations. However, particle numbers of several hundred thousands up to billions, as they are necessary for material design, are impossible during one-processor operation (Intel-Xeon cluster with Myrinet, communication via MPI).



Research Lab
Distributed Computing: Lustre

Service offers of the Competence Center

- Development and porting of parallel applications
- Performance analysis and tuning
- Benchmarking of cluster systems and applications
- Consulting with respect to the introduction of cluster systems and the entry into grid computing
- Visualization of very large amounts of data
- HPC system consulting
- Software design for parallel applications

Technical equipment of the Fraunhofer ITWM

- Production cluster: PC cluster with 128 CPUs, Dual XEON, 256 Gbyte main memory
- Benchmarking and visualization system: 32 CPUs Dual Opteron, Infiniband, 128 Gbyte main memory
- Dedicated Fraunhofer Grid system: 32 CPUs Dual Opteron, Infiniband, 128 Gbyte main memory
- Parallel file system lab
- VR laboratory
- PC cluster for the testing of new technical concepts

I/O performance increase with inexpensive hardware and parallel file systems

The development of hard disk technology does not show any considerable improvement of I/O performance, completely in contrast to chip technology. Therefore, current hard disk systems cannot provide the throughput of data required by the connected components. The demand for hard disk memory is simultaneously doubled every 15 months; the clock rate of available CPUs is growing at the same velocity. The low I/O throughput of the hard disk memory is thus restricting the performance of the entire system, which reduces the productivity of cluster systems.

In the framework of the research platform "Distributed Computing", the distributed file system "Lustre" (from Linux and cluster) is evaluated with respect to a media archive in cooperation with the companies Linux Networx and tecmath AG. Lustre is a performant future storage system; an especially important aspect is the available I/O bandwidth. The system was first developed as open source and is now commercially handled by the company Cluster File Systems, Inc. Its development was induced by the requirements of the large US research laboratories with respect to high-performance computing (HPC) storage systems:

- capacities of several 100 Tbyte
- high availability
- constant on-load throughput
- scaling of up to several thousand clients

These storage systems are necessary in clusters, for the storage of satellite images and CAD/CAM data records, and in the field of high-resolution video data (HDTV).

The data throughput of the distributed file system is improved in two steps: first, individual hard disk drives are connected in the form of a RAID system. Subsequently, several of these object storage target computers (OST) are combined to a joint system. The combination of several OSTs forms the Lustre file system. In such a way, Lustre reaches the scaling of the disk I/O bandwidth by simply joining further OSTs. A G-bit Ethernet technology is used within the joined system, each OST server being provided with two Gbit Ethernet ports.

Five Linux clients were used for a first measurement of the throughput. Measurements were carried out with a parallelized IOzone benchmark and the benchmark PRIOmark which is developed within the IPACS project. The inexpensive RAID servers which are applied are running at full load.

Additional load measurements are carried out with the media archive software of the company tecmath AG; this is a software package which has also been installed for operation at different TV stations. A comparison with respect to costs and performance of the installed memory systems and Lustre is especially interesting with respect to the development of future products.

Contact:

Martin Vogt
☎ +49 (0) 6 31/3 03-18 06
vogt@itwm.fraunhofer.de

Dr. Peter Klein, Dr. Dirk Merten, Matthias Klein, Mathias Dalheimer
Christian Peter, Martin Vogt, Dr. Franz-Josef Pfreundt, Nikolai Ivlev, Dr. Boris Briehl
Dr. Tiberiu Rotaru, Evgeny Ivanov, Dr. Dimitar Stoyanov, Dr. Susanne Hahn, Dr. Robert Zillich

Fraunhofer Chalmers Research Centre for Industrial Mathematics FCC

The Fraunhofer Chalmers Research Centre for Industrial Mathematics has successfully concluded its initial phase from September 2001 until December 2004. It is closely cooperating with the Fraunhofer ITWM and the Chalmers University of Technology, thus occupying a special position among the Swedish and European institutes of applied research.

The income of the year 2004 amounted to 2.1 million Euros, distributed as follows: 43 percent industrial projects, 18 percent public projects, and 39 percent basic funding by Chalmers or project funding by the Fraunhofer-Gesellschaft. The number of employees of the FCC has increased from six in September 2001 to 19 at the end of 2004. Thus, the FCC now has approximately the size of a department of the ITWM.

Up to date, an entire number of 100 projects in cooperation with numerous companies of different size and from different branches have been initiated at the FCC; 70 of these projects have already been concluded successfully. The number of industrial partners has meanwhile increased to more than 50, which has not remained without effects for the ITWM because of the growing volume of common projects of FCC and ITWM. Four fields of competence offered by the FCC will be described on the following pages:

- computational physics
- quality engineering
- bioinformatics and system biology
- financial and insurance mathematics

Dr. Uno Nävert
☎ +46 (0) 31/7 72-42 85
uno.navert@fcc.chalmers.se

Back row: Dr. Johan Carlson, Prof. Jaques de Maré, Anders Ålund, Daniel Segerdahl, Dr. Henning Schmidt, Sebastian Tafuri, Tomas Hermansson, Prof. Rikard Söderberg, Dr. Per Hörfelt, Dr. Thomas Svensson, Dr. Uno Nävert
Middle row: Dr. Marina Alexandersson, Jenny Ekenberg, Dr. Ann-Brith Strömberg, Alexandra Janhiainen, Martina Westman, Annika Eriksson
Front row: Erik Höök, Johan Havner, Fredrik Ekstedt, Dr. Robert Rundqvist, Dr. Mats Jirstrand, Andreas Mark, Domenico Spensieri, Ola Karlsson

Computational Physics

Research in the field of "Computational Physics" is focused at the FCC on the computer simulation of partial differential equations describing physical processes. The main subjects are flow mechanics and electromagnetism.

With respect to flow mechanics, there are primarily two important areas: "Fiber movement in flows" and "Topology optimization of flow systems". Flows in connection with fibers occur in many different production processes, e. g., during the production of nonwovens or paper.

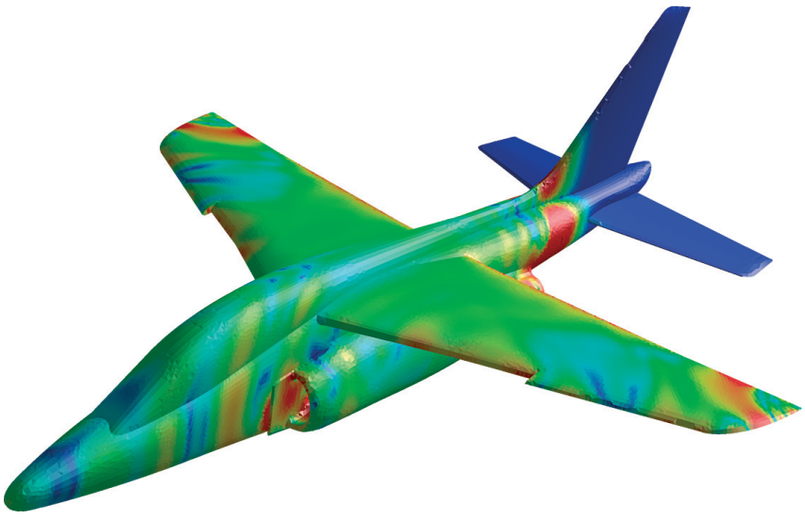
In flows of cellulose suspensions, flocks form out of individual fibers. The modeling of the fiber orientation and of the flocculation represents two important steps towards a better understanding of the fiber movements and the flow. In order to find access to the problem, the fiber dynamics must first be examined more closely. The fibers are modeled as a chain of spheres connected by elastic joints. A tool has been developed at the FCC which allows for the simulation of the flexible fiber movement in combination with a given flow.

Topology optimization is applied in many areas at the FCC, for example with respect to flow mechanics, thermomechanics, structure mechanics, and electromechanics. It is multi-disciplinary, i. e. it includes the coupling of many different physical areas and examines 3d systems. One main subject at the FCC is the topology optimization of Low-Reynolds flows. A software tool has been developed here which can be applied for the topology optimization with adapted target functions and boundary conditions in the case of general continuum mechanical problems.

Numerical methods are applied in "Computational Electro-Magnetics" (CEM) for the solution of complex electromagnetic problems. Several important applications of CEM are, for example, antenna design and electromagnetic compatibility.

The computation of electromagnetic fields is based on the Maxwell equations. The solution of these equations requires structured or unstructured computational grids. Unstructured grids are able to represent any arbitrarily formed body very well; however, they require more complex data structures. Structured grids, on the other hand, are based on more simple data structures, thus only being able to represent the geometry in an approximate way.

Already for a long time now, the FCC has applied a hybrid method for the computation of electromagnetic fields in aircrafts. Unstructured grids are used for those geometric areas which must be represented very exactly. All the remaining areas are represented by structured grids. Hence, a coupling of different methods is required for the numerical simulation of the Maxwell equations. Finite difference methods are used on structured grids, whereas finite volume or finite element methods are applied with respect to the unstructured grids.



Surface flows after the impact of an electromagnetic pulse running from nose to tail of an aircraft; the flows were computed by a hybrid method consisting of finite elements and finite differences.

Contact:

Dr. Robert Rundqvist
☎ +46 (0)31/7 72-42 96
robert.rundqvist@fcc.chalmers.se

Quality Engineering

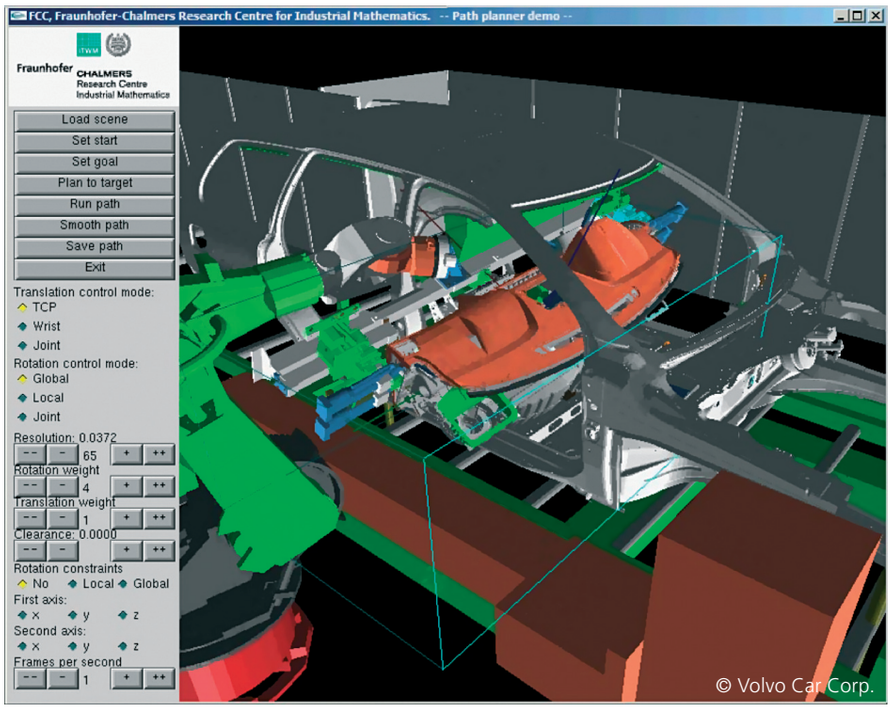
Sensitive products and production concepts are often confronted with quality problems leading to a belated introduction on the market, entailing in lost revenues. The possible simulation, optimization, and verification of products and production concepts at an early stage of design allows for an easy generation of high-quality products in a very short time. Fewer variations concerning production and processes result in a substantial profit for a company due to lower costs for adjustments, rejects, and complaints. Quality is one of the most important decision criteria for customers; hence, quality control is a very important part of business strategy.

Robust design, variation simulation, inspection planning, and the diagnosis of variation sources are important activities of quality control during the production process. A geometry variation resulting from the production and assembly of individual components continues during the production process or might even be reinforced, eventually resulting in a product which does not fulfill nominal values any longer.

Although modern enterprises already apply virtual prototypes in order to substitute real ones, visualize assembly processes, and program robots offline, the full potential of a virtual factory has not been reached yet. One limit is the time required for programming. Most of the programming with respect to the movement of robots is done manually, because the available automatic support has still remained very limited. A further restriction is the geometric exactness between virtual model and reality.

All the virtual models which are currently used for the simulation and verification of robots and assembly processes possess nominal values. In the real world, all the components and equip-

Very much faster than a simulation engineer: within only three minutes, the FCC path planner computes the optimal path for the construction robot in order to install the dashboard.



Contact:

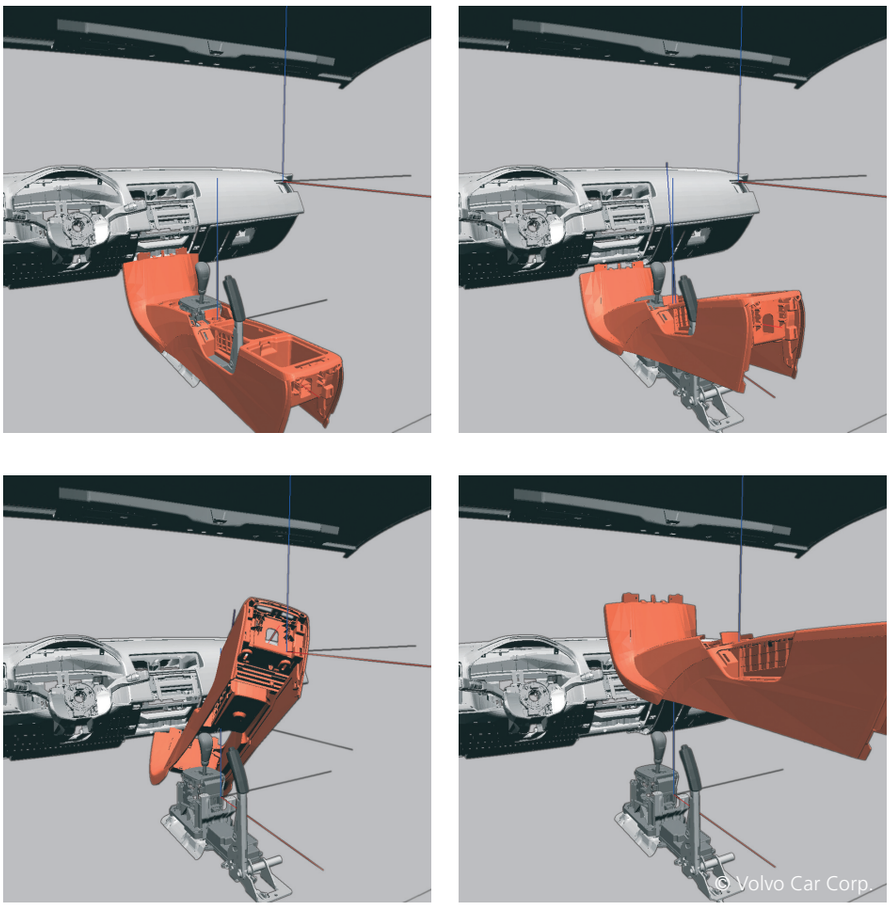
Dr. Johan Carlson
☎ +46 (0)31/7 72-42 89
johan.carlson@fcc.chalmers.se

ments are subject to geometric variations frequently resulting in conflicts and requiring adjustments. In order to fulfill future exactness requirements and production throughputs, geometric tolerances must be accounted for during the path planning. This is the first step from a nominal towards a production-adapted virtual model.

In the case of many products, the visual impression of the surfaces is also very important for customer satisfaction. The objective is a detection of visual defects as early as possible, which has been effected up to now through the inspection by especially trained personnel. The advantages of computers and image processing methods allow for the development of an online system of automatic surface inspection. The system consists of cameras providing high-resolution images, and image analysis algorithms for the detection of visual surface defects.

Example: Path planning of solid bodies and industrial robots

This project in cooperation with the Volvo Car Corporation has the objective of an automatic planning of collision-free paths for industrial robots. The paths are computed from the initial position up to a final configuration and account for minimum cycles, path lengths, and joint wear. The automatic computations in combination with the visualization, simulation, and verification of an assembly process shorten the setup times required during production. Simulation software for automatic path planning has been developed for the company Volvo which accounts for the kinematics of virtual 3d models and allows for the interaction with a collision tester.



The FCC path planner quickly finds the optimal solution also for the assembly of the center console.

Bioinformatics and System Biology

Today, the biotech and pharmaceutical industry has to face new challenges due to the enormous amounts of biological and medical data. Apart from the handling of these amounts of data, the types of analysis are also considerably differing from the state-of-the-art of a few years ago. Applied research in the fields of "System Biology" and "Bioinformatics" is the key for a better understanding and exploitation of the enormous and complex amounts of data. However, many tools are not adapted to the new situation.

Bioinformatics and biostatistics

Activities of the FCC in the field of bioinformatics include the research, development, and application of computer-aided methods and tools in order to enlarge the exploitability of biological and medical data, which also refers to the query, storage, organization, analysis, and visualization with respect to the data. Bioinformatics combines genetics, mathematics, and computer science in order to allow for the handling of DNA sequences and gene expression data.

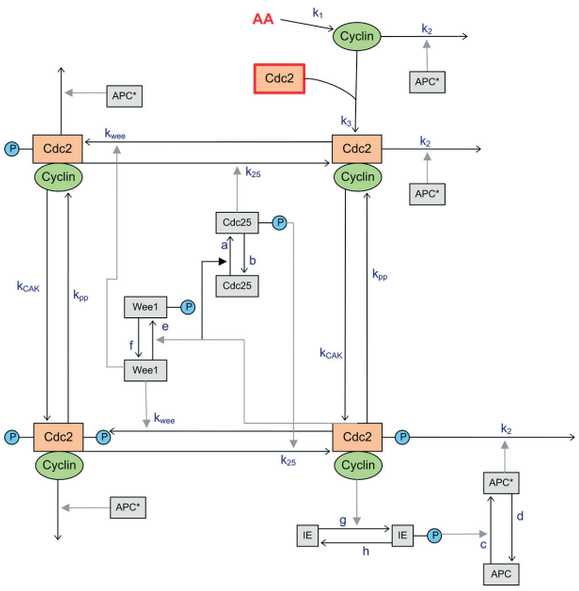
The research group of the FCC is one of the leading developers of SLAM, a software package for species-independent gene search. It has also been a member of the consortiums for the decoding of the genome of mouse and rat.

System biology

"System biology" focuses on the development and application of computation methods and mathematical models for biological systems in close cooperation with academic and industrial partners. The special competence of the FCC refers to the field of control systems and dynamic systems; the institute has special long-term experience with respect to the software development and application of control theory within projects from the engineering and pharmaceutical industry.

Example: The project BIOSIM

BIOSIM is an EU project in cooperation with approximately 40 partners and provided with an overall budget of 10.7 million Euros. The FCC participates in the development of mathematical models for a better description of the control system of glucose insulin in the human body. Besides, we are working on the problem in which way quantitative models can be used for the understanding of the regulation mechanisms of electric activities and hormonal secretions in pancreatic alpha and beta cells.



Screenshot of the software PathwayLab: model of the cell cycle control in frog eggs; the program translates the network to differential equations.

Contact:

Dr. Mats Jirstrand
☎ +46 (0) 31/7 72-42 50
mats.jirstrand@fcc.chalmers.se

Financial and Insurance Mathematics

The research group of financial and insurance mathematics at the FCC has established itself during the previous year and has meanwhile successfully acquired new projects.

In the field of financial mathematics, the successful cooperation with "Front Capital Systems" has been continued. With respect to insurance mathematics, there were primarily two projects: in the project about "Solvency II", cooperation with the Swedish insurance community has been continued, and within the project "Asset and Liability Management" (ALM), cooperation between the FCC and the Fraunhofer ITWM has been intensified.

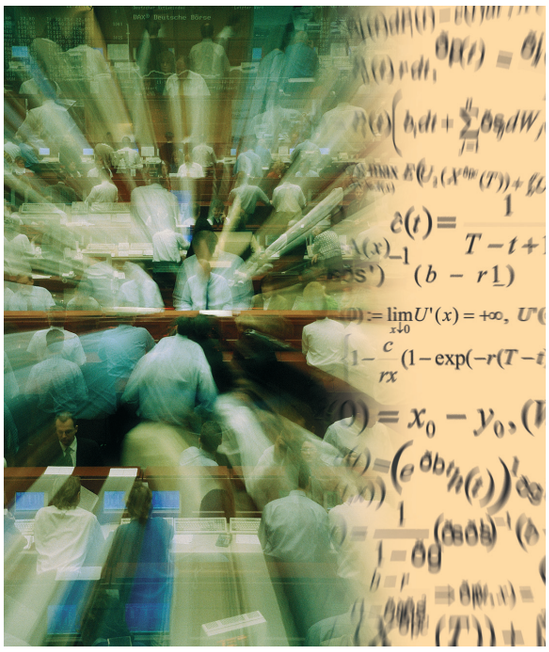
We are pleased to announce that, based on the results and the newly developed simulation tool we have now been able to acquire a further ALM project for this year in cooperation with another Swedish insurance company.

The following will exclusively refer to the common project of the FCC and the ITWM with respect to the second Swedish National Pension Fund (AP2).

The Swedish pension system is based on a legal code regulating the interest on the paid contributions and the increase of pensions. The objective is the balancing of the entire system in such a way that the contributions will not be less than the amount of pensions paid. The predictions which are made are nevertheless exclusively based on the current numbers. Above all, no demographic predictions are used.

The four Swedish National Pension Funds are entitled to reinvest the current surplus funds in such a way that the resulting profits return as high as possible and the system remains constantly balanced as far as possible. This objective is to be controlled regularly by ALM studies. The long-term investment strategy must be examined in order to realize possible changes on the market and to modify the strategy accordingly.

These ALM studies are traditionally carried out by external consultants. Hence, the proceedings with respect to the simulation are a black box for the pension fund. In particular, external consultants do not account for the special properties of the pension system, so that no connection is installed between the developments on the financial markets and the developments within the pension system. The main task of the German-Swedish cooperation project was the representation of these relations by a simulation model.



Contact:

Fredrik Ekstedt
☎ +46 (0) 31/7 72-42 94
fredrik.ekstedt@fcc.chalmers.se

Talks

Andrä, Heiko et al.
Spezifische Strukturoptimierungsmethoden für Gussteile
Workshop »Integrierte Prozess-Simulation zur Optimierung von Gussbauteilen«, Kaiserslautern, April 2004

Andrä, Heiko
Multikriterielle Optimierung von akustisch wirksamen Komponenten
Workshop »Innovative Methoden und Materialien in der Fahrzeugakustik«, Kaiserslautern, September 2004

Andrä, Heiko
Einführung in die Boundary-Element-Methode
TU Kaiserslautern, summer term 2004

Andrä, Heiko
Festigkeitslehre
Berufsakademie Mannheim,
summer term 2004 and winter term 2004/05

Bitsch, Gerd
Ermüdungssimulation für metallische Bauteile
Workshop »Integrierte Prozess-Simulation zur Optimierung von Gussbauteilen« Kaiserslautern, April 2004

Broz, Jochen
Simulation elektrochemischer Systeme unter Butler-Volmer-Kinetik
ITWM-Seminar, Kaiserslautern, June 2004

Caiazzo, Alfonso
Analysis of Lattice-Boltzmann Initialization Routines
ICMMES 2004, Braunschweig, July 2004

Dreßler, Klaus
Betriebsfestigkeit in der Automobilentwicklung
IWM Kolloquium, Freiburg, February 2004

Dreßler, Klaus
Advanced Fatigue Prediction-Trends und Herausforderungen
DaimlerChrysler Corporate Technology Colloquium, Stuttgart, September 2004

Dreßler, Klaus
The invariant approach for load prediction
Customer loading and durability
FCC & Chalmers Göteburg, December 2004

Günther, Marco
Parameter estimation in power networks
STM Jahrestreffen, Stenungssund, October 2004

Hanne, Thomas
Simulationsgestützte Optimierungsverfahren in der Produktionslogistik
SimForum Steyr'04. Profactor Produktionsforschung GmbH, 2004

Hanne, Thomas
Application issues in multiobjective evolutionary algorithms
Dagstuhl-Seminar 04461, »Practical Approaches to Multi-Objective Optimization«, November 2004

Hensel, Hartmut
Dosisberechnung in der Photonen-Strahlentherapie mit deterministischen Transportgleichungen
DKFZ, Heidelberg, July 2004

Hietel, Dietmar
Simulation und Optimierung von Spinn- und Ablageprozessen
19. Hofer Vliesstofftage, Hof, November 2004

Hietel, Dietmar
NESPRI – Nebelfreies Spritzen von Außenfassaden
Workshop-Highlights aus InnoNet, Göttingen, January 2004

Hietel, Dietmar
NESPRI – Nebelfreies Spritzen von Außenfassaden
Gesprächskreis Forschung, Innovation und Technologie im Handwerk, Hannover Messe Industrie, April 2004

Hietel, Dietmar
Simulierte Realität zur Auslegung von Produkten und Produktionsprozessen
14. Sitzung des Themenverbundes NUSIM, Oberhausen, January 2004

Iliev, Oleg
On modeling and simulation of saturated porous media flows
INTAS workshop on Flows in Porous Media, Minsk, May 2004

Iliev, Oleg
Modern methods for solving linear and nonlinear systems
Universität Kaiserslautern, summer term 2004

Iliev, Oleg; Ettrich, Norman; Naumovich, Hanna
On simulation of porous media flows at riverbasin scale
IP Workshop, Berlin, September 2004

Iliev, Oleg; Linn, Joachim; Moog, Mathias; Niedziela, Dariusz; Starikovicius, Vadimas
On the performance of certain iterative solvers for coupled systems arising in discretization of non-Newtonian flow equations
ECCOMAS, Finland, July 2004

Iliev, Oleg; Laptev, Vsevolod; Vasileva, Daniela
On algorithms and software for simulation of flow through oil filters
ECMI, Eindhoven, Netherlands, June 2004

Iliev, Oleg; Linn, Joachim; Moog, Mathias; Niedziela, Dariusz; Starikovicius, Vadimas
On iterative solution of large scale matrix equations arising in discretization of non-Newtonian flow equations
Conference on numerical methods for PDEs, Bourgas, Bulgaria, September 2004

Jegorovs, Jevgenijs
Third order correction to the Helmholtz equation
MMA Conference, Jurmala, June 2004

Kehrwald, Dirk
A Lattice-Boltzmann method for modeling shear-thinning fluids
HYKE-Workshop »Numerical and asymptotic methods for kinetic equations«, Saarbrücken, February 2004

Kehrwald, Dirk
Parallele Gitter-Boltzmann-Simulation komplexer Strömungen
NAFEMS-Seminar »Die Simulation komplexer Strömungsvorgänge«, Wiesbaden, May 2004

Kehrwald, Dirk
Lattice Boltzmann simulation of shear-thinning fluids
ICMMES 2004, Braunschweig, July 2004

Klein, Peter
Die MMM-Toolbox
Workshop der MAVO MMM, Fraunhofer-Zentrale München, November 2004

Korn, Ralf
Lehrerfortbildung »Mathematik und Ökonomie«
Düsseldorf, January 2004

Korn, Ralf
Worst-case portfolio optimization
Bachelier-Seminar, Paris, France, February 2004

Korn, Ralf
Monte Carlo simulation and American option pricing with forward-backward sde
Imperial College London, England, April 2004

Korn, Ralf
Wider die Götter – Risikomanagement im Wandel der Zeit
Max-Slevogt-Gymnasium Landau, May 2004

Korn, Ralf
Option pricing: an introduction to theoretical models and practical problems
Abdus Salam Institute, Trieste, Italy, March 2004.

Korn, Ralf
Optimal portfolios: new variations of an old theme
RMR Rouen 2004, Université de Rouen, France, June 2004 and
Conference on financial mathematics and insurance, Samos, Greek, September 2004

Korn, Ralf
Continuous-time portfolio optimization
Summer School in Jyväskylä, Finland, August 2004

Korn, Ralf
Moderne Methoden der Portfolio-Optimierung: Probleme der Praxis mit der Theorie
DAA-Nachwuchsworkshop, Reisensburg, August 2004

Korn, Ralf
Credit rating and Basel II
Workshop, METU Ankara, Türkei, September 2004

Korn, Ralf
Derivatives: Introduction and advanced aspects
Workshop, METU Ankara, Turkey, September 2004

Korn, Ralf
Applicability of continuous-time finance: Optimal portfolios with transaction costs
DMV-Tagung, Heidelberg, September 2004

Korn, Ralf
Mathematik und Praxis
Technologie- und Innovationsforum, TU Kaiserslautern, September 2004

Korn, Ralf
Recent Results in continuous-time portfolio optimization
University of Essex, England, December 2004

Krekel, Martin
Optimal portfolios with fixed consumption and income streams
Bachelier Finance Society, Third World Congress, Chicago, USA, July 2004

Kruse, Susanne
Cliquet options under the assumption of stochastic volatility
International Conference on Stochastic Finance 2004, Universidade Técnica de Lisboa, Lissabon, Portugal, September 2004

Kruse, Susanne
Pricing forward starting options in the Heston model on stochastic volatility
Karlsruher Stochastik-Tage 2004, Universität Karlsruhe (TH), Karlsruhe, March 2004

Küfer, Karl-Heinz
Klinische Strahlentherapieplanung – ein komplexes Optimierungsproblem
Intensivtage der IGS Otterberg, January 2004

Küfer, Karl-Heinz
Multicriteria optimization of radiotherapy – mathematical models
Massachusetts General Hospital, Boston (MA), USA, May 2004

Küfer, Karl-Heinz
Multikriterielle Optimierung der Strahlen-therapie – Mathematische Konzepte
Seminar des DKFZ, Heidelberg, June 2004

Küfer, Karl-Heinz
Unschärfe und multikriterielle Optimierung – Modellbeispiele aus der Praxis
BBAW, Berlin, November 2004

Küfer, Karl-Heinz
Radiotherapieplanung – ein komplexes Optimierungsproblem
Seminar des IZWR, Friedrich-Schiller-Universität Jena, December 2004

Küfer, Karl-Heinz; Siedow, Norbert
Bohrplan-Optimierung von Temperierbohrungen im Werkzeug- und Formenbau
Industrieworkshop, Dortmund, June 2004

Kuhnert, Jörg
Finite Poinset Method (FPM): A meshfree approach for incompressible flow simulations
TU Eindhoven, Netherlands, February 2004

Kuhnert, Jörg
Finite Pointset Method for compressible fluids: theory and industrial application for airbags
crashMAT 2004, April 2004

Latz, Arnulf
Stochastic modelling and simulation of particle filtration in microstructures
ECMI-Conference, Eindhoven, Netherlands, July 2004

Latz, Arnulf
Virtuelles Material- und Produktdesign von Filtern und Filtermedien
Kolloquium Filtertechnik, Karlsruhe, April 2004

Latz, Arnulf
Simulation of air filtration in microstructures
Symposium Textile Filter, Chemnitz, March 2004

Latz, Arnulf
Simulation of fluid particle separation in realistic three dimensional fiber structures
Workshop on X-Ray Tomography, 3D Reconstruction, Fluid Dynamic Simulation, Toulouse, France, February 2004

Linn, Joachim
Über den Phasenraum der Folgar-Tucker-Gleichung
Oberseminar »Angewandte Mathematik«, FB Mathematik Universität Saarbrücken, January 2004

Linn, Joachim
The Folgar-Tucker equation as a differential algebraic system: Recent results on the problem of trace conservation
International Symposium on Trends in Application of Mathematics to Mechanics, Darmstadt, August 2004

Linn, Joachim
Fertigungs- und Funktionssimulation für metallische Bauteile
Seminar der IHK Bonn/Rhein-Sieg: »Innovation Aluminium – Technologien für den Mittelstand«, Hydro Aluminium GmbH, December 2004

Linn, Joachim
Gießsimulation mit MAGMASOFT® als »High Performance Computing«-Anwendung
ITWM-Workshop »Integrierte Prozess-Simulation zur Optimierung von Gussbauteilen«, Kaiserslautern, April 2004

Marheineke, Nicole
Turbulence effects on fibre motion in melt-spinning process of nonwovens
Euromech Colloquium, CIRM, Luminy, France, April 2004 und
International Conference on Mathematical Modelling, Addis Ababa, Ethiopia, October 2004

Marheineke, Nicole
Fibre motion in turbulent flows
ECMI-Conference, Eindhoven, Netherlands, June 2004

Marheineke, Nicole
Mathematische Modellierung und Simulation von Faden-Turbulenz-Wechselwirkung
DMV-Jahrestagung, Heidelberg, September 2004

Merten, Dirk
The Ipacs Project: application benchmarks and performance modeling
Workshop on Performance Characterization, Modeling and Benchmarking for Existing and Emerging HPC Systems, Oakland, USA, May 2004

Mohring, Jan; Halfmann Thomas; Broz, Jochen; Zemitis, Aivars; Basso, Giuliano; Lagoni, Per
Automated model reduction of complex gas pipeline networks
PSIG Conference, Palm Springs USA, October 2004

Mohring, Jan; Jegorovs, Jevgenijs
Optimal shape of the reflex tube of a bass loud-speaker
ISMA Conference, Leuven, Belgium, September 2004

Monz, Michael
Multicriteria optimization of radiotherapy – a software prototype
Massachusetts General Hospital, Boston (MA), USA, May 2004

Müller, Marlene
Nonparametric components in discrete choice and generalized regression
Computational Management Science Conference, Neuchatel, Swizerland, April 2004

Müller, Marlene
Redesigning ratings: assessing the discriminatory power of credit scores under censoring
Workshop Credit Risk Models, Mainz, April 2004 und Workshop Risk Analysis in Finance and Insurance, München, June 2004

Nickel, Stefan
Dynamic multi-commodity capacitated facility location
Mathematics of the Supply Chain, Oberwolfach, April 2004

Nickel, Stefan
Planning patient transports in hospitals: Theory and Practice
OR 2004, Tilburg, Netherlands, September 2004

Nickel, Stefan
Territory Design: Algorithms and GIS-Integration
SEIO 2004, Cadiz, Spain, October 2004

Orlik, Julia
Homogenization algorithm for contact problems between bone and prosthesis
Catania, Italy, December 2004

Overbeck, Ludger; Müller, Marlene
Credit Risk Modeling
CASE Distinguished Lecture Series, Berlin, January 2004

Pfreundt, Franz-Josef
IPACS Benchmarks
SC 2004, Pittsburgh, USA, November 2004

Pfreundt, Franz-Josef
Benchmarking Turorial
ISC 2004, Heidelberg, June 2004

Pop, Serban Rares
Stability analysis of the float glass process
ECMI-Conference, Eindhoven, Netherlands, June 2004

Prätzel-Wolters, Dieter
Control theory – An overwiew
Systems biology
Workshop on Life and Material Sciences (2 Lectures), Trieste, March 2004

Rheinländer, Martin
Asymptotic investigation of the Lattice-Boltzmann method and grid coupling
HYKE-Workshop »Numerical and asymptotic methods for kinetic equations«, Saarbrücken, February 2004

Rheinländer, Martin
A consistent grid coupling for Lattice-Boltzmann schemes
ICMMES 2004, Braunschweig, July 2004

Rief, Stefan
Modeling and simulation of dewatering processes in the press section of a paper machine
Simulation and Process Control for the Paper Industry, München, March 2004

Rösch, Ronald
Prüfung texturierter Materialien
IBV-Workshop, Glanerbrug, Netherlands, February 2004

Schladitz, Katja
3d image analysis and modeling of microstructures
Statistical Seminar, Chalmers University of Technology, Göteborg, Sweden, May 2004

Schladitz, Katja
3D-Bildanalyse und Modellierung von Mikrostrukturen
GSF Forschungszentrum für Umwelt und Gesundheit, Neuherberg, June 2004

Schladitz, Katja
Charakterisierung der Mikrostruktur von Filtermaterialien
25. BV-Forum, Kaiserslautern, July 2004

Schladitz, Katja
Characterization of the microstructure of filter materials
Workshop »Spatial statistics, image analysis and signal processing within biology and technology«, Smögen, Sweden, August 2004

Schladitz, Katja
Geometric analysis of 3D images of microstructures
Workshop »X ray tomography, 3D reconstruction, fluid dynamic simulation, towards realistic quantitative tools for the engineering of fibrous filters«, Toulouse, France, February 2004

Schröder, Michael
Market areas of competitive facilities under gravity-based attraction and continuous demand
EWGLA XV, Saarbrücken, September 2004

Schulz, Volker
Optimierte Materialauswahl akustischer Komponenten im Fahrzeugbau durch den Einsatz von Computersimulationen
Werkstofftag, Köln, November 2004

Schulz, Volker
Modeling of a resin-bond nonwoven
P&G Global Modeling Days, Schwalbach, October 2004

Siedow, Norbert
Simulationsprobleme der Glasindustrie
Treffen Verbund Werkstoffe/Bauteile, Kaiserslautern, March 2004

Siedow, Norbert
Simulation des Strahlungstransports
Seminar Fraunhofer IISB, Erlangen, December 2004

Siedow, Norbert; Grosan, Teodor
A fast radiative heat transfer model for semi-transparent materials
Fluent CFD Konferenz, Bingen, September 2004

Siedow, Norbert; Wegener, Raimund
Wavelength averaged (gray) absorption coefficient for radiative transfer in glass
ECMI-Conference, Eindhoven, June 2004

Steiner, Konrad
Rechnergestützte Simulation - Das Werkzeug der Zukunft für eine prozessintegrierte Material- und Produktgestaltung
ISC Bronnbach, April 2004

Steiner, Konrad
Lattice Boltzmann methods for complex fluids in complex structures
Conf. Num. Meth. PDEs, Slanchev Bryag, Bulgaria, September 2004

Tiwari, Sudarshan
Domain decomposition method based on particle codes for continuum and rarefied gas flows
37th AIAA Thermophysics Conference, Portland (OR), USA, June 2004

Tiwari, Sudarshan; Kuhnert, Jörg

Finite Pointset Method (FPM) for two-phase and low mach number flows
First Indo-German Conference on PDE, Scientific Computing and Optimization in Applications, Trier, September 2004

Tramecon, Alain; de Luca, Patrick; Kuhnert, Jörg
Finite Pointset Method: A meshfree method for continuum mechanics, first applications in the LCM field
JST 2004, Le Havre, France, December 2004

Trinkaus, Hans
A spreadsheet method for navigating in decision spaces
MCDM 2004, Whistler, B.C., Canada, August 2004

Trinkaus, Hans
knowCube for navigating in decision spaces
OR 2004, Tilburg, Netherlands, September 2004

Trinkaus, Hans
Unschärfe und Subjektivität – Entscheidungsfindung in der Praxis
BBAW, Berlin, November 2004

Wawrenczuk, Arkadiusz
FPM + radiation = meshfree approach in radiation problems
ECMI Conference, Eindhoven, Netherlands, June 2004

Wegener, Raimund
Mathematik als Technologie
WRO-Tagung, Oberwolfach, March 2004

Wiegmann, Andreas
Virtual material design with GeoDict and free boundary motion using LevelDict
Fraunhofer UMSICHT, Oberhausen, January 2004

Wiegmann, Andreas
Simulation und Optimierung von Filtern
Fraunhofer-NUSIM-Verband, Frankfurt, July 2004

Wiegmann, Andreas
Material generation, filtration simulation and virtual filter material design
NETIAM-Workshop, Kaiserslautern, September 2004

Wiegmann, Andreas
Simulation der Tiefenfiltration durch Vliesstoffe
19. Hofer Vliesstofftage, November 2004

Günther, Marco
Mathematik für Ingenieure
Fachhochschule Wiesbaden, winter term 2003/04

Korn, Ralf
Continuous-time portfolio optimization in finance and insurance
L'Université Louis Pasteur, Straßburg, France, winter term 2004/05

Kruse, Susanne
Statistik – Deskriptive Statistik
Fachhochschule Ludwigshafen, Ludwigshafen/Rhein, March bis June 2004

Kruse, Susanne
Statistik – Wahrscheinlichkeitstheorie und Induktive Statistik
Fachhochschule Ludwigshafen, Ludwigshafen/Rhein October bis December 2004

Küfer, Karl-Heinz
Theory of polyhedra and graphs
TU Kaiserslautern, summer term 2004

Küfer, Karl-Heinz
Probability and algorithms
TU Kaiserslautern, winter term 2004/05

Latz, Arnulf
Aspekte der Unordnung in kondensierter Materie
Universität Mainz, winter term 2004/05

Melo, Teresa
Optimization methods for logistics systems planning
TU Kaiserslautern, winter term 2004/05

Müller, Marlene
Semiparametric methods
Humboldt-Universität zu Berlin, WS 2003/04

Müller, Marlene
Non- and semiparametric modeling I
Humboldt-Universität zu Berlin, WS 2004/05

Schladitz, Katja; Rauhut, Markus; Krüger, Kai; Jablonski, Andreas
Kompaktkurs »Topology and image analysis«,
TU Kaiserslautern, March 2004

Schröder, Michael
Competitive location theory: models and algorithms
TU Kaiserslautern, summer term 2004

Schulz, Volker
Technische Mechanik I
Fachhochschule Mannheim – Hochschule für Technik und Gestaltung, winter term 2004/05

Publications

Andrä, Heiko et al.
Spezifische Strukturoptimierungsverfahren für Gießereien
Burblies, A.; Sauter, J. (Eds.): Simulation in der Produkt- und Prozessentwicklung, pp. 165-170, Fraunhofer IRB Verlag, Stuttgart, 2004

Armbrust, Ove; Berlage Thomas; Hanne, Thomas; Lang, Patrick; Münch, Jürgen; Neu, Holger; Nickel, Stefan; Rus, Ioana; Sarishvili, Alex; Van Stockum, Sascha; Wirsen, Andreas
Simulation-based software process modeling and evaluation
Advances in SE&KE – World Scientific Publishing, Singapore, 2004

Bitelli, Marco; Flury, Markus; Campbell, Gaylon S.; Schulz, Volker
Characterization of a spiral-shaped time domain reflectometry probe
Water Resources Research, vol. 40, W09205, doi: 10.1029/2004WR003027, 2004

Caiazzo, Alfonso
Analysis of Lattice-Boltzmann initialization routines
Handed in: Journal of Statistical Physics

Ciegis, Raimondas; Iliev, Oleg; Rief, Stefan; Steiner, Konrad
On modelling and simulation of different regimes for liquid polymer moulding
J. Comp. Meth. Appl. Math., 4, pp. 131-162, 2004
Also: Berichte des Fraunhofer ITWM, no. 63, 2004

Dreyer, Alexander
Combination of symbolic and interval-numeric methods for analysis of analog circuits
Proc. 8th International Workshop on Symbolic Methods and Applications in Circuit Design, Wroclaw, Polen, September 2004

Westkämper, Engelberg; Klein, Peter; Gottwald, Bernhard; Sommadossi, Silvana; Gemmler, Armin
Die Molekulardynamik-Methode (MD) als Beitrag zum gezielten Engineering von Beschichtungsprozessen am Beispiel des Sputterns
Tagungsband der Oberflächentage, Dresden 2004

Ettrich, Norman; Steiner, Konrad; Thomas, Martin; Rothe, René
Surface models for coupled modeling of runoff and sewer flow in urban areas
Proceedings, 6th International Conference on Urban Drainage Modeling, September 2004

Feldmann, Sven; Lang, Patrick
A least squares approach to reduce stable discrete linear systems preserving their stability
Linear Algebra and its Applications, no. 381, pp. 141-163, 2004

Gal, Tomas; Hanne, Thomas
Nonessential objectives and the LOOPS method in MCDM
European Journal of Operational Research 2004

Gaspar, Francisco; Iliev, Oleg; Lissabona, Francisco; Naumovich, Hanna; Vabishchevich, Petr
On numerical solution of 1D poroelasticity equations in a multilayered domain
Berichte des Fraunhofer ITWM, no. 66, 2004

Godehardt, Michael; Sych, Tetyana; Schladitz, Katja
Analysis of volume images - a tool for understanding the microstructure of foams
Symposium »Cellular Metals and Polymers«, Fürth 2004

Grosan, Teodor; Pop, Ioan
Radiation effect on free convection over a vertical flat plate embedded in a non-Newtonian fluid saturated porous medium
Handed in: Int. J. Appl. Mech. Engng., 2004

Grosan, Teodor; Pop, Ioan
Radiation effects on free convection from a vertical cone embedded in a fluid saturated porous medium
Handed in: Studia Univ. Babes-Bolyai, Mathematica, 2004

Grosan, Teodor; Postelnicu, Adrian; Pop, Ioan
Free convection boundary layer over a vertical cone in a non-Newtonian fluid saturated porous medium with internal heat generation
Technische Mechanik, 24, pp. 91-104, 2004

Günther, Marco; Klar, Axel; Materne, Thorsten; Wegener, Raimund
Multivalued fundamental diagrams and stop and go waves for continuum traffic flow equations
SIAM Journal on Applied Mathematics, 64 (2), pp. 468-483, 2003

Hamacher, Horst; Korn, Elke; Korn, Ralf; Schwarze, Silvia
Mathematik und Ökonomie
Universum Verlag, Wiesbaden, 2004

Hanne, Thomas
Nonessential objectives and network-based multicriteria decision making
Ferreira, M. A. M., Menezes R.; Catanas, F. (Eds.): Temas em Métodos Quantitativos, vol. 4, pp. 153-168, Silabo, Lissabon, 2004

Hanne, Thomas; Neu, Holger
Simulating Human Resources in Software Development Processes
Berichte des Fraunhofer ITWM, no. 64, 2004

Hanne, Thomas, Nickel, Stefan
A multiobjective evolutionary algorithm for scheduling and inspection planning in software development projects
Feature Issue of European Journal of Operational Research on Scheduling with Multiple Objectives, 2004

Härdle, Wolfgang; Müller, Marlene; Sperlich, Stefan; Werwatz, Axel
Nonparametric and semiparametric models
Springer-Verlag, Heidelberg, 2004

Helfen, Lukas; Baumbach, Tilo; Cloetens, Peter; Stanzick, Heiko; Schladitz, Katja; Banhart, John
Investigation of the pore initiation process in metal foams by synchrotron-radiation computed tomography
Handed in: Applied Physical Letters, 2004

Hensel, Hartmut; Iza-Teran, Rodrigo; Siedow, Norbert
Deterministic model for dose calculation in photon radiotherapy
Handed in: Physics in Medicine and Biology, 2004

Hietel, Dietmar; Junk, Michael; Kuhnert, Jörg; Tiwari, Sudarshan
Meshless methods for conservation laws
Analysis and Numerical Methods for Conservation Laws, Springer-Verlag, Heidelberg, New York, 2004

Iliev, Oleg; Laptev, Vsevolod
On numerical simulation of flow trough oil filters
J. Computers and Visualization in Science, 6, pp. 139-146, 2004

Iliev, Oleg; Linn, Joachim; Moog, Mathias; Niedziela, Dariusz; Starikovicius, Vadimas
On the performance of certain iterative solvers for coupled systems arising in discretization of non-Newtonian flow equations
Neittaanmäki et al. (Eds.): Proc. ECCOMAS 2004
Also: Berichte des Fraunhofer ITWM, no. 62, 2004

Iliev, Oleg; Mikelic, Andro; Popov, Petr
Fluid structure interaction problems in deformable porous media: Toward permeability of deformable porous media
Berichte des Fraunhofer ITWM, no. 65, 2004

Mohring, Jan; Broz, Jochen; Halfmann, Thomas; Zemitis, Aivars; Basso, Giuliano; Lagoni, Per
Automated Model Reduction of Complex Gas Pipeline Networks
Pipeline Simulation Interest Group (PSIG 2004), Palm Springs, USA, October 2004

Jegorovs, Jevgenijs
Third order correction to the Helmholtz equation
Proceedings of MMA Conference, Jurmala, Latvia, 2004

Kalcsics, Jörg; Nickel, Stefan; Schröder, Michael
Towards a Unified Territory Design Approach – Applications, Algorithms and GIS Integration
TOP, Spanish Statistical and Operations Research Society (SEIO), invited review, submitted for publication

Kaßbohm, Sven; Müller, Wolfgang H.; Feßler, Robert
Attenuation factors for the use with Fourier series for computing periodic structures with arbitrary stiffness distribution
Handed in: Computational Material Science, 2004

Kaßbohm, Sven; Müller, Wolfgang H.; Feßler, Robert
Fourier series for computing the response of periodic structures with arbitrary stiffness distribution
Computational Materials Science, 2004

Keck, Rainer; Hietel, Dietmar
A projection technique for incompressible flow in the meshless Finite Volume Particle Method
Advances in Computational Mathematics, Special Issue on Meshless Methods, 2004

Kehrwald, Dirk
Parallel Lattice-Boltzmann simulation of complex flow
Tagungsband des NAFEMS-Seminars »Die Simulation komplexer Strömungsvorgänge«, Wiesbaden, May 2004

Kehrwald, Dirk
Lattice-Boltzmann simulation of shear-thinning fluids
Handed in: Computers & Fluids

Klar, Axel; Wegener, Raimund
Traffic flow: models and numerics
Degond, P. et al. (Eds.): Modeling and Computational Methods for Kinetic, pp. 219-258, 2004, Birkhäuser

Korn, Ralf
Realism and practicality of transaction cost approaches in continuous-time portfolio optimization: The scope of the Morton-Pliska approach
Mathematical Methods of Operations Research 60 (2), pp. 165-174

Korn, Ralf; Kraft, Holger
On the stability of continuous-time portfolio problems with stochastic opportunity set
Mathematical Finance, 14(3), pp. 403-414, 2004

Korn, Ralf; Kruse, Susanne
Einfache Verfahren zur Bewertung von inflationsgekoppelten Finanzprodukten
Blätter der DGVFM, Band XXVI, Heft 3, pp. 351-367, May 2004

Korn, Ralf; Menkens, Olaf
Worst-case investment with applications for banks and insurance companies
Abschlussband des DFG-Schwerpunkts »Interagierende stochastische Systeme hoher Komplexität«

Korn, Ralf
Worst-case scenario investment for insurers
Insurance Mathematics and Economics, 2004

Krekel, Martin; de Kock, Johan; Korn, Ralf; Man, Tin-Kwai
An analysis of pricing methods for basket options
WILMOTT, May 2004

Kuhnert, Jörg; Tiwari, Sudarshan; Subramanyam, Annadata Bhaskar; Sundar, Subhia
On parallelization and load balancing aspects of Finite Poinset Method
Handed in: SIAM Journal on Scientific Computing, 2004

Latz, Arnulf
Filtermaterialdesign per Software
Litus 1/04, pp. 68-69, 2004

Latz, Arnulf; Wiegmann, Andreas
Virtuelles Filtermaterialdesign mit GeoDict / FilterDict
Laboratory IT User Services, 1, 2004

Latz, Arnulf; Wiegmann, Andreas
Simulation der Luftfiltration in Mikrostrukturen
Proceedings des Symposium Textile Filter, Chemnitz, March 2004

Linn, Joachim
On the frame-invariant description of the phase space of the Folgar-Tucker equation
A. Buikis, R. Ciegis, A.D. Fitt (Eds.): Progress in Industrial Mathematics at ECMI 2002, pp. 327-332, Springer (2004); also: Berichte des Fraunhofer ITWM, no. 41

Linn, Joachim
The Folgar-Tucker model as a differential-algebraic system for fiber orientation calculation
Proceedings of the STAMM conference 2004

Marheineke, Nicole
Modelling of turbulence effects on fibre motion
Progress in Industrial Mathematics at ECMI, Springer, 2004

Mohring, Jan; Halfmann Thomas; Broz, Jochen; Zemitis, Aivars; Basso, Giuliano; Lagoni Per
Automated model reduction of complex gas pipeline networks
Proceedings of PSIG Conference, Palm Springs, USA, October 2004

Mohring, Jan; Jegorovs, Jevgenijs
Optimal shape of the reflex tube of a bass loudspeaker
Proceedings of ISMA Conference, Leuven, Belgium 2004

Moog, Mathias; Linn, Joachim; Iliev, Oleg
Flow simulation of the plastic injection moulding process
Tagungsband des NAFEMS-Seminars »Die Simulation komplexer Strömungsvorgänge«, Wiesbaden, May 2004

Müller, Marlene
Generalized Linear Models
J. Gentle, W. Härdle, Y. Mori (Eds.): Handbook of Computational Statistics, Volume I: Concepts and Fundamentals. Springer-Verlag, Heidelberg, 2004

Nickel, Stefan; Melo, Teresa; Saldanha da Gama, Francisco
Dynamic multi-commodity facility location: a mathematical modeling framework for strategic supply chain planning
D. Ahr; R. Fahrion; M. Oswald; G. Reinelt (Eds.): Operations Research Proceedings 2003, pp. 95-102, Springer-Verlag, Berlin, 2004

Niedziela, Dariusz; Latz, Arnulf; Iliev, Oleg
Simulations of viscoelastic polymer melts flows
Tagungsband des NAFEMS-Seminars »Die Simulation komplexer Strömungsvorgänge«, May 2004

Ohser, Joachim; Schladitz, Katja; Koch, Karsten; Nöthe, Michael
Diffraction by image processing and its application in materials science
Berichte des Fraunhofer ITWM, no. 67, 2004

Orlik, Julia
Homogenization for contact problems with periodically rough surfaces
Berichte des Fraunhofer ITWM, no. 59, 2004

Orlik, Julia
Homogenization of strength, fatigue and creep durability of composites with near periodic structure
Mathematical Models and Methods in Applied Sciences (revised in December 2004)

Panda, Satyananda; Feßler, Robert
A computer algebra tool for the stability analysis of interfacial flows
FM 182 International Mech. Engineering Conference & Expo. IMEC 2004

Plontke, Stefan; Siedow, Norbert; Hahn, Hartmut; Wegener, Raimund; Zenner, Hans-Peter; Salt, Alec
1D- und 3D-Computer-Simulationen zur Versuchsplanung und -interpretation bei pharmakokinetischen Studien am Innenohr nach lokaler Medikamentenapplikation
Altex, 21(3), pp. 77-85, 2004

Pop, Serban Rares
Two dimensional short wave stability analysis of the floating process
Erscheint in: Progress in Industrial Mathematics at ECMI , Springer-Verlag, Berlin, 2004

Pop, Serban Rares
Stability analysis of two superposed fluids in the presence of a large horizontal gradient
Handed in: Heat and Mass Transfer, Springer-Verlag, 2004

Pop, Serban Rares; Grosan Teodor; Pop Ioan
Radiation effects on the flow near the stagnation point of a stretching sheet
Handed in: Technische Mechanik, 2004

Repsch, Matthias; Huber, Ulrich; Maier, Martin; Rief, Stefan; Kehrwald, Dirk; Steiner, Konrad
Process simulation of LPM (Liquid Polymer Moulding) in special consideration of fluid velocity and viscosity characteristics
Handed in: Proceedings of FPCM-7, 2004

Repsch, Matthias; Huber, Ulrich; Rief, Stefan; Kehrwald, Dirk; Steiner, Konrad
New perceptions regarding the influence of RTM – process parameters on the microstructure of a non-crimp fibre fabric bed
Handed in: Composites Part A

Rheinländer, Martin
A consistent grid-coupling for Lattice-Boltzmann schemes
Handed in: Journal of Statistical Physics

Rotaru, Tiberiu; Nägeli, Hans-Heinrich
Dynamic load balancing by diffusion in heterogeneous systems
J. Parallel Distrib. Comput. 64, 4, 2004

Rotaru, Tiberiu; Nägeli, Hans-Heinrich
Fast algorithms for fair dynamic redistribution in heterogeneous environments
Appl. Numer. Math., 49 (1), 2004

Scherrer, Alexander; Küfer, Karl-Heinz; Monz, Michael; Alonso, Fernando; Bortfeld, Thomas,
IMRT planning on adaptive volume structures – a breakthrough in computational complexity
Berichte des Fraunhofer ITWM, no. 60

Schmitt, Theo G.; Thomas, Martin; Ettrich, Norman
Analysis and Modeling of Flooding in Urban Drainage Systems
Journal of Hydrology, 299, pp. 300-311, 2004

Schmitt, Theo G.; Thomas, Martin; Ettrich, Norman
Assessment of urban flooding by dual drainage simulation model RisUrSim
Proceedings, 6th International Conference on Urban drainage modeling, September 2004

Schröder, Michael; Heinemann, Friedrich; Kruse, Susanne; Meitner, Matthias
GPD-linked Bonds as a Financing Tool for Developing Countries and Emerging Markets
ZEW (Zentrum für Europäische Wirtschaftsforschung) Discussion Paper no. 04-64, 2004

Siedow, Norbert; Lochegnies Dominique; Grosan, Teodor; Romero, Eric
Application of a new method for radiative heat transfer in flat glass tempering
Handed in: ACERS, 2004

Slavov, Vladimir; Dimova, Stefka; Iliev, Oleg
Phase-field method for 2D dendritic growth
Lecture Notes in Computer Science, 2907, pp. 404-411, Springer-Verlag, 2004

Stets, Wolfram; Hartmann, Dierk; Ohser, Joachim; Taeubner, Kai
Klassifizierung der Morphologie von Lamellengraphit im Gefüge von Gusseisen mit Lamellengraphit
Gießerei, pp. 20-30, 9/2004

Thomas Halfmann; Tim Wichmann
Symbolic methods in industrial analog circuit design
Scientific Computing in Electrical Engineering (SCEE 2004), Capo D'Orlando, Italy, September 2004

Tiwari, Sudarshan; Kuhnert, Jörg
Grid free method for Poisson equation
Buchbeitrag zu Wavelet Analysis and Apllications, New Age International (P), Ltd. Publishers (2004)

Tiwari, Sudarshan; Kuhnert, Jörg
A numerical scheme for solving incompressible and low mach number flows by Finite Pointset method
Springer Lecture Notes in Computational Science and Engineering, 2004

Tiwari, Sudarshan; Kuhnert, Jörg
Modeling of two phase flows with surface tension by Finite Pointset Method (FPM)
Handed in: J. Comp. App. Math., 2004

Trinkaus, Hans L., Hanne, Thomas
knowCube: a visual and interactive support for multicriteria decision making
Computers & Operations Research, 32, pp. 1289-1309, 2005

Velásquez, Rafael; Melo, Teresa
Solving a large-scale dynamic facility location problem with variable neighbourhood and token ring search
Proceedings of the 39th Annual Conference of the Operational Research Society of New Zealand, November 2004

Wiegmann, Andreas; Latz, Arnulf; Rief, Stefan
Simulation der Tiefenfiltration durch Vliesstoffe
Proceedings der 19. Hofer Vliesstofftage, November 2004

Wirsen, Andreas; Lang, Patrick; Humer, Matthias
Systems for monitoring and analyzing torsional vibrations in turbine generator shaft lines
Proceedings of 16th International Conference on Electrical Machines, September 2004, Krakau, Poland

Scientific Graduation Theses

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

Admassi Aberra, Tesfaya
Topology preserving skeletonization of 2d and 3d binary images
Master thesis, TU Kaiserslautern, FB Mathematik

Amirbekyan, Artak
Modelling of deflectometric imaging for surface quality evaluation
Master thesis, TU Kaiserslautern, FB Mathematik

Bornhofen, Sandra
The waveform-relaxation method for the numerical solution of differential-algebraic equations
Diploma thesis, TU Kaiserslautern, FB Mathematik

Dalheimer, Matthias
Competitive Scheduler
Diploma thesis, TU Kaiserslautern, FB Wirtschaftsingenieurwesen

Fehsenfeld, Beate
Strangeness-free DAE systems and their numerical treatment
Diploma thesis, TU Kaiserslautern, FB Mathematik

Feitig, Stefan
Model predictive control
Diploma thesis, TU Kaiserslautern, FB Mathematik

Flores Cantu, Hector
Modeling and optimizing solidification processes
Master thesis, TU Kaiserslautern, FB Mathematik

Maus, Benjamin
Approximation of non-classically damped systems
Bachelor thesis, TU Kaiserslautern, FB Mathematik

Montalvo Urquizo, Jonathan
Analysis and optimization of an engine mounting system with respect to comfort
Master thesis, TU Kaiserslautern, FB Mathematik

Muntz, Sabine
Simulation of fluid structure interaction in porous deformable media
Diploma thesis, TU Kaiserslautern, FB Mathematik

Novikovs, Andrejs
Effects of grid distortion on numerical solution of certain hyperbolic equations
Master thesis, TU Kaiserslautern, FB Mathematik

Ostrovska, Arina
Space-time Finite Element approximation and numericalsolution of hereditary linear viscoelasticity problems
Diploma thesis, TU Kaiserslautern, FB Mathematik

Panagiotis, Koutsovasilis
Adapting Macro-Model Techniques to DAE Systems
Master thesis, TU Kaiserslautern, FB Mathematik

Sasi, Sarath
High quality surface meshes for sintering simulations
Master thesis, IIT Madras

Schick, Christian
A mathematical analysis of foam films
Dissertation, TU Kaiserslautern, FB Mathematik

Steinebach, Jessica
Heuristic algorithms for a capacitated hub location problem in postal delivery networks
Diploma thesis, TU Kaiserslautern, FB Mathematik

Strautins, Uldis
Investigation of fiber orientation dynamics within the Folgar-Tucker model with hybrid closure
Master thesis, TU Kaiserslautern, FB Mathematik

Sych, Tetyana
Estimation of geometric characteristics of foam structures
Master thesis, TU Kaiserslautern, FB Mathematik

Teichmann, Emanuel
Numerical solution of three-dimensional topology optimization problems in elasticity
Diploma thesis, TU Kaiserslautern, FB Mathematik

Velásquez, Rafael
Solving a large-scale dynamic facility location problem with variable neighborhood search and token ring search
Diploma thesis, TU Kaiserslautern, FB Mathematik

Voegeli, Annette
Optimierungsverfahren für ein Hochleistungs-Sortiersystem
Diploma thesis, Philipps-Universität Marburg, FB Mathematik und Informatik

Wagner, Björn
Entwicklung eines Ansatzes zum hochperformanten Zugriff auf große, verteilte n-dimensionale Bilddaten am Beispiel zweier Kernalgorithmen aus der 3D-Bildanalyse
Diploma thesis, TU Kaiserslautern, FB Informatik

Wichmann, Tim
Symbolische Reduktionsverfahren für nichtlineare DAE-Systeme
Dissertation, TU Kaiserslautern, FB Mathematik

Winterfeld, Anton
Maximizing volumes of lapidaries by use of hierarchical GSIP-models
Diploma thesis, TU Kaiserslautern, FB Mathematik

Zimmer, Peter
Comparative evaluation of distributed filesystems
Diploma thesis, TU Kaiserslautern, Fachbereich Informatik

Participation on Fairs and Conferences

Abschlusskolloquium der Fraunhofer-WISA »Magnesium Leichtbau«
Rüsselsheim, June 2004 (Poster)

Aktionstag »Teamarbeit für Deutschland« – Eine Initiative des Bundesministeriums für Wirtschaft und Arbeit
Kaiserslautern, May 2004, Exhibitor

Automobilzulieferer Baden-Württemberg
Stuttgart, November 2004, Exhibitor

Bachelier Society, Third World Congress
Chicago (IL), USA, July 2004, Lecture

CIME Summer School »Stochastic Geometry«
Martina Franca, Italy, September 2004, Participation

CompStat 2004
Prag, Czechia, August 2004, Invited Session Organizer

Computational Management Science Conference
Neuchatel, Swizerland, April 2004, Lecture

Control 2004
Sinsheim, May 2004, Exhibitor

DMV-Tagung »Leichtbau und Betriebsfestigkeit«
München, October 2004, Participation

e_GASGRID Workshop
Brüssel, Belgium, June 2004, Lecture

EAGE
Paris, France, June 2004, Exhibitor and Participation

ECMI-Conference
Eindhoven, Netherlands, June 2004, Lectures

Entwurfsplattformen komplexer angewandter Systeme und Schaltungen (EkompaSS), 3. Workshop
Hannover, May 2004, Software presentation »Analog Insydes« and Poster

Euromold
Frankfurt, December 2004, Exhibitor

FEST Workshop
Kaiserslautern, October 2004, Lecture and Participation

Future Forum – Der Zukunftskongress für Jugendliche
Schorndorf, November 2004, Lecture

Glasstec
Düsseldorf, November 2004, Exhibitor

HYKE-Workshop »Numerical and asymptotic methods for kinetic equations«
Saarbrücken, February 2004, Lectures

ICMMES 2004
Braunschweig, July 2004, Lectures

Industrie-Seminar der Universität Dortmund
Dortmund, May 2004, Lectures

International Conference on »Spatial Point Process Modeling and its Applications«
Benicassim, Castellon, April 2004, Participation

International Conference on Electrical Machines
Krakau, Poland, September 2004, Poster

International Conference on Stochastic Finance 2004
Lissabon, Portugal, September 2004, Lecture

International MAGMASOFT User Meeting
Königswinter, October 2004, Participation and Exhibitor

Karlsruher Stochastik-Tage, 6th German Open Conference on Probability and Statistics
Karlsruhe, March 2004, Lecture and Participation

Lastdaten – Analyse, Bemessung und Simulation
Workshop, Kaiserslautern, November 2004, Organizer, Lectures

MAGMA-Forum »Eigenschaften gegossener Leichtmetallbauteile«
Aschaffenburg, May 2004, Participation

MAGMA-Seminar »Gusseisen – ein Werkstoff mit Zukunft«
Leipzig, May 2004, Participation

Materialica
München, September 2004, Exhibitor

Mathematik-Workshop
Paderborn, October 2004, Participation

Medica
Düsseldorf, November 2004, Exhibitor

Motor ship »Technik« during »Jahr der Technik«
On the river Rhine, June-September 2004, Exhibitor

NAFEMS-Seminar »Die Simulation komplexer Strömungsvorgänge«
Wiesbaden, May 2004, Exhibitor and Lectures

NAFEMS-Tagung »Analyse von Mehrkörper-systemen«
Wiesbaden, October 2004, Participation

Nano 2004, 7th International Conference on Nanostructured Materials
Wiesbaden, June 2004, Participation

NETIAM Workshop »Complexity at the molecular level«
Eindhoven, Netherlands, December 2004, Participation and Co-Organizer

NETIAM Workshop »Modelling criminality in the urban environment«
Florenz, Italy, June 2004, Participation and Co-Organizer

NETIAM Workshop »Modelling the business environment«
Ventspils, Latvia, August 2004, Participation and Co-Organizer

NETIAM-Workshop »Challenges in visualisation, simulation and design for virtual porous materials«
Kaiserslautern, September 2004, Lecture and Organizer

Schulung »Intelligente Kameras«
Puchheim, July 2004, Participation

Spatial Statistics, Image Analysis and Signal Processing within Biology and Technology
Smögen, Sweden, August 2004, Lecture

Supercomputing SC 2004
Pittsburgh (PA), USA, November 2004, Exhibitor

Symposium Neue Materialien: »Cellular Metals and Polymers«
Fürth, October 2004, Poster

Tag der Mathematik für Schüler
TU Kaiserslautern, FB Mathematik, July 2004, Exhibitor and Lectures

Technologie- und Innovationsforum PFALZ
Kaiserslautern, September 2004, Exhibitor and Lecture

Schüler-Technik-Tag
TU Kaiserslautern, May 2004, Exhibitor

UseR! 2004 Konferenz
Wien, Austria, May 2004, Participation

VDI Konferenz »Berechnung im Fahrzeugbau«
Würzburg, September 2004, Participation

Workshop »X-ray tomography, 3D reconstruction, fluid dynamic simulation, towards realistic quantitative tools for the engineering of fibrous filters«
Toulouse, France, February 2004, Lecture

Guests

Workshop »Simulation und Design von Filtern und Filtermaterialien«
Kaiserslautern, September 2004, Organizer and Lectures

Workshop »Credit Risk Models«
Mainz, April 2004, Lecture

Workshop »Industrielle Bildverarbeitungssysteme (IBV)«
Glanerbrug, Netherlands, February 2004, Lecture

Workshop »Innovative Methoden und Materialien in der Fahrzeugakustik«
Kaiserslautern, September 2004, Organizer and Lectures

Workshop »Integrierte Prozess-Simulation zur Optimierung von Gussbauteilen«
Kaiserslautern, April 2004, Organizer and Lectures

Workshop on Risk Analysis in Finance and Insurance
München, June 2004, Participation

Zulieferer Innovativ
Ingolstadt, July 2004, Exhibitor

12th Summer School in Image Processing
Graz, Österreich, July 2004, Participation

19. Hofer Vliesstofftage
November 2004, Exhibitor and Lectures

24. Heidelberger Bildverarbeitungsforum »Automatisierte optische Messtechnik und Bildverarbeitung«
Stuttgart, March 2004, Participation

25. Heidelberger Bildverarbeitungsforum »Mathematische Methoden für die Bildverarbeitung«
Kaiserslautern, July 2004, Organizer

26. Heidelberger Bildverarbeitungsforum »Sichtbarmachen von Materialeigenschaften für die quantitative Bildanalyse«
Hanau, November 2004, Participation

38. DGM Metallographietagung
Bochum, September 2004, Poster

43. Internationale Chemiefasertagung
Dornbirn, Österreich, September 2004, Exhibitor

7th Int. Conference on Biaxial/Multiaxial Fatigue and Fracture
Berlin, June 2004, Participation

Amstutz, Samuel (CNRS – Laboratoire MIP, Université Paul Sabatier, Toulouse, France)
Strömungsdynamik, Strukturmechanik, Elektromagnetismus, Bildverarbeitung
October 2004 to June 2005

Bazhlekov, Ivan (TU Eindhoven, Netherlands)
Mehrphasenströmung, Methode der Randelemente
February 2004

Ewing, Richard (Texas A&M University, College Station, USA):
Strömung in porösen Medien
February 2004

Geerdes, Hans-Florian (ZIB Berlin)
Optimierung
May 2004

di Giovanni, Luigi (Universität Brüssel, Belgien)
Delay managenemt in public transport
July 2004

Hylla, Timo (Universität Trier)
Optimierung
October to November 2004

Kumar, Ratish (Indien)
Viskoelastizität
May to July 2004

Laporte, Gilbert (Universität Montreal, Kanada)
Vehicle routing
June 2004

Lazarov, Raytco (Texas A&M Univeristy, College Station, USA)
Methode der Finiten Elemente, Methode der Finite Volumen, Strömung in porösen Medien
June 2004

Li, Zhilin (North Carolina State University, Raleigh, USA)
Immersed-Interface-Methoden
July 2004

Masmoudi, Mohamed (CNRS – Laboratoire MIP, Université Paul Sabatier, Toulouse, France)
Topologieoptimierung
June 2004

Mikelic, Andro (Université Claude Bernard Lyon 1, Lyon, France)
Homogenisierung
February 2004

Patel, Danesh Kumar
Partikelmethoden
April to July 2004

Saldanha da Gama, Francisco (Universität Lissabon, Portugal)
Discrete facility location
September 2004

Sheppard, Adrian (Australian National University, Canberra, Australien)
Poren-Netzwerkmodelle für Mehrphasenströmungen
September to October 2004

Slavov, Vladimir (Universität Sofia, Bulgarien)
Probleme mit freien Rändern, Phase-Field-Methode
April 2004 to June 2004 and September 2004 to November 2004

Starikovicius, Vadimas (Vilniaus Gedimino Technikos Universitetas, Wilna, Litauen)
Rechnergestützte Strömungssimulation
April 2004 to June 2004

Tsukrov, Igor (University of New Hampshire, Mechanical Engineering Dept., USA)
Lecture: Micromechanical modeling of solids with cracks and cavities of various shapes
March 2004

Verboven, Pieter (Universität Leuven, Belgien)
Modellierung im Agro-Food-Bereich
May 2004

Weinert, Klaus (Universität Dortmund)
Evolutionäre Optimierung von Druckgusswerkzeugen
May 2004

Zemitis, Aivars (Ventspils University College, Ventspils, Lettland)
Schnelle Löser für Eletrostatik und Wärmeleitung in Mikrostrukturen
October to December 2004

Collaboration in Boards, Editorships

PD Dr. Heiko Andrä
- International Journal of Solids and Structures (Appraiser)
- Journal of Computational Methods in Applied Mathematics (Appraiser)
- Springer CVS (Appraiser)

Dr. Norman Ettrich
- Geophysics (Appraiser)

Dr. Marco Günther
- Member of: Wissenschaftlich-Technischer Rat der Fraunhofer-Gesellschaft (WTR)

PD Dr. Oleg Iliev
- Journal of Computational Methods in Applied Mathematics (Editorial Board)
- Journal of Mathematical Modelling and Analysis (Editorial Board)
- Springer Lecture Notes in Computer Science (Expert)

Dr. Dirk Kehrwald
- Journal of Statistical Physics (Appraiser)
- Assistent Member of: Wissenschaftlich-Technischer Rat der Fraunhofer-Gesellschaft (WTR)

PD Dr. Karl-Heinz Küfer
- Working Group »OR im Gesundheitswesen« of the GOR (Chairman)
- Mathematics of Operations Research (Appraiser)
- Medical Physics (Appraiser)
- Working Group »Struktur und Innovation« of the BBAW Berlin
- Zentralblatt für Mathematik (Reviewer)
- Mathematical Programming (Appraiser)

PD Dr. Arnulf Latz
- Journal of Physics (Reviewer)

Dr.-Ing. habil. Alexander Lavrov
- Working Group »Praxis der mathematischen Optimierung« of the GOR (Assistant Chairman)
- VDI-FML Technical Committee »Modellbildungsprozesse« (Member)
- RiMEA-Project (Richtlinie für Mikroskopische Entfluchtungs-Analysen) (Member)
- Ständige Promotions- und Habilitationskommission: Nationale Technische Universität der Ukraine (Member)

Dr. Marlene Müller
- Computational Statistics (Associate Editor)
- International Association for Statistical Computing (Mitglied des BoD der European Regional Section)
- Computational Statistics and Data Analysis (Appraiser)

Prof. Dr. Helmut Neunzert
- European Journal of Applied Mathematics (Editorial Board)
- Monte Carlo Methods and Application (Editorial Board)
- Springer Series on Industrial Mathematics (Editorial Board)
- International Jury: Wittgenstein- und Startpreise in Wien (Member)
- International jury of the program »Mathematik und ...«, Wiener Wissenschafts-, Forschungs- und Technologiefond WWTF (Chairman)
- Evaluierungskommission Mathematik: Project »Evaluierung der Lehre« of the TU Kaiserslautern and of the ETH Zürich
- Fellow of the Royal Society of Edingburgh, since June 2003

Dr. Julia Orlik
- MMAS (Appraiser)

Prof. Dr. Dieter Prätzel-Wolters
- ECMI – Council
- GAMM-Fachausschuss »Dynamik und Regelungstheorie«
- MACSI-net – Executive Committee
- Member of: Graduiertenkolleg »Mathematik und Praxis« der Technischen Universität Kaiserslautern
- Member of: Rheinland-pfälzischer Landesschwerpunkt »Mathematik und Praxis«
- Member of: Hauptkommission der Fraunhofer-Gesellschaft

Dr. Ronald Rösch
- Fraunhofer-Allianz Vision (Member)

Dr. Katja Schladitz
- Leichtbau-Cluster (Member)

Dr. Volker Schulz
- Advances in Water Resources (Appraiser)

Dr. Norbert Siedow
- International Journal of Thermal Sciences (Reviewer)
- Simulation Practice and Theory (Reviewer)

Dr. Konrad Steiner
- Computers & Fluids (Appraiser)
- Journal of Statistical Physics (Appraiser)

Dr. Jörg Wenzel
- Zentralblatt für Mathematik (Reviewer)
- Studia Mathematika (Appraiser)

Andreas Wiegmann, PhD
- Numerical Algorithms (Appraiser)

Dr. Andreas Wirsen
- KMU IT-Netzwerk Kaiserslautern (ITWM-Assistent)