Johann Radon Institute for Computational and Applied Mathematics (RICAM)

of the

Austrian Academy of Sciences (ÖAW)

A N N U A L R E P O R T 2 0 0 3

This report has been compiled by the Institute Director Heinz W. Engl based on input by all group leaders and all members of the Institute. This version of the report does not contain confidential parts, especially detailed research plans, and can hence be freely distributed.

1.) The Development of the Institute in General: Personnel, Infrastructure

The Institute started its operation officially on January 1, 2003, the official opening ceremony took place in Linz on March 28, 2003. The program and some photographs can be found on the Institute homepage www.ricam.oeaw.ac.at. It was certainly an event which gave the applied mathematics in general and the Institute in particular high public visibility, highlights were certainly the personal words by Johann Radon's daughter Dr. Brigitte Bukovics and the public lecture by Peter Deuflhard.
If course, the planning process had begun before January 2003, especially concerning infrastructure and personnel. As detailed in the proposal which underwent several stages of review and rephrased in the Mission Statement approved by the Board at its first meeting, the Institute plans to

- do basic research in computational and applied mathematics according to highest international standards
- obtain the motivation for its research topics also from challenges in other scientific fields and industry
- emphasize interdisciplinary cooperation between its workgroups and with institutions with similar scope and universities world-wide
- cooperate with other disciplines in the framework of special semesters on topics of major current interest
- attract gifted Postdocs from all over the world and to provide an environment preparing them for international careers in academia or industry
- cooperate with universities by involving PhD-students into its research projects
- promote, through its work and reports about it, the role of mathematics in science, industry and society.

The first year was dedicated to building up the infrastructure and to attract scientists that will enable us to achieve these goals; as we hope this report will show, we are well under way, and also, the scientific achievements obtained in the short period that the scientists we could attract were in residence so far conform to high international standards. It is a priority to encourage collaborations between the groups at the Institute, and to this end, we started with internal and external seminars as soon as the first scientists had started to work in Linz (for details see below). First plans for Special Semesters were formulated; their realization will be started as soon as the budget figures for 2004 and 2005 are known.

When the Institute started its operation, it had no office space, the first employees had to be temporarily housed in university offices. In early 2003, it was decided by the University of Linz that the institute could rent space in a building under construction ("Hochschulfondsgebäude"), and the Institute could move into this space in late August. We currently have 14 rooms (including our own seminar and lecture room) totaling 327 m². After a bidding process, we selected furniture for these rooms, which was available just in time for moving in August. Now, the Institute has an ideal spatial infrastructure, which will, however, not provide sufficient space soon if we are successful in attracting external funds as planned, e.g. via FWF projects. But there are already expansion plans at the university (e.g., in connection with a Science Park) which will hopefully allow the Institute to grow.

The Institute has its offices in the same building as the Industrial Mathematics Institute of the University of Linz, the Industrial Mathematics Competence Center (which are also headed by the Institute Director Heinz W. Engl) and part of the FWF Special Research Area SFB013 "Numerical and Symbolic Scientific Computing", other university institute which cooperate closely with RICAM via their heads are in the next building (with the only exception of RISC –

the Research Institute of Symbolic Computaticluster on, which is located in nearby Hagenberg). This close proximity of a large number of applied mathematicians in different institutions will provide ample opportunities for cooperation and was the main reason for choosing the offered space at the campus of the University of Linz over other options in Linz which might have provided more space, but further away.

Parallel to the furnishing of the office space, the computing infrastructure was planned; a short overview over what was bought in 2003 and what is planned for 2004 follows:

IT-Infrastructure:

Florian Tischler was hired half time as software engineer at RICAM; he is also employed half time at the Industrial Mathematics Institute at Linz University, which provides a lot of synergies. Before, he was the software engineer at SFB013.

His first task was to develop the hardware and software concepts for RICAM in collaboration with the ÖAW computer center. As a consequence, the following hardware was purchased in 2003:

Servers:

Communication server:
A dual Xeon server from Transtec was bought as communication server. The server houses the RICAM webpage including database access, email access through pop3 and imap, spam and virus filters for email services, webmail access, groupware scheduler, mailing list manager and cvs repository. As operating system, Linux is used with extra access control kernel patches to add an extra security layer. All used software (except for the virus scanner) is open source and free of charge!

Fileserver:
A dual Xeon server with 800GB raid array from Transtec was bought as file server. The file server allows centralized user management and data storage for Windows and Linux clients. Every user can access his/her data from any client in the network with both Linux and Windows clients. Data is backed up during night to the central backup server owned by Johannes Kepler University of Linz. The operating system is Linux with extra access control kernel patches to add an extra security layer. All used software is open source and free of charge.

Terminal server:
A dual Xeon server from Transtec was bought as Windows based terminal server. The terminal server allows access to Windows applications on linux through the rdesktop client. The operating system is Windows2003 Server with Terminal Services licensed.

Peripheral devices:

48 port 100Mbit switch:
We obtained a 48 port 100Mbit switch from Austrian Academy of Sciences computer center.
Monitors:
19” TFT displays where bought. The displays are currently used together with the laptops and will then be used for the 2004 planned workstations.

Laser printer:
A HP Laserjet 4300 with duplex and network interface was bought for fast black and white printing.

Color laser printer:
A HP color Laserjet 4600 with duplex and network interface was bought for fast color printing and printing of presentation slides.

Video projector:
A lightweight mobile video projector for presentations was bought.

Clients:

Laptops:
After many comparisons, Acer Travelmate 800 laptops were bought as the best compromise between mobility and power. They serve as standard computing, office and presentation equipment for the scientific employees. Each laptop is equipped with 1GB memory extension to obtain better computing performance and a CD burner and USB flash memory for data exchange. As operating systems, both Linux and Windows are installed. MS Office is also usable under Linux with the help of the CrossOver Office Windows emulator. As standard scientific software, Matlab, Mathematica and Maple for both Windows and Linux are installed as needed.

Plans for 2004:

Servers:

This depends on the number and the requirements of the scientific employees. It is likely that via an agreement with the super computing department of the University of Linz Computing Center, we can get access to a 128CPU SGI Altix Machine owned by them. This agreement will also require some investment from our side.

Peripheral devices:

Hardware firewall:
We will obtain a Cisco PIX firewall from the Austrian Academy of Sciences computing center.

12 port 1000Mbit switch:
We will obtain a 12 port 1000Mbit switch for faster access to servers and cluster computers from the Austrian Academy of Sciences computing center.

Clients:

PC architecture based dual processor workstations will be bought for every employee.
Currently, some testing is done to decide if we should buy workstations with Intel 32 bit cpu (Xeon) or with the new AMD 64 bit cpu (Opteron). Operating systems will be both Linux and Windows. Under Linux, the workstations will be able to work in a cluster mode with the application transparent cluster software openmosix. As scientific software, Matlab, Mathematica and Maple will be installed both for Linux and Windows as far as needed.

It was crucial to have a secretariat in place in the early stages on the Institute in order to manage the organizational steps involved wit building up the infrastructure and with hiring scientific personnel. We employed Annette Rathmair (now Weihs) already in the early spring of 2003.

The crucial step was of the course the process of hiring the scientific employees. From the outset, we aimed at recruiting internationally and to hire only PostDocs (or even more senior scientists) who should then, in due course, bring in external funds via FWF and similar projects for hiring PhD students. So far, we succeeded in hiring 14 scientists; the selection process for additional positions is under way. Based on advertisements on the internet and in some scientific publications and via personal contacts, we received close to 100 applications, many of them from highly qualified candidates. Based on the suggestions by the group leaders, the Institute Director made hiring proposals to the ÖAW which were followed in all cases. This process resulted in the following hires:

Name	**At RICAM since**	**Doctorate: year, institution**	**Came to RICAM from**
Antonio Leitao	1.04.2003	1997, University of Frankfurt/Main	Univ. of Santa Catarina, Brazil, Assoc. Professor
Arnd Rösch	1.10.2003	1995, TU Chemnitz-Zwickau 2001, Habilitation TU Berlin	TU Berlin, Senior research assistant
Arne Winterhof	1.08.2003	1996, TU Braunschweig 2001, Habilitation, University of Vienna	National University of Singapore, Research Scientist
Carsten Schneider	1.05.2003	2001, University of Linz	University of Linz
Christian Schmeiser (half time)	1.10.2003	1984, TU Vienna 1989, Habilitation, TU Vienna	TU Vienna, Assoc. Professor (still there half time)
Gottlieb Pirsic	1.04.2003	1998, University of Salzburg	ÖAW, Institute for Discrete Mathematics
Johannes Kraus	1.09.2003	1997, University of Salzburg	Montanuniversität Leoben, Assistant Professor
Jörn Saß	1.08.2003	2001, University of Kiel	University of British Columbia, Postdoctoral position
Josef Schicho	1.10.2003	1995, University of Linz 2001, Habilitation, University of Linz	University of Linz, Assoc. Professor
Klaus Scheicher	1.10.2003	1997, TU Graz	University of Linz, Assistant Professor
Mircea Marin	1.03.2003	2000, University of Linz	University of Tsukuba, Guest researcher
Matevosyan Norayr	1.07.2003	2003, KTH Stockholm	KTH Stockholm
Sergei Pereverzyev	1.09.2003	1980, Ph.D. (cand.sc.), Ukrain. Acad. Of Sci. 1989, Habilitation (Dr.sc.), USSR	University of Kaiserslautern, Visiting Professor
Sven Beuchler	1.10.2003	2003, TU Chemnitz	TU Chemnitz, Scientific employee

In order to enable the Board and the ÖAW to get to know our scientists one by one, we structure the scientific part of this report by group and scientist.

In addition to doing their own research, these scientists and the group leaders should emphasize collaboration between different groups. The first step to achieve this is of course that everybody has to get to know everybody else scientifically and personally. To achieve this, we started

- Radon Seminars, which are mainly talks by RICAM members and other scientists from Linz on their work, and
- Radon Colloquia, were scientists from other institutions speak.

A list of these seminars and colloquia held in 2003 follows:

Radon Colloquia:

Prof. Dr. Johann Baumeister FB Mathematik, J.W. Goethe Universität, Frankfurt/Main 6.Okt., 14 Uhr, HF 136
Title: Optimale Steuerung mit Impulskontrollen am Beispiel eines Besteuerungsproblems
Abstract: Wir betrachten ein Modell für die Regulierung eines Fischereimonopols durch Besteuerung. Das Problem besteht darin, eine optimale Fangstrategie zu finde, wobei die Höhe des "Ertrags" der Fischereiwirtschaft zu maximieren ist. Mathematisch liegt ein Kontrollproblem mit unendlichem Horizont und Impulskontrollen vor. Wir analysieren die Optimalitätsbedingungen und finden so die optimale Politik.
Prof. Christian Schmeiser TU Vienna/ RICAM 12. Nov., 17:30 Uhr, HS 10
Title: Aspects of the mathematical modelling of chemotaxis
Abstract: Classical models for the chemotactic movement of cells such as amoebae or leucocytes do not take into account certain effects which are based on their individual behavior. Two approaches for the derivation of continuum models will be presented allowing for a transition from microscopic to macroscopic behavior. They are based on modelling by kinetic transport equations and by stochastic differential equations, respectively. This leads to the derivation of new macroscopic (continuum) models. Some of the latest developments in this field will be reviewed including numerical simulations reproducing experimental observations.
Prof. Dr. Arnold Reusken RWTH - Aachen 19. Nov., 15:30 Uhr, BA 9911
Title: Parallel multilevel tetrahedral grid refinement
Abstract: In this talk we introduce and analyze a parallel version of a multilevel red/green local refinement algorithm for tetrahedral meshes. The serial version of this algorithm is known in the literature (Bank, Bey, Bastian). We introduce a new data distribution format that is very suitable for parallelization of the multilevel refinement algorithm. This format is called an admissible hierarchical decomposition. We will prove that the application of the parallel refinement algorithm to an input admissible hierarchical decomposition yields an admissible hierarchical decomposition. We will show that due to this property one has good data locality (hence little communication) and at the same time only a small amount of copies (small storage overhead).
Prof. Dr. Peter Schuster Institut für Theoretische Chemie und Molekulare Strukturbiologie, Universität Wien 15. Dez., 10:15 Uhr, HS 3
Different Kinds of Robustness of Genetic Networks
Prof.Dr. Karl Kunisch Mathematisches Institut, Universität Graz 15.Dez., 15:30 Uhr, HF 136
Title: Optimization and Optimal Control for Variational Problems
Abstract: Control of fluids, closed loop optimal control and Hamilton-Jacobi Bellman equation; model reduction based on proper orthogonal decomposition; optimal control with constraints, semi-smooth Newton methods in function spaces; level set methods combined with second order optimization methods.
Prof. Dr. Dr.h.c. Wolfgang Hackbusch Max-Planck-Institut für Mathematik in den Naturwissenschaften, Leipzig 17. Dez., 16 Uhr, HS14
Title: Hierarchical Matrices with a Weak Admissibility Condition

Radon Seminars:

Dr. Norayr Matevosyan
RICAM/Group: Analysis of Partial Differential Equations
13.Okt., 15:30 Uhr, HF 136

Title: Free boundaries and some applications to Superconductivity problems

Abstract: We will talk about Free Boundary problems, especially Free Boundary problems with contact points and an application to a Superconductivity problem. In this framework we will also discuss a special monotonicity formula due to Alt, Caffarelli, Friedman, and its application for the regularity of solutions.

Dr. Antonio Leitao
RICAM/Group: Analysis of Part. Diff. Equations
20.Okt., 15:30 Uhr, HF 136

Title: On the Relation between Constraint Regularization, and Level-Set methods

Abstract: We consider regularization methods based on the coupling of Tikhonov regularization and projection strategies. From the resulting constraint regularization method we obtain level set methods in a straight forward way. Moreover, we show that this approach links the areas of asymptotic regularization to inverse problems theory, level set methods, and shape optimization.

PD Dr. Arnd Rösch
RICAM/Group: Inverse Problems
27. Okt., 15:30 Uhr, HF 136

Title: Optimal Control of Elliptic and Parabolic PDEs

Abstract: The talk is divided in two parts. The first part is an introduction is optimal control theory governed by PDEs. The general structure of optimal control problem, necessary and sufficient optimality conditions, and specific difficulties are discussed. The second part is devoted to the numerical solution of optimal control problems. After presentation of known results, a new approach using superconvergence properties is presented. Numerical tests confirm the theoretical results.

Prof. Sergei Pereverzyev
RICAM/Group: Inverse Problems
3. Nov., 15:30 Uhr, HF 136

Title: General approach to regularization of linear ill-posed problems in Hilbert Space

Abstract: Using some recent results we are going to present a sketch of Regularization theory for linear ill-posed problems in Hilbert scale. The following topics will be discussed: 1) Relationship between optimal order of accuracy and qualification of regularization methods. 2) Optimal adaptation to unknown solution smoothness. 3) Discretization strategy for linear ill-posed problems. 4) Some applications

Dr. Josef Schicho
RICAM/Group: Symbolic Computation
10. Nov., 15:30 Uhr, HF 136

Title: Algebraic Constraints

Abstract: An algebraic constrained is a condition on n variables ranging over the real numbers that can be expressed by polynomial equations or inequalities or combinations of them. Universal and existential quantifiers are also allowed. In this survey talk, we give an overview on some applications in which algebraic constraints arise, discuss the most important methods for solving as well as the main difficulties, especially related to the ill-posed-ness of the solution problem.

Dr. Carsten Schneider
RICAM/Group: Symbolic Computation
17. Nov., 13:30 Uhr, HF 136

Title: Symbolic Summation in Difference Fields

Abstract: The algorithmic problem of symbolic summation can be most easily introduced by presenting it as the discrete analogue of the well-known problem of “symbolic integration'' or “integration in finite terms''. In this survey talk I will present different methods how one can treat indefinite and definite summation problems in the difference field setting. Within this presentation the theoretic background is based on Karr's Summation Algorithm (1981) which is, in a sense, the summation counterpart of Risch's algorithm for indefinite integration. Special emphasize is put on my computer algebra implementation Sigma that helps scientists in practical problem solving.

Dr. Sven Beuchler RICAM/Group: Direct Field Problems 17. Nov., 15:30 Uhr, HF 136
Title: Multi-level solver for the p-Version of the FEM.
Abstract: In this talk, we investigate fast solvers for linear systems of algebraic equations arising from the discretization of boundary value problems using Finite Elements. More precisely, we consider preconditioning as Domain Decomposition methods and several multi-level methods (multi-grid and wavelets).
Dr. Johannes Kraus RICAM/Group: Direct Field Problems 24. Nov., 15:30 Uhr, HF 136
Element-based interpolation and coarse-grid selection in algebraic multigrid methods
The knowledge of individual finite element matrices can be exploited for constructing superior prolongation in Algebraic MultiGrid (AMG) methods, addressing non-M matrices, in particular. However, element-based methods rely on some mechanism for generating coarse element matrices. This talk comments on element agglomeration and the basic principles of AMGe and spectral AMGe. Furthermore, a specific algorithm for computing artificial element matrices to be used in element-based AMG (AMGe) is proposed.
Dr. Jörn Saß RICAM/Group: Financial Mathematics 1. Dez., 15:30 Uhr, HF 136
Portfolio Optimization under Partial Information
We consider a multi-stock market model where prices satisfy a stochastic differential equation with instantaneous rates of return (drift process) modeled as an unobserved continuous time, finite state Markov chain. The investor wishes to maximize the expected utility of terminal wealth. Partial observation means that for his investment decisions only the prices are available to him. While the optimal terminal wealth and the existence of an optimal strategy are known in a quite general setting, it is not possible to determine an optimal trading strategy explicitly without specifying a model for the drift process. We give an overview of some recent results and then motivate our continuous time Markov chain model for the drift which leads to a hidden Markov model (HMM) for the stock returns. An explicit representation of the optimal trading strategy in terms of the unnormalized filter of the drift process can be derived using HMM filtering results and Malliavin calculus. Aspects of parameter estimation, simulation, and application to historical prices will be discussed. For the latter we show how the extension to non-constant volatilities an improve the optimization results considerably.

In late 2003, a discussion concerning adding research groups (in addition to those mentioned in the original proposal) arose. We (= the Institute Director Heinz W. Engl and the two appointed Deputy Directors Ulrich Langer and Peter Markowich) plus the additional Group Leaders (Walter Schachermayer, Gerhard Larcher, Bruno Buchberger, Josef Schicho, Christian Schmeiser) decided on a procedure for such cases: First, a proposal must be submitted which should outline the scientific aims of a prospective new groups emphasizing how it would fit into the Institute, which would then be sent to the Board for review. Upon a recommendation of the Board, a new group could be established by the Institute Director provided the necessary funds would be available. This procedure was followed when Prof. Karl Kunisch (Universität Graz) proposed a group on “Optimization and Optimal Control”. The Chairman of the Board informed us that the Board made a recommendation to establish this group, which will be followed if and as soon as we know that the budget for 2004 is sufficient. In that case, this new group will be able to hire at least two scientists in 2004, which will bring the total number of PostDocs up to 27 (from the 25 in the original proposal); these positions have already bee advertised (pending budgetary approval) and interesting applications have been received.
Also, Prof. Anton Arnold has expressed interest in establishing a RICAM group. The above-mentioned process will be initiated if and when he accepts the offer for a chair at TU Graz.

Not only the two prospective positions in the new group to be headed by Prof. Kunisch have been advertised, but also applications to the other groups have been encouraged. It is intended to bring the size of the Institute to 27 PostDocs in 2004, the hiring proposals will be made to the ÖAW as soon as we know the budget for 2004. In addition to these positions funded by the ÖAW (and by the contribution of the Upper Austrian Government to the ÖAW for RICAM), we hope to be able to fund PhD student positions already in 2004 via FWF projects. From April 2004, several of these positions will be funded at RICAM via SFB013.

As mentioned in the original proposal and again in the mission statement, Special Semester will be an important part of the plans of the Institute. We currently have plans for three topics, namely

- Mathematical Modelling of Cell Motion and Cell Movement
- Computational Mechanics.
- Gröbner bases.

The Institute Director has led an NSF-funded Special Semester on Inverse Problems at the Institute for Pure and Applied Mathematics at UCLA in the fall of 2003 and thereby gained important experience for similar activities at RICAM. The planning of the Special Semester took least two years, and agreements with many of the long-term participants were concluded about one year before the start of the semester. This was only possible since the budget for that Special Semester was known about two years in advance. At RICAM, we do not have information about the 2004 budget at the time this report is written (January 2004), a situation which makes planning a Special Semester completely impossible. We understand this for this initial period of the Institute, but need to emphasize that it will be absolutely essential for the success of the Institute to know at least the order of magnitude of the budget for more than one year in a row in order to be able to make commitments both when offering positions and especially when making commitments for Special Semesters.

2.) The Scientific Achievements and Plans of the Institute

In order to enable the Board and the ÖAW to get to know our scientists one by one, we structure the scientific part of this report by group and scientist, at least for this initial report:

Group "Computational Methods for Direct Field Problems"

Group Leader:

O.Univ.-Prof. Dr. Ulrich Langer

Researchers:

Dr. Sven Beuchler
Dr. Johannes Kraus

The "Computational Mathematics Group" has focused on the development, analysis and implementation of novel fast computational methods for direct field problems. The first group of methods, developed by S. Beuchler, belong to Domain Decomposition (DD) solvers for large scale algebraic equations arising from the so-called hp finite element discretization of second-order elliptic Partial Differential Equations (PDEs). It is worth to mention that these DD solvers are highly parallel. The second group of solvers, developed by J. Kraus, belong to Algebraic MultiGrid (AMG) methods. AMG methods are very important as black-box solvers for practical applications because they do not require any hierarchical discretization structure.

Recent publications of the group leader have also contributed to these two main research fields in 2003. The publications [1] – [4] and [7] are devoted to DD techniques and parallel algorithms for PDEs, whereas the papers [5] and [6] deal with AMG methods. In [6], we have started a cooperation with J. Schicho who is one of the group leaders of the Symbolic Computation Group. In this paper we have developed a new symbolic element preconditioning technique.

1. Douglas C., Haase G., Langer U.: A tutorial on elliptic PDE solvers and their parallelization, *SIAM Series on Software, Environments*, and Tools, Vol. 16, 135 pages, SIAM, Philadelphia, 2003.
2. Korneev V.G., Langer U.: Domain decomposition methods and preconditioning, *Encyclopedia of Computational Mechanics*, Chapter 19, 44 pages, 2004 (to appear).
3. Korneev, V.G., Langer U., Xanthis, L.: On fast domain decomposition solving procedures for hp-discretizations of 3d elliptic problems. *Computational Methods in Applied Mathematics* 3, 536 – 559, 2003.
4. Korneev, V.G., Langer U., Xanthis, L.: Fast adaptive domain decomposition algorithms for hp-discretizations of 2d and 3d elliptic equations: recent advances. *Hermis Journal of Computer Mathematics and its Applications* 4, 2003 .
5. Langer U., Pusch D., Reitzinger S.: Efficient preconditioners for boundary element matrices based on grey-box algebraic multigrid methods. *International Journal for Numerical Methods in Engineering* 58, 1937 – 1953, 2003

6. Langer U., Reitzinger S., Schicho J.: Symbolic Methods for the Element Preconditioning Technique. In "*Symbolic and Numerical Scientific Computation*" (ed. by F. Winkler and U. Langer), Springer, LNCS 2630 , 293 – 308, 2003.
7. Langer U., Steinbach O.: Boundary element tearing and interconnecting methods. *Computing* 71, 205 – 228, 2003.

In December 2003 we made an agreement on a **Collaborative Research Project** titled "*Robust Scientific Computing Methods and High Performance Algorithms*" between the Johann Radon Institute for Computational and Applied Mathematics (RICAM) of the Austrian Academy of Sciences and the Central Laboratory for Parallel Processing (CLPP) of the Bulgarian Academy of Sciences. We will cooperate on DD as well as AMG methods. In particular, we hope to extend the symbolic element preconditioning technique to new classes of problems.

Dr. Sven Beuchler

The research area of Dr. Sven Beuchler is the field of solution methods for systems of linear algebraic equations arising from discretizations of elliptic boundary value problems. One of these methods is the finite element method (FEM).
On the one hand, the polynomial degree p can be increased while the mesh size h is kept constant, on the other hand the polynomial degree p can be kept small while the mesh size h is decreased. The first method is called p-version of the FEM, and the second one h-version of the FEM. For uniformly elliptic problems, Dr. Beuchler has investigated several preconditioning techniques in order to solve systems of linear algebraic equations efficiently in his PhD-thesis, [2], [12]. All of these preconditioners base on Domain Decomposition methods (DD-methods) of Dirichlet-Dirichlet-type. Such a preconditioner has several ingredients, the solver related to the problem of the subdomains (interior solver), the Schur complement preconditioner and the extension operator.

Research 2003 before RICAM

In the last years, Dr. Beuchler has proposed several preconditioners for the interior solver. He has investigated two types of solvers, namely wavelet methods and multi-grid-like preconditioners. The multi-grid preconditioners use interpretations of the p-version element stiffness matrix as an h-version-FEM discretization matrix of a degenerate elliptic problem. The corresponding systems of linear algebraic equations can be preconditioned by robust multi-grid-like solvers, multi-grid with line-smoother, [3], [6], [10], BPX-preconditioners, [6], [10], or AMLI-preconditioners, [1].
The wavelet methods, [4], are based on the tensor product structure of the p-version element stiffness matrix. Moreover, with the methods of multi-resolution analysis, the optimality of all preconditioners has been shown, [5], [9].
In [7], [11], numerical experiments for the DD-preconditioner without extension in 2D are given.

Research 2003 at RICAM

In October 2003, Dr. Beuchler has started his work at RICAM. In the last months, he has investigated the problem of the discrete harmonic extension of a polynomial function on a face (in 3D) or edge (in 2D) to the interior of the hexahedron or quadrilateral.
Using methods of multi-resolution analysis, he has proposed a first technique for an optimal discrete harmonic extension, [8], [13]. A second similar technique will be prepared in 2004.

Cooperations:

- internal cooperation
  - with the Symbolic Computation group of RICAM (Prof. Dr. J. Schicho) is intended,
  - with the project groups F1306 (Prof. Dr. U. Langer) and F1319 (Dr. J. Schöberl/Prof. Dr. P. Paule) of SFB F013, Linz, Austria,
  - with the FWF-START project hp-FEM (Dr. J. Schöberl), Linz, Austria,
- external cooperation with
- Prof. Dr. V.G. Korneev, Russian State University, St. Petersburg, Russia,
- Prof. Dr. R. Schneider, Mathematisches Seminar, University of Kiel, Germany,
- Prof. Dr. C. Schwab, Seminar for Applied Mathematics ETH Zürich, Switzerland,
- Prof. Dr. L. Demkowicz, University of Texas, Austin, USA,
- Doz. Dr. M. Jung, Institute for Scientific Computing, TU Dresden, Germany.

Visits and Talks, 2003:

- 20.3.03 Linz: Multi-level solver for the p-Version of the FEM.
- 25.3.03 Abano Terme, GAMM-Jahrestagung 2003: Multi-grid solver for the p-Version of the FEM.
- 21.7.03 Berlin, 15th International Conference on Domain Decomposition methods: A Dirichlet-Dirichlet DD-preconditioner for p-FEM.
- 26.8.03 Leipzig, GAMM-Seminar: Multiresolution weighted norm equivalences and applications.
- 22.9.03 Ehrenfriedersdorf, FEM Symposium 2003: A DD-preconditioner for p-FEM.

Visits and Talks 2004/05 (planned):

- 24.2.-28.2.04 San Francisco, PP04: Multi-level solvers for degenerated problems.
- 1.3.-4.3.04 San Francisco, Sandia National Labs. (invited)
- 22.3.-26.3.04 Dresden, GAMM-Jahrestagung: A DD-preconditioner for p-FEM.
- September, 2004 Ehrenfriedersdorf, Chemnitz FEM Symposium.
- January, 2005 New York, 16th international Conference on Domain Decomposition Methods, DD16.

published:

1. Sven Beuchler: AMLI preconditioner for the p-version of the FEM. Numerical Linear Algebra with Applications, 10(8), 721-732, 2003.

PhD-Thesis:

2. Sven Beuchler: Multi-level solver for degenerated problems with applications to p-versions of the FEM. Dissertation, TU-Chemnitz, 2003.

accepted:

3. Sven Beuchler: Mutli-grid solvers for the p-version of the fem. Proceedings of the GAMM-conference held in Padua 2003.
4. Sven Beuchler, Reinhold Schneider, Christoph Schwab: Multiresolution weighted norm equivalences and applications. Numerische Mathematik.

submitted:

5. Sven Beuchler: Optimal preconditioners for the p-version of the FEM. Math. Comp.

6. Sven Beuchler: Fast solvers for degenerated problems. SIAM Journal Num. Analysis.
7. Sven Beuchler: A Dirichlet-Dirichlet DD-preconditioner for p-FEM. Applied Numerical Mathematics.
8. Sven Beuchler: Optimal extension operators on tensor product meshes. Applied Numerical Mathematics.

Preprints TU-Chemnitz, SFB 393 and RICAM:

9. Sven Beuchler: Optimal preconditioners for the p-version of the FEM. Report SFB 393 03-03, March 2003.
10. Sven Beuchler: Fast solvers for degenerated problems. Report SFB 393 03-04, March 2003.
11. Sven Beuchler: A Dirichlet-Dirichlet DD-preconditioner for p-FEM. Report SFB 393 03-12, May 2003.
12. Sven Beuchler: Multi-level solver for degenerated problems with applications to p-versions of the FEM. Report SFB 393 03-14, July 2003.
13. Sven Beuchler: Extension operators on tensor product meshes in 2D and 3D. Technical Report 2003-02, RICAM, Linz, December 2003.

Dr. Johannes Kraus

Dr. Johannes Kraus joined the Johann Radon Institute for Computational and Applied Mathematics (RICAM) on September 1, 2003.
His working area and scientific main interests are Algebraic Multigrid (AMG) and Multilevel Methods for systems of linear algebraic equations arising from discretization of partial differential equations describing direct field problems. For such large sparse-matrix problems AMG methods, similar to Geometric Multigrid (GMG), often provide solvers with asymptotic optimality with respect to the arithmetical complexity. However, there are situations of practical interest in which this property gets lost and the convergence rate of iterative solvers based on AMG techniques deteriorates.
For instance, problems in Computational Fluid Dynamics (CFD) - inducing non-symmetric matrices with highly varying coefficients - or, Electromagnetic Field (EMF) problems - inducing non-M matrices with a particularly large (near) null space - are a real challenge for new generation algebraic multigrid methods. Other applications driving the research of Dr. Kraus gather Solid and Structural Mechanics (SSM) problems including elastoplastic continuum modelling.

Before September 2003

Dr. Kraus held the position of an Assistant Professor at the Department of Applied Mathematics, University of Leoben. He was involved in industrial projects with AVL List GmbH and Voest Alpine Industries. During this time his research was concerned with CFD and the development and analysis of multilevel preconditioners [1].
The Austrian Science Foundation provided Dr. Kraus with an Erwin Schrödinger fellowship for visiting Lawrence Livermore National Laboratory (LLNL) from August 2000 to September 2001. There, he continued his research on algebraic multilevel preconditioners [2].
At the same time he started his work on AMG and established his international scientific contacts. In April 2003, Dr. Kraus visited LLNL again.

1. J. Kraus and C. Brand. Condition numbers of approximate Schur complements in two- and three-dimensional discretizations on hierarchically ordered grids. *Computing*, 65:135—154, 2000.
2. J. Kraus. An algebraic preconditioning method for M-matrices: Linear versus nonlinear multilevel iteration. *Num. Lin. Alg. Appl.*, 9:599—618, 2002.

Talks at International Conferences 2003

Dr. Kraus gave a talk on “Multilevel Preconditioning Based on Element Agglomeration” at the 11th Copper Mountain Conference on Multigrid Methods, Copper Mountain, Colorado, on April 1, 2003.

Since September 2003

Dr. Kraus prepared a proposal for a research project that he is going to apply for at the Austrian Science Foundation. In this three-year term project titled “Algebraic Multigrid and Multilevel Methods for Direct Field Problems” it is planned that Dr. Kraus acts as principal investigator and supervisor of two Ph.D. students.

Publications 2003/04

The cooperation with Van Emden Henson and Panayot Vassilevski from LLNL continues and a joint publication on element-free interpolation in AMG [3] has been finished by Dr. Kraus in December 2003.
Another publication on agglomeration based Algebraic Multilevel Iteration (AMLI) for non-M matrices [4] he is going to finish in January 2004.

3. V.E. Henson, J. Kraus, and P. Vassilevski. Computing interpolation weights in AMG based on multilevel Schur complements. Technical Report 2003-01, RICAM, Linz, December 2003.
4. J. Kraus. Algebraic multilevel iteration based on element agglomeration: Application to non-M matrices. Technical Report, RICAM, Linz, 2004.

5. M. Brezina, A. Cleary, R. Falgout, V. Henson, J. Jones, T. Manteufel, S. McCormick, and J. Ruge. Algebraic multigrid based on element interpolation AMGe. *SIAM J. Sci. Comput.*, 22:1570—1592, 2000.
6. J. Jones and P. Vassilevski. AMGe based on element agglomeration. *SIAM J. Sci. Comput.*, 23:109—133, 2001.
7. J. Kraus. Computational molecules in algebraic multigrid. Work in progress.

Major cooperation partners

- Prof. Dr. R. Falgout, Prof. Dr. J. E. Jones, Prof. Dr. V. E. Henson, Prof. Dr. P. Vassilevski: CASC, Lawrence Livermore National Laboratory (USA)
- Prof. Dr. R. Hiptmair: Department of Mathematics, ETH Zürich (Switzerland)
- Prof. Dr. C. Pflaum: Department of Computer Sciences, University of Erlangen-Nürnberg (Germany)
- Prof. Dr. G. Haase: Institute for Mathematics, University of Graz (Austria)
- Prof. Dr. U. Langer: SFB F013, project F1306, Linz (Austria)

Visits

For 2004 Dr. Kraus plans a one-month visit at LLNL, USA.
Dr. Kraus is going to give an invited talk titled “Element-Based Interpolation and Coarse-Grid Correction in Algebraic Multigrid” at the ETH Zürich on January 14, 2004.
Furthermore, it is planned to invite Prof. Dr. R. Hiptmair and Prof. Dr. C. Pflaum to visit the RICAM in 2004. A visit of scientists from LLNL is planned for 2004 or 2005.

Inverse Problems Group

Group Leader:

o.Univ.- Prof. Dipl.-Ing. Dr. Heinz W. Engl

Researchers:

Dr. Sergei Pereverzyev
Dr. Arnd Rösch

Inverse problems have been a focus of research in Linz for many years, both at the Industrial Mathematics Institute of the University and at industry-related institutions like the former Christian Doppler Laboratory for Mathematical Modelling and Numerical Simulation and its successor, the much larger Industrial Mathematics Competence Center. Also, there are several projects dealing with inverse problems in SFB013.
In order not to duplicate these efforts, the hiring policy for the RICAM group has been to employ people who have expertise in areas linking inverse problems to other fields. In the case of Dr. Rösch, this other field is optimal control, in the case of Dr. Pereverzyev, it is statistics and complexity theory. Both have already obtained their habilitation. Dr. Resmerita, who should joint the group in early 2004, has worked in optimization in Banach spaces and has obtained expertise in inverse problems at the UCLA special semester to be mentioned below. It should also be mentioned that in the RICAM group "Analysis of PDEs", there is Dr. Antonio Leitao, who has also worked on inverse problems. Thus, the inverse problems group is well-positioned to obtain profile, but also to cooperate both with other groups at RICAM and with other inverse problems groups in Linz and elsewhere.

In the fall of 2003, Prof. Engl led a Special Semester on Inverse Problems at the Institute of Pure and Applied Mathematics (IPAM) situated at UCLA. This semester, whose budget of about 700.000$ was provide mainly by NSF, consisted of tutorials, an industry study group, several large and many smaller workshops and was attended by many long- and short-term visitors. For details of the program see www.ipam.ucla.edu/programs/inv2003. This semester will certainly push the field of inverse problems forward and also gave high visibility for the Linz group. In the next two years, IPAM will run two week-long "reunion conferences" devoted mainly to reports about progress on cooperations started during the special semester.

It should be mentioned that the experience gained by planning and running this IPAM Special Semester will prove valuable for the special semester programs we plan to run at RICAM.

Recent papers by the group leader on inverse problems include

1. H.W.Engl, P.Kügler, The influence of the equation type on iterative parameter identification problems which are elliptic or hyperbolic in the parameter, Europ. Journ. of Appl. Math. 14 (2003) 129-163

2. H.W.Engl, Identification of parameters in polymer crystallization, semiconductor models and elasticity via iterative regularization methods, submitted

3. M. Burger, H.W.Engl, J. Haslinger, U. Bodenhofer, Regularized data-driven construction of fuzzy controllers, Journ. of Inverse and Ill-Posed Problems 10 (2002), 319-344

4. B. Buchberger, H.W.Engl, M.Rosenkranz, Solving linear boundary value problems via non-commutative Gröbner bases, Applicable Analysis 82 (2003), 655-675

5. H.W.Engl, P.Kügler, Parameter identification in industrial problems via iterative regularization methods, in: ECMI 2002 Proc., A. Fitt, ed., Springer 2003

6. H.W. Engl, P. Kügler, Nonlinear inverse problems: theoretical aspects and some industrial applications, in: Multidisciplinary Methods for Analysis, Optimization and Control of Complex Systems, V. Capasso, ed., Springer, to appear

7. M.Burger, H.W.Engl, A.Leitao, P.Markowich, On inverse problems for semiconductor equations, submitted

Dr. Sergei Pereverzyev

Scientific Achievements 2003

The general field of research of Dr. Pereverzyev is Numerical Analysis of Inverse Problems. It is well-known that the numerical treatment of ill-posed inverse problems with noisy data requires the application of special regularization methods. Typically, these methods are defined in an infinite dimensional setting and have to be discretized for an implementation. Thus, the most important issue in such implementation is the proper choice of the regularization and discretization parameters. The latter should be chosen in such a way that the error caused by data noise (inevitable error which is usually unknown) is not dominated by the discretization error.
During the year 2003 the main research activity has been aimed at regularization methods for ill-posed problems in analysis and statistics with emphasis on the development of adaptive strategies for regularization parameter choice and for problem discretization. Adaptation here means that corresponding strategy does not use *a priori* information concerning problem elements, but nevertheless it allows to obtain results which are optimal in some appropriate sense.
At least two types of adaptation can be discussed in the context of inverse problems theory: One of them is the adaptation to unknown solution smoothness. In 2003 two results in this direction have been obtained in cooperation with Peter Mathé (WIAS-Berlin). First accomplishment of this research is a general adaptation strategy for regularization parameter choice which allows to reach the best order of accuracy for all linear ill-posed problems that in principle can be treated in an optimal way by a regularization method with fixed qualification. Another achievement of the above mentioned research is a theorem concerning the structure of the error analyzed in terms of the noise level, the regularization parameter and as a function of the parameters driving the discretization. As a result, a discretization strategy is proposed, which automatically adapts to the unknown solution smoothness and provides the optimal order of accuracy. This part of research was completed when Dr. Pereverzyev was employed at RICAM.
Another type of adaptation, being of special interest for statistics, is the adaptation to unknown noise structure. To the best of our knowledge the first result in this direction has been obtained in 2003 in cooperation with Alexander Goldenshluger (University of Haifa, Israel). This research addresses the problem of estimating the value of a linear functional from indirect random noisy observations, and an estimation procedure is proposed which adapts to unknown smoothness of the solution and the (also unknown) eigenvalue decay rate of the noise covariance operator. It is shown that accuracy of this adaptive estimator differs only by a logarithmic factor from what one could achieve in the case of known smoothness.

Scientific cooperation with scientists from other institutions

During the year 2003 the research work has been conducted in cooperation with the following groups and scientists:

- Group of Functional Analysis headed by Prof. Dr. Eberhard Schock, Department of Mathematics, University of Kaiserslautern:

Investigation of inverse problems in Banach spaces. As a result, one article has been submitted to *SIAM Journal of Numerical Analysis*.

- Group of Geomathematics headed by Prof. Dr. Willy Freeden, Department of Mathematics, University of Kaiserslautern:

Regularization of geopotential determination within the framework of the forthcoming Gravity Field and Ocean Circulation Explorer (GOCE) mission. The results will be presented in Oberwolfach Meeting on Geomathematics (Spring, 2004) and in the 2nd International GOCE-Workshop (Summer, 2004).

- Group of Optimization and Inverse Problems headed by Prof. Dr. H. Hömberg, Weierstraß-Institute, Berlin:

Regularization methods for grating profile reconstruction. The writing of an article is in progress.

- PD. Dr. Peter Mathé, Weierstraß-Institute, Berlin.

Adaptive strategies for regularization and discretization of linear ill-posed problems. As a result, two articles have been published in *Inverse Problems*.

- Dr. Alexander Goldenshluger, Department of Statistics, University of Haifa, Israel.

Inverse problems of Statistics. The results are presented in a paper published in *Bernoulli*.

Participation at conferences.

During the year 2003 the following conferences have been attended:

- International Workshop on Numerical and Symbolic Scientific Computing (St. Wolfgang, Austria, June 16-21, 2003).

Invited talk with the title “Discretization strategy for ill-posed Inverse Problems”.

- Annual Meeting of German Mathematical Union (DMV) (Rostock, Germany, September 14-19).

Invited talk in the Minisymposium “Inverse Problems” with the title “Adaptive parameter choice in some iterative methods for nonlinear ill-posed problems”.

- Inverse Problems Workshop Series II (UCLA, Los Angeles, USA, November 12-20).

Invited talk with the title “General approach to regularization of linear ill-posed problems in Hilbert spaces”.

- International conference “Mathematical Statistics 3” (CIRM, Marseille, France, December 15-19).

Invited talk with the title “Adaptive model selection in inverse statistical estimation”.

Visits to other scientific institutions

There were two visits of Weierstraß-Institute for Applied Analysis and Stochastics (Research Group 4 lead by Prof. Dr. D. Hömberg). These visits were connected with joint research on the inverse problem of profile reconstruction in diffractive optics.
During the first visit (February 4-8, 2003), a talk with the title “Regularization parameter choice for profile reconstruction problem” was given.
During the second visit (November 23 – December 7, 2003), a talk with the title “General approach to regularization in Hilbert space” was given.

Publications

1. H. Harbrecht, S. Pereverzyev, R. Schneider, Self-regularization by projection for noisy pseudodifferential equations of negative order, Numer. Math. 95 (2003), 123-143.
2. P. Mathé and S. V. Pereverzyev, Discretization strategy for linear ill-posed problems in variable Hilbert scale, Inverse Problems **19** (2003), 1263-1278.
3. A. Goldenshluger and S. V. Pereverzyev, On adaptive inverse estimation of linear functionals in Hilbert scales, Bernoulli **9** (2003), no. 5, 783-807
4. G. Bruckner and S. V. Pereverzyev, Self-regularization of projection methods with a posteriori discretization level choice for severely ill-posed problems, Inverse Problems **19** (2003), 147-156.
5. P. Mathé and S. V. Pereverzyev, Geometry of linear ill-posed problems in variable Hilbert scales, Inverse Problems **19** (2003), 789-803.

Submitted paper:
S. V. Pereverzyev and E. Schock, On the adaptive selection of the parameter in regularization of ill-posed problems

Dr. Arnd Rösch

Introduction

Dr Rösch' main research areas are optimal control and the theory of inverse problems governed by partial differential equations (especially elliptic and parabolic PDEs). His research interests include theoretical and numerical aspects of this area. Therefore, a close cooperation between the research groups on inverse problems, on optimal control, and numerics at the RICAM is a key point for his work.

Research 2003

In 2003 Dr Rösch focused on

1. Sufficient second order conditions for optimal control problems

The theory of sufficient second order optimality conditions was extended to optimal control problems with pointwise mixed control-state constraints. A joint paper [1] with Prof Tröltzsch (TU Berlin) was published in SIAM Journal of Control and Optimization.

2. Regularization of state constrained optimal control problems

State constrained optimal control problems have a lot of properties which makes the theory and numeric really challenging. A new approach (using the Lavrentiev regularization technique) was introduced in a joint work [2] with Prof Tröltzsch and Dipl-Ing Meyer (both TU Berlin).

3. Approximation of control constrained optimal control problems

The approximation of optimal control problems by finite dimensional problems is a very actual research field. Error estimates for parabolic problems are published in [3]. A new approach using superconvergence properties is established in a joint paper [4] with Dipl-Ing Meyer (TU Berlin).

Publications

1. A. Rösch and F. Tröltzsch, Sufficient second-order optimality conditions for a parabolic optimal control problem with state constraints. SIAM Journal of Control and Optimization, 42(1): 138-154, 2003.
2. C. Meyer, A. Rösch and F. Tröltzsch, Optimal control of PDEs with regularized pointwise state constraints. Submitted to Computational Optimization and Applications. Technical report 2003/14, Institute of Mathematics, TU Berlin.
3. A. Rösch, Error estimates for parabolic optimal control problems with control constraints. Submitted to ZAA, Technical report 2003/18, Institute of Mathematics, TU Berlin.
4. C. Meyer and A. Rösch, Superconvergence properties of optimal control problems. Accepted for publication in SIAM Journal of Control and Optimization, Technical report 2003/17, Institute of Mathematics, TU Berlin.

Talks

1. Optimal error estimates for abstract optimal control problems, Conference “Numerical Techniques for Optimization Problems with PDE constraints, Oberwolfach, February 16-22, 2003.
2. Error estimates for constrained least squares problems, Seminar “Inverse Problems”, Linz, April 28, 2003.
3. Lavrent’ev type regularization of optimal control problems with pointwise state constraints, International workshop on “Numerical and Symbolic Scientific Computing”, St. Wolfgang/Strobl, June 16-21, 2003.
4. Parabolic control problems with pointwise mixed control state constraints, 21st IFIP TC 7 Conference on System Modelling and Optimization, Sophia Antipolis, July 21-25, 2003.
5. Superkonvergenzeffekte bei Optimalsteueraufgaben, Jahrestagung der DMV, Rostock, September 15-19, 2003.
6. Error estimates and superconvergence properties of elliptic optimal control problems, Workshop “Control of PDEs”, Berlin, December 11-13, 2003.

Symbolic Computation Group

Group Leaders:

O.Univ.-Prof. DDr. Bruno Buchberger
Ao.Univ.-Prof. Dr. Josef Schicho (also employed by RICAM)

Further researchers:

Dr. Mircea Marin
Dr. Carsten Schneider

The Symbolic Computation Group at RICAM has benefited from the long research tradition and international standing of the Research Institute of Symbolic Computation (RISC), founded by Bruno Buchberger. In symbolic computation, one develops methods to manipulate “symbolic data” such as polynomials, formulae, or mathematical theorems/proofs. The goal is that the automatization of mathematics by the invention of mathematics on higher and higher levels gains in speed, efficiency, elegance, and breadth of applicability. An example is the symbolic solution of linear boundary problems [1] by Prof. Buchberger, Prof. Engl, and M. Rosenkranz. Other recent contributions of the first group leader to this goal are [2-6] (the contributions of the other group members are listed in the corresponding personal sections).

Five years of experience in the special research area on numeric and symbolic scientific computation have given ample evidence that interactions between symbolic computation and numerical computation are important and fruitful on several levels. For instance, in [7], symbolic methods have been used for speeding up a numerical algorithm; and in [8], numerical methods have been used for solving a symbolic problem.

1. B. Buchberger, H. W. Engl, and M. Rosenkranz, Solving boundary value problems via noncommutative Gröbner bases, Journal of Applicable Analyis 82 (2003), 655-675.
2. B. Buchberger, Algorithm invention and veirfication by lazy thinking, Proceedings SYNASC 2003.
3. B. Buchberger and A. Craciun, Algorithm synthesis and lazy thinking: examples and implementations in Theorema, Proceedings of the International MKM Symposium, 2003.
4. B. Buchberger, Automated computing, solving, proving: a key to the information age, Proceedings APLAS 2003.
5. B. Buchberger, Computational mathematics, computational logic, and symbolic computation, Proceedings CSL 2003.
6. B. Buchberger, Mathematik und Informatik: eine Liebeserklärung, to appear in IMN (ÖMG) 2004.
7. U. Langer, S. Reitzinger, and J. Schicho, Symbolic methods for the element precondi-tioning technique, in: U. Langer and F. Winkler (editors), Symbolic and Numerical Scientific Computation, LNCS 2630 , Springer, 2003, 293–308.
8. G. Bodnar, B. Kaltenbacher, P. Pau, and J. Schicho, Exact real computation in computer algebra, in: U. Langer and F. Winkler (editors), Symbolic and Numeric Scientific Computation, LNCS 2630, Springer, 2003, 114-129.

Bruno Buchberger's research focuses on the theoretical foundation, the implementation, and the application of the Theorema system for MKM (mathematical knowledge management) as described in the RICAM proposal. So far, the Theorema project could not yet be pursued within RICAM. In 2004, PostDocs should be employed by RICAM who work with Bruno Buchberger in the Theorema project. In 2004, the emphasis will be on

- a major re-design of the system that allows the users to design and implement their own reasoners (or, in other words, to computer-support the object level and the meta-level of theory exploration at the same time). This feature is not yet available in any of the current mathematical software systems. Its logical foundation is demanding and its practical relevance is enormous because in detailed case studies it turned out that the possibility of working at the object level and the meta level at the same time is most probably the decisive feature that makes human mathematical theory exploration so efficient, flexible, and creative.

- the further clarification of the notion and the methodology of systematic computer-assisted mathematical theory exploration. The central idea in this endeavor is the use of schemes (concept schemes, problem schemes, knowledge schemes, and algorithm schemes) for the computer-assisted generation of mathematical theories. Reasoning techniques are then used for verifying or disproving the items of the theory generated by schemes.

- the case study of Buchberger’s Gröbner basis theory: By now, 10 textbooks and approximately 600 research papers are available in this theory. We will start to formulate the known results on Gröbner bases using the MKM tools developed within Theorema with the goal of providing an interactive Gröbner bases laboratory, which combines the available knowledge and algorithmics of the theory. This will also be a preparatory step for a Special Semester on Gröbner bases to be proposed within RICAM.

- the case study of theory exploration in the area of functional analysis in cooperation with the Inverse Problems Group as started in the paper [1] mentioned above, where a major breakthrough in the algorithmic symbolic treatment of linear boundary value problems using symbolic computation techniques (especially noncommutative Gröbner bases) was made. We will apply this methodology to a broader class of problems but will also expand the methodology to include other symbolic computation techniques.

The Theorema project is also funded outside RICAM (by the cooperation of RISC faculty and PhD students, by PhD fellowships sponsored by the Upper Austrian Government, by SFB013, and by the EU Thematic Network “Mathematical Knowledge Management”) so that, including the PostDoc positions within RICAM (Dr. Marin and two more positions to be filled soon), a considerable workforce can be devoted to the ambitious goals of Theorema.

Dr Josef Schicho

Introduction

The main expertise of Dr. Josef Schicho is in the field of computational algebraic geometry, in particular rational surfaces. As a consequence of his activities in a special research area (SFB) for numerical and symbolic scientific computing (SFB013), he now focuses also on algebraic problems with numerical aspects.

Research 2003

1. Computational algebraic geometry

In CAD/CAM, surfaces arise in parametric form (polynomial splines or rational splines) or in implicit form (as the zero set of a polynomial function). For many applications, it is important to be able to switch between these two representations. The two conversions are called implicitization and parameterization. In previous years, Dr. Schicho developed various algorithms for parameterization of algebraic surfaces, and he has been invited to give surveys [4,5] on this topic.
While the implicit equation is unique up to a constant, there are many different parametric representations for the same surface. In [3], Dr. Schicho gave a method to check if a parameterization is unnecessarily complicated and to simplify it if that is the case.
A cooperation with Prof. Jüttler (University of Linz) adapted some of the existing methods for curves to the numerical situation. Together with J. Gahleitner (University of Linz), they gave an algorithm for parameterizing planar cubics. Together with Dr. Shalaby (University of Linz), they gave an algorithm for spline implicitization. This algorithm works for arbitrary analytic parameterizations, not necessarily polynomial.
In continuation of research on singularities, Dr. Bodnar (University of Linz), Dr. Encinas (University of Valladolid) and Dr. Schicho improved Villamayors algorithm for singularity resolution. The idea is to avoid overlaps in the chart representation in the result by using local rings and term orders.

2. Symbolic and numerical scientific computing

Element Preconditioning is a technique in algebraic multigrid methods for solving elliptic boundary value problems. For each element, one has to construct a relatively small matrix satisfying some optimality conditions. Solving that many optimization problems numerically is time consuming. Prof. Langer, Dr. Reitzinger (both at the University of Linz, SFB013) and Dr. Schicho bypassed this in [6] by solving the problem once symbolically and instantiating the solution formula.
In exact real computation, one usually is restricted to continuous problems. However, some important problems in computer algebra are not continuous. Dr. Bodnar (University of Linz), Dr. Kaltenbacher (formerly SFB013, now University of Erlangen), Dr. Pau (University of Linz) and Dr. Schicho applied techniques from the theory of ill-posed problems to regularize these problems.

Publications

1. J. Gahleitner, B. Jüttler, and J. Schicho, Approximate parameterization pf planar cubics, in: T. Lyche, M. Mazure, and L. Schumaker (editors), Curve and surface design: Saint-Malo 2002, Nashboro Press, 2003, 167-176.
2. B. Jüttler, J. Schicho, and M. Shalaby, Spline implicitization of planar curves, in: T. Lyche, M. Mazure, and L. Schumaker (editors), Curve and surface design: Saint-Malo 2002, Nashboro Press, 2003, 225-235.

3. J. Schicho, Simplification of surface parameterizations – a lattice polygon approach, Journal of Symbolic Computation 36 (2003), 535-554.
4. J. Schicho, Algorithms for Rational Surfaces, Proceedings AGGM 2002, to appear, 185-200.
5. J. Schicho, Parameterization of Rational Surfaces, in: Z. Li and W. Sit (editors), Computer mathematics (ASCM 2003), World Scientific, 2003, 17-22.
6. U. Langer and S. Reitzinger, and J. Schicho, Symbolic methods for the element preconditioning technique, in: U. Langer and F. Winkler (editors), Symbolic and Numeric Scientific Computation, LNCS 2630, Springer, 2003, 293-308.
7. G. Bodnar, B. Kaltenbacher, P. Pau, and J. Schicho, Exact real computation in computer algebra, in: U. Langer and F. Winkler (editors), Symbolic and Numeric Scientific Computation, LNCS 2630, Springer, 2003, 114-129.
8. G. Bodnar, S. Encinas, and J. Schicho, Locally presented schemes in resolution of singularities, submitted.

Cooperations

Name	Institution	Topic	Publication
G, Bodnar	University of Linz	Singularities	[8]
G. Bodnar	University of Linz	Symbolics/numerics	[7]
S. Encinas	University of Valladolid	Singularities	[8]
J. Gahleitner	University of Linz	Parameterization	[1]
H. Hauser	University of Innsbruck	Singularities	in progress
B. Jüttler	University of Linz	Algebraic curves	[1,2]
B. Kaltenbacher	University of Erlangen	Symbolics/numerics	[7]
U. Langer	University of Linz	Symbolics/numerics	[6]
P. Pau	University of Linz	Symbolics/numerics	[7]
S. Reitzinger	University of Linz	Symbolics/numerics	[6]
M. Shalaby	University of Linz	Implicitization	[2]

Invited Talks

1. Workshop on constructive algebra and verification, Dagstuhl, Ill-posed problems in computer algebra
2. MSRI Workshop on computational commutative algebra, Berkeley, The method of adjoints
3. Asian Symposium on Computer Mathematics 2003, Peking, Parameterization of rational surfaces (cancelled because of SARS)
4. ESF Workshop on computational methods for algebraic spline surfaces, Kefermarkt, Del Pezzo surfaces

Contributed Talks

1. SFB Workshop on numerical and symbolic scientific computation, Strobl, Shelling convex polygons
2. Applications of Computer Algebra 2003, North Carolina, Symbolic methods for element preconditioning (presentation of joint work with U, Langer and S. Reitzinger)
3. International Symposium for Symbolic and Algebraic Computation 2003, Philadelphia, Spline implicitization of planar curves (poster presentation)

Visits of Institutions

1. January (winter term 2002/3), University of Innsbruck, Guest professorship, lecture on algorithmic algebraic geometry

Leader of Funded Project

1. SFB 13 Numeric and symbolic scientific computation, subproject 03, Proving and solving over the reals (FWF)
2. P1551 Resolution of Singularities in Algebraic Geometry and Number Theory, joint project with H. Hauser/University of Innsbruck (FWF)
3. 21/2003 Effective methods for algebraic geometry, Acciones Integradas with University of Valladolid (ÖAD)

Students

Dr. Schicho has supervised the thesis of Dr. Mohamed Shalaby and is currently supervising three other PhD-theses (Tobias Beck, Janka Pilnikova, Ibolya Szilagyi).

Dr. Mircea Marin

Introduction

Dr Marin's main research area is constraint functional logic programming, with special emphasis on calculi for solving systems of equations in theories defined by conditional rewrite rules. His early achievements were in the design and implementation of a scheme which integrates higher-order functional logic programming with collaborative constraint solving, where constraint solvers can be accessed on demand as services provided in an open environment (such as the internet). He is currently working on identifying useful computational models (calculi) for higher-order constraint functional logic programming.
Other research interests are: (1) rule-based programming, with practical applications in the implementation of deduction systems in a language based on rules whose application is driven by user-defined strategies, and (2) programming with sequence variables.

Research 2003

In 2003 Dr Marin focused on applications of the constraint functional logic programming paradigm for Origami programming and on the design and implementation of systems for rule based programming and programming with sequence variables.

1. Origami programming

Origami paper folding has a long tradition in Japan's culture and education. In [4,9], Dr. Marin together with Prof. Dr. Ida (University of Tsukuba) and Prof. Takahashi (Kawase High school) have developed a software system, based on constraint functional logic programming and web technology, for simulating origami paper folding steps on a computer. Further cooperation with Prof. Dr. Buchberger (Linz) and Prof. Dr. Robu (Cluj University) aims at the automatic proof of general theorems on the result of origami folding sequences by using algebraic methods, in particular the theory of Gröbner bases.

2. Programming with sequence variables

The concept of sequence variables has proved useful in many areas such as theorem proving, unification, term rewriting, symbolic computation, and computational logic. Still, the expressive power of this concept is not yet completely understood, and a better formalization is still desirable. The computer algebra system Mathematica provides some limited support for programming with sequence variables. To overcome the current limitations of programming, Dr. Marin proposed a number of useful programming extensions in [2,5].

3. Rule based programming

The design and implementation of a rule based programming system which takes advantage of the advanced features of the Mathematica computer algebra system was stimulated by the involvement of Dr. Marin in the development of the Theorema system. The result of this research is the rule based programming system ρLog [6,7,8,10], which provides good support for programming deduction systems and solvers which rely on the exploration of a huge search space, in accordance with a certain strategy. ρLog enabled compact and efficient implementations of various procedures for unification with sequence variables in free, flat and restricted flat theories [6,7]. A fruitful cooperation with Dipl.-Ing. Piroi (RISC-Linz) revealed that ρLog is also useful for rule-based deduction and for generating proofs which can be browsed in a human readable format [8,10].

Publications

1. N. Kobayashi, M. Marin, and T. Ida. Collaborative constraint functional logic programming in an open environment, IEICE Transactions on Information and Systems, E86-D(1) (2003), 63-70.
2. M. Marin. Functional programming with sequence variables: the Sequentica package, Proceedings of 17th UNIF (2003), 65-78.
3. N. Kobayashi, M. Marin, and T. Ida. A Web Oriented System for Equational Solving, Proceedings of 12th WFLP (2003), 309-312.
4. T. Ida and M. Marin. Functional logic Origami programming with Open CFLP, Proceedings of 5th International Mathematica Symposium (2003), 397-404.
5. M. Marin and D. Tepeneu. Programming with sequence variables: the Sequentica Package, Proceedings of 5th International Mathematica Symposium (2003), 17-24.
6. M. Marin and T. Kutsia. On the implementation of a rule-based programming system and some of its applications, Proceedings of the 4th International Workshop on the Implementation of Logics (2003), 55-68.
7. M. Marin and T. Kutsia. Programming with transformation rules, Proceedings of 5th International Workshop on Symbolic and Numeric Algorithms for Scientific Computing (2003), 157-167.
8. M. Marin and F. Piroi. Rule-based deduction and views in Mathematica. SFB013 Report 2003-43, (2003).
9. T. Ida, M. Marin, and H. Takahashi. Constraint functional logic programming for Origami construction. In Proceedings of the First Asian Symposium on Programming Languages and Systems, LNCS 2895 (2003).
10. M. Marin and F. Piroi. Deduction and presentation in ρLog, Mathematical Knowledge Management Symposium, ENTCS (2003), to appear.

Cooperations

Name	Institution	Topic	Publication
T. Ida	University of Tsukuba	Origami programming	[4,9]
H. Takahashi	Kawase highschool, Japan	Origami programming	[4,9]
A. Middeldorp	University of Innsbruck	lazy narrowing calculi	in progress
T. Kutsia	RISC-Linz	Rule-based programming	[6,7]
F. Piroi	RISC-Linz	Deduction and presentation	[8,10]
N. Kobayashi	University of Tsukuba	Collaborative programming	[3]

Contributed Talks

M. Marin. Programming with sequence variables. Theorema-Omega workshop organized by B. Buchberger, May 24-27 (2003).

Visits of Institutions

8-14 December 2003, University of Innsbruck. Lazy narrowing calculi for conditional rewrite systems, joint research with A. Middeldorp.

Dr Carsten Schneider

Introduction

Dr. Schneider's research interest is computer algebra and its application in other research areas. In particular, his main topic is symbolic summation. More precisely, he is interested in proving multisum identities and in simplifying complicated multisum expressions that usually occur in counting problems, like chemistry (e.g. the number of molecules in certain structures), computer sciences (e.g. complexity analysis of algorithms) or physics (e.g. statistical physics).
Unfortunately (for RICAM), Dr. Schneider has left RICAM after only a few months to join a newly approved FWF project led by Dr.Paule; he will certainly cooperate further with RICAM.

Research 2003

C. Schneider made progress in the algorithmic theory of symbolic summation in the following contexts:

a. Symbolic summation in difference fields

In general, Schneider designs summation algorithms which are based on a very general class of difference fields, so called ? S-fields. This algebraic setting enables to describe a huge class of sequences, like hypergeometric terms, as shown in [5], or most d'Alembertian solutions, a subclass of Liouvillian solutions, of linear recurrences. More generally, ? S-fields allow to describe rational terms consisting of arbitrarily nested indefinite sums and products. So far, Schneider developed algorithms that enable to solve parameterized linear difference equations in ? S-fields which contain telescoping, creative telescoping, and recurrence solving. Hence his algorithms contribute in a very general setting to indefinite summation (telescoping) and definite summation (creative telescoping, solving recurrences).

Based on these results, more general algorithms were created. He developed algorithms that constructively decide if certain classes of sum extensions contribute to simpler telescoping or creative telescoping solutions. Moreover, the representation and simplification of products were refined [5]. Besides this, a more general framework has been created that enables to deal with summation problems involving objects that can be described by a linear recurrence, like orthogonal polynomials. This opens a completely new class of applications; new cooperations have been started already.

b. Symbolic summation and applications

With these new algorithms, implemented in form of the summation package *Sigma* in the computer algebra system Mathematica, various nontrivial problems could be solved. E.g., in [1], harmonic number identities are proven that are closely related to the problem of proving the irrationality of various zeta-functions. Moreover, in [2,3] summation identities involving Harmonic numbers could be only proven with *Sigma* so far. Those identities were the key step in order to generalize linear Padé approximation to the logarithm to quadratic and higher order Padé. Another example [4] comes from statistical physics: In the context of counting the number of certain rhombus tilings (Krattenthaler, 2000), a very complicated proof of a multisum identity based on hypergeometric transformations could be simplified to a straightforward proof by applying Schneider's package Sigma. Moreover, generalizations that enable to sum over linear recurrences give various new applications. For instance, the celebrated "Totally Symmetric Plane Partition Theorem" (Stembridge, 1995) can be now proven almost automatically with the summation package Sigma; an article by C. Schneider with G.Andrews and P.Paule is in preparation.

Publications in 2003

1. P. Paule and C. Schneider, Computer Proofs of a New Family of Harmonic Number Identities, Adv. in Appl. Math., 31 (2003), 359-378.
2. K. Driver, H. Prodinger, C. Schneider, and A. Weideman, Padé Approximations to the Logarithms II: Identities, Recurrences, and Symbolic Computation. Ramanujan Journal, to appear.
3. K. Driver, H. Prodinger, C. Schneider, and A. Weideman, Padé Approximations to the Logarithms III: Alternative Methods and Additional Results. Ramanujan Journal, to appear.
4. C. Schneider, A Note on the Number of Rhombus Tilings of a Symmetric Hexagon and Symbolic Summation, submitted.
5. C. Schneider, Product Representations in ? S-Fields, submitted.

Cooperations

Name	Institution	Topic	Publication
G. Andrews	Pennsylvania State University	Plane partitions	in preparation
H. Prodinger	University of the Witwatersrand	Padé approximation	[2,3]
A. Weideman	University of Stellenbosch		

Invited Talks

Applications of Computer Algebra 2003, Raleigh: Symbolic Summation in ? S-Fields.

Contributed Talks

International Workshop on "Numerical and Symbolic Scientific Computing", St. Wolfgang/ Strobl: Padé Approximation, Multisums, and Theorema.

As already mentioned, Dr. Schneider has joined an FWF project led by Dr. Paule, so that no scientific plans for the next years are to be reported here.

Financial Mathematics Group

Group Leaders:

Univ.-Prof. Dr. Gerhard Larcher
o.Univ.-Prof. Dr. Walter Schachermayer

Researchers:

Dr. Gottlieb Pirsic
Dr. Jörn Saß
Dr. Klaus Scheicher
Univ.-Doz. Dr. Arne Winterhof

Ph.D and Diploma Students (not funded by RICAM):

Nina Brandstätter
Anna Varbanova
Harald Schön
Markus Hahn

It is the aim of this group to combine two quite different approaches to mathematical finance.

The first approach (especially represented by the group leader Gerhard Larcher) is concerned with simulation. We are especially interested in simulation based on Monte Carlo and on quasi-Monte Carlo methods. We investigate fundamental questions arising in this context (complexity estimates, construction and analysis of well distributed point sets, analysis of simulation schemes,…) and the possibilities of the applications of these techniques to problems in finance. Recent papers of the group leader dealing with this aspect of research and partly carried out with members of the RICAM are:

1. Larcher, G. and Leobacher, G., An optimal strategy for hedging with short-term futures contracts, Math. Finance 13: 331 – 344, 2003.
2. Larcher, G. and Leobacher, G., Quasi-Monte Carlo and Monte Carlo Methods and their Applications in Finance., to appear in Surveys on Mathematics for Industry, 2004.
3. Larcher, G., Leobacher, G., Scheicher, K., On the tractability of the Brownian Bridge Algorithm, Journal of Complexity 19: 511 – 528, 2003.
4. Larcher, G. and Pillichshammer, F., Sums of distances to the nearest integer and the discrepancy of digital nets, Acta Arithmetica 106: 379 – 407, 2003
5. Larcher, G., Pillichshammer, F. and Scheicher, K., Weighted discrepancy and high-dimensional numerical integration, BIT Numerical Mathematics 43: 123 – 137, 2003.
6. Larcher, G., Predota, M. and Tichy R.F., *Arithmetic* average options in the hyperbolic model, Monte Carlo Methods and Applications 9: 227-240, 2003.

The other approach (especially represented by the group leader Walter Schachermayer) is concerned with stochastic finance. In the center of the investigations in this direction at the moment is the "utility maximisation in incomplete financial markets" (see also the detailed descriptions of related work in this directions in the report of Jörn Saß).
Recent papers of the group leader dealing with this aspect of research for example are:

1. J. Hugonnier, D. Kramkov, W. Schachermayer, On the Utility Based Pricing of Contingent Claims in Incomplete Markets, submitted (2003).
2. D. Kramkov, W. Schachermayer, Necessary and sufficient conditions in the problem of optimal investment in incomplete markets.
   Annals of Applied Probability, 13:1504—1516, (2003).
3. W. Schachermayer, A Super-Martingale Property of the Optimal Portfolio Process, Finance and Stochastics, 7: 433-456, (2003).

Dr. Gottlieb Pirsic

Introduction

Dr. Pirsic works mainly in the area of uniform distribution modulo 1, more specifically the field of quasi-random point sets in the unit cube and the investigation of their main properties, such as their discrepancy measure. The applications of such (according to their low discrepancy) well distributed point sets are called quasi-Monte Carlo (QMC) methods (in analogy to the Monte Carlo methods, where 'naturally' random points are used) and are employed in diverse areas like financial mathematics, physics or imaging. The discrepancy measure then serves as a parameter of quality or contributes to an error estimate of the method used. Building on the foundations of this field of QMC methods laid out by Prof. Harald Niederreiter, quite a large portion of Dr. Pirsic's work deals with digital point sets and sequences, which are especially amenable to analysis by the theory of finite fields. Also more complex structures come into use, like algebraic function fields.

Research 2003

In 2003, Dr. Pirsic worked on two projects, both dealing with the analysis of the discrepancy of point sets by Walsh-Fourier analysis, in different topological spaces.

Discrepancy estimates of digital nets by Walsh analysis

This is collaboration in a project submitted by Univ.Ass.Dr. Pillichshammer (Univ. Linz) and ao. Univ.Prof. Wolfgang Schmid (Univ. Salzburg) to the FWF. In this, the attempt is to get better estimates of the discrepancy of digital point sets, more specifically, digital (t,m,s)-nets constructed over some finite field, by using Walsh functions. These functions not only constitute the dual group of the unit cube in the context, but also a complete orthonormal basis of its square-integrable Lebesgue function space, hence Fourier transformation methods can be usefully applied.
Dr. Pirsic's contribution is in the generalization from binary to arbitrary finite fields. Results for two-dimensional nets already have been obtained. A preprint is in preparation, work is still ongoing.

Discrepancy on the Sierpinski carpet

In a similar way to the unit cube, well distributed point sets can be considered in other spaces. In collaboration with several co-authors, general results on various notions of discrepancy of point sets on the Sierpinski carpet were obtained in [2]. (The Sierpinski carpet is a rectangular variant of the well-known Sierpinski triangle fractal.) Dr. Pirsic in particular gave a version of the Erdos-Turán-Koksma inequality for the carpet star discrepancy and application to digital point sets on the carpet.

Also, a paper on algebraic function fields with applications to the construction of digital point sets and algebraic codes has been submitted [1].

Publications

1. H. Maharaj, G. L. Matthews, and G. Pirsic, Riemann-Roch spaces of the Hermitian function field with applications to algebraic geometry codes and low-discrepancy sequences, submitted to Journal of Pure and Applied Math.
2. L. L. Cristea, F. Pillichshammer, K. Scheicher and G. Pirsic, Discrepancy estimates for point sets on the s-dimensional Sierpinski carpet, submitted, 2004.

Cooperations

Name	Institution	Topic	Publication
L.L. Cristea	T.U. Graz	Fractals	[2]
F. Pillichshammer	Univ. Linz	Fractals	[2]
K. Scheicher	RICAM	Fractals	[2]
W. Schmid	Univ. Salzburg	Low-discrepancy seq.s	
P. Kritzer	Univ. Salzburg	Low-discrepancy seq.s	

Invited Talks

1. Workshop on low-discrepancy sequences and point sets, Univ. Salzburg, ‘Eine Diskrepanzformel für digitale (0,m,2)-Netze in allgemeiner Basis mittels Walshanalyse’
2. Univ. Linz, Quasi-Monte Carlo methods, digital point sets and discrepancy estimates

Visits of Institutions

1. 11 July- 25 July, University of Salzburg, research with P. Kritzer

Dr. Jörn Saß

Introduction

One important problem of financial mathematics is the derivation of optimal trading policies in continuous time market models (e.g. for stocks and bonds). While even in rather complex models the value of the optimization problem or the optimal wealth of the investor can often be computed explicitly this is not true for the corresponding trading strategy. Only its existence is known and in simple models (Black-Scholes model, no restrictions), where it can be computed, the performance of the optimal strategy is quite poor when applied to market data. In more realistic models (transaction costs, non-constant coefficients) the computation of these strategies is numerically difficult. In 2003 the research of Dr Saß was focused on finding more explicit trading strategies for different optimization problems to make the modern portfolio theory better applicable.

Research 2003

One possible extension of the Black-Scholes model is the use of non-constant appreciation rates (drift of the stock returns). Dr Saß and Prof. Haussmann (UBC, Vancouver) consider a model where these rates are given as a continuous time Markov chain. But the stock prices are the only information an investor has. Hence these rates cannot be observed, so a hidden Markov model (HMM) results or, more general, an optimization problem under partial information arises. In [1] an explicit trading strategy is derived using extended HMM filtering results and Malliavin calculus, the involved parameter estimation (EM algorithm, new method to estimate the constant volatility) is dealt with, and these strategies are applied to market data. In [2] the model is generalized to cover non-constant volatilities and stochastic interest rates, and in [3] a quite successful volatility model (dependence on the filter for the rates) is proposed.

Another part of Dr Saß' work deals with models under transaction costs. Usually transaction costs are defined in three different ways: proportionally to the volume of trade (proportional cost), proportionally to the portfolio value (fixed cost) or consisting of a constant component (constant cost) and proportional cost.

All approaches lead to plausible optimal strategies in view of the considered type of transaction costs. But the results are not satisfying in so far as either the transaction cost structure seems to be unrealistic or the derived optimal strategies are not realistic and hardly determinable.

Based Dr. Saß' PhD thesis, he and Prof Irle (University of Kiel) consider a combination of fixed and proportional cost. In continuous time, they maximize for a suitable class of stationary trading strategies the asymptotic growth rate. In the discrete time CRR model they embed the portfolio optimization under transaction costs into the theory of Markovian controlled processes in such a way that many results of this theory can be applied. In particular, optimal strategies for finite time horizon problems can be determined using the algorithm of dynamic programming.

Publications (accepted)

1. U. G. Haussmann and J. Saß, Optimal terminal wealth under partial information for HMM stock returns, AMS-IMS-SIAM Summer Conference Proceedings, to appear

Publications (submitted):

2. J. Saß and U. G. Haussmann, Optimizing the terminal wealth under partial information: The drift process as a continuous time Markov chain, resubmitted
3. J. Saß and U. G. Haussmann: Portfolio optimization under partial information: Stochastic volatility in a hidden Markov model, submitted

Cooperations

Name	Institution	Topic	Publication
U. G. Haussmann	UBC, Vancouver	HMMs in finance	[1,2,3]
A. Irle	University of Kiel	transaction costs	2 in progress

<u>Conferences and Workshops (invited talks)</u>

1. MITACS Trade and Finance – Theme Meeting at the MITACS 4th Annual Conference, May 7, Ottawa, Canada, Optimal portfolios with rates of returns as hidden Markov chains
2. Workshop Financial and Actuarial Mathematics, October 2-4, Graz, Austria, Optimizing the terminal wealth: An HMM for the stock returns

<u>Conferences and Workshops (contributed talks, posters)</u>

3. Operations Research 2003, September 3-5, Heidelberg, Germany, Portfolio optimization under partial information: Stochastic volatility and parameter estimation in a hidden Markov model (talk)
4. 8th Meeting of the Austrian Mathematical Society, September 22- 26, Bolzano, Italy, Portfolio optimization under partial information: An HMM for the stock returns (talk)
5. Autumn School on Risk Management, September 29 – October 2, TU Munich, Germany, Portfolio optimization under partial information: An HMM for the stock returns (poster)

<u>Visits at Institutions</u>

1. Abteilung für Finanzmathematik, JKU, Linz, Austria, February 3, invited talk: Portfoliooptimierung bei partieller Information
2. Department of Mathematics, McMaster University, Hamilton, Canada, February 12-13, invited talk: Portfolio optimization under partial information: A hidden Markov model
3. Department of Financial and Actuarial Mathematics, TU Vienna, Austria, December 2-3, invited talk: Portfolio optimization under partial information

<u>Students</u>

Dr. Saß supervises jointly with Prof Larcher one PhD thesis (Markus Hahn).

<u>Dr. Klaus Scheicher</u>

<u>Research 2003</u>

Number Systems and Fractals

It is well known that each positive integer *n* can be expressed uniquely in base *b*, where *b* is an integer greater than one.

This concept can be generalized in several directions.

On the one hand the base sequence $1,b,b^2,\dots$ can be replaced by a sequence $1=u_0<u_1<u_2$.. to obtain representations of positive integers. Of special interest is the case where the base sequence is defined by a linear recurrence. A famous example belonging to this class is the so-called Zeckendorf representation.

On the other hand, one can generalize the set of numbers which can be represented. We mention two kinds of number systems belonging to this class:

The so called *beta-expansions* introduced by Rényi which are representations of real numbers in the unit interval as sums of powers of a real base number beta. These digit representations of real numbers are strongly related to digit representations of positive integers if beta is a zero of the characteristic polynomial of a linear recurring base sequence. Of special interest is the case where beta is a Pisot number.
Another kind of number systems which admit the representation of a set which is different from the set of integers are the so-called *Canonical Number Systems* (for short CNS).

Both concepts are intimately related to fractal geometry. In both cases, the set of numbers having digits only after the decimal point (i.e. the analogon to the unit interval) has fractal boundary and induces a tiling of the *n*-dimensional space.

QMC Algorithms

Recent results in the theory of quasi-Monte Carlo methods have shown that the weighted Koksma-Hlawka inequality gives better estimates for the error of quasi-Monte Carlo algorithms.

It is a well known fact, that error bounds for quasi-Monte Carlo algorithms are quite conservative. It has been shown by I. Sloan and H. Wozniakowski, that one can get better estimates by introducing weights for the importance of the coordinates. Moreover the tractability of the problem is related to the magnitude of the sum of these weights. The paper [3] is a first step in finding out how to choose the weights.

These results have strong applications in mathematical finance. Paskov and Traub introduced quasi-Monte Carlo methods to evaluate collateralized mortgage backed securities (CMOs). They could reduce their problem to the problem of computing certain integrals in 360 dimensions in the unit cube.

QMC algorithms also seem to be useful for several kinds of path integration: in mathematical finance, pricing of Asian style options becomes tractable; in physics, QMC algorithms have been successfully applied for Feynman-Kac path integrals.

It is widely believed that QMC algorithms are effective for dimensions less than 30. Although the CMO problem is apparently of higher dimension, the lower-dimensional effects seem to be dominating. For this reason, Caflisch and Morokoff introduced the notion of the “effective dimension” of an integration problem.

In [3], the so-called Brownian Bridges Algorihtm for path integration was analyzed.

Publications

1. K. Scheicher and J. M. Thuswaldner, Digit systems in polynomial rings over finite fields, Fields Appl., 9:322--333, 2003.
2. G. Larcher, F. Pillichshammer and K. Scheicher, Weighted Discrepancy and High-Dimensional Numerical Integration, BIT Num. Math., 43:121--135, 2003.
3. G. Larcher, G. Leobacher and K. Scheicher, On the tractability of the Brownian Bridge algorithm, J. Complexity, 19:511--528, 2003.
4. K. Scheicher and J. M. Thuswaldner, On the Characterization of Canonical Number Systems. Osaka J. Math., to appear.

5. S. Akiyama and K. Scheicher, Intersecting two-dimensional fractals with lines, submitted, 2003.
6. L. L. Cristea, G. Pirsic, F. Pillichshammer and K. Scheicher, Discrepancy estimates for point sets on the s-dimensianal Sierpinski carpet, submitted, 2004.

Cooperations

Name	Institution	Topic	Publication
S. Akiyama	Univ. Niigata/Japan	Fractals	[5]
L.L. Cristea	T.U. Graz	Fractals	[6]
G. Larcher	Univ. Linz	QMC Algorithms	[2,3]
G. Leobacher	Univ. Linz	QMC Algorithms	[3]
F. Pillichshammer	Univ. Linz	QMC Algorithms / Fractals	[2,6]
G. Pirsic	RICAM	Fractals	[6]
J.M. Thuswaldner	M.U. Leoben	Number Systems	[1,4]

Contributed Talks

1. 23. Journées Arithmétiques, Graz, On the Characterization of Canonical Number Systems.
2. 8. Österreichisches Mathematikertreffen, Bozen, On the Characterization of Canonical Number Systems.

Dr. Arne Winterhof

Introduction

Dr Winterhof's main research area is the theory of finite fields including applications in cryptography, coding theory, and random number generation. In his field of interest are also related areas as combinatorics, (computer) algebra, (algorithmic) number theory, and theoretical computer science.
His most important achievements are the development of new exponential sum techniques, bounds on the number of solutions of equations over finite fields, and their applications in cryptography, pseudorandom number generation, coding theory, and number theory.

Research 2003

In 2003 Dr. Winterhof focused on cryptography and random number generation.

Nonlinear pseudorandom number generators

Nonlinear methods for the generation of pseudorandom numbers are attractive alternatives to linear methods. Initially, a nonlinear generator was defined as a recurrence sequence over a finite field. More recently, explicit representations were also studied. A 'good' lattice structure is a desirable feature of pseudorandom numbers for Monte-Carlo simulations and a low linear complexity profile is disastrous for applications in cryptography. In [2,3] Dr Winterhof and Dr Dorfer (TU Vienna) proved that both figures of merit provide essentially the same quality measures. Lower bounds on the linear complexity of recursive and explicit nonlinear pseudorandom numbers were deduced by Dr Gutierrez (Santander University), Dr

Shparlinski (Macquarie University Sidney), and Dr Winterhof in [4] and by Dr Meidl (NU Singapore) and Dr Winterhof in [9], respectively. Additionally, in [10] Dr Meidl and Dr Winterhof introduced new explicit nonlinear generators over a finite field of period coprime to the characteristic of the finite field and studied the linear complexity of these sequences. Up to now only explicit generators of period equal to the cardinality of the finite field have been studied. In [13] Dr Winterhof and Prof Niederreiter (NU Singapore) proved bounds on multiplicative character sums of nonlinear pseudorandom numbers in parts of the period. These results yield information on the distribution of primitive elements in finite fields and provide a first step for the derandomization of search algorithms for primitive elements.

Cryptographic functions

A recent trend in cryptography is the search for theoretical results that support the assumption that certain cryptosystems are secure. Dr Winterhof focused on results on systems based on the intractability of the discrete logarithm and proved lower bounds on the complexity of the discrete logarithm and the Diffie-Hellman mapping. In particular he improved lower bounds on the linear complexity [15] and in joint work with Dr Meidl he obtained new results on the autocorrelation of the discrete logarithm sequence [11] over a finite field. Dr Winterhof and Dr Lange (University of Bochum) studied polynomials representing the elliptic curve discrete logarithm in [8] and Boolean functions representing the most significant bit of the finite field discrete logarithm in [7]. Dr Winterhof and Dr Kiltz (University of Bochum) analyzed some cryptographic functions closely related to the Diffie-Hellman problem called P-Diffie-Hellman functions [5,6] which were introduced by Dr Kiltz. They showed that the existence of a low degree polynomial representing a P-Diffie-Hellman function on a large set would lead to an efficient algorithm for solving the Diffie-Hellman problem. Motivated by this result they proved lower bounds on the degree of such interpolation polynomials.
Boneh and Venkatesan have proposed a polynomial time algorithm in a non-uniform model for recovering a "hidden" element of a finite field of prime order from very short strings of the most significant bits of the residue of several multiples of this element with randomly chosen multipliers. In [14] Dr Shparlinski and Dr Winterhof modified the scheme and amplified the uniformity of distribution of the multipliers and thus extended this result to subgroups of the finite field which are more relevant to practical usage.
The result can be applied to the bit security of Diffie-Hellman related encryption schemes starting with subgroups of very small size, including all cryptographically interesting subgroups. Based on these advances the same authors and Prof Codenotti (University of Chicago) showed in [1] that for several natural classes of ‘structured’ matrices, including symmetric, circulant, Hankel, and Toeplitz matrices, approximating the permanent modulo a prime is as hard as computing the exact value. Results of this kind are well known for arbitrary matrices. However, the techniques do not seem to apply to ‘structured’ matrices.
In [12] Prof Niederreiter and Dr Winterhof proved results on the distribution of points in an orbit of the projective linear group over a finite field acting on an element of the field. These results support a conjecture of Klapper. The result can be interpreted as result on the security of certain cryptosystems.

Publications

1. B. Codenotti, I. Shparlinski, and A. Winterhof, On the hardness of approximating the permanent of structured matrices, Computational Complexity, to appear.
2. G. Dorfer and A. Winterhof, Lattice structure and linear complexity profile of nonlinear pseudorandom number generators, Applicable Algebra in Engineering, Communication and Computing 13 (2003), 499-508.
3. G. Dorfer and A. Winterhof, Lattice structure of nonlinear pseudorandom number generators in parts of the period, Proceedings MCQMC 2002, to appear.
4. J. Gutierrez, I. Shparlinski, and A. Winterhof, On the linear and nonlinear complexity profile of nonlinear pseudorandom number generators, IEEE Transactions on Information Theory 49 (2003), 60-64.
5. E. Kiltz and A. Winterhof, Polynomial interpolation of cryptographic functions related to the Diffie-Hellman problem, Proceedings Workshop on Coding and Cryptography 2003, 281-288.
6. E. Kiltz and A. Winterhof, Lower bounds on weight and degree of bivariate polynomials related to the Diffie-Hellman mapping, Bulletin of the Australian Mathematical Society, to appear.
7. T. Lange and A. Winterhof, Interpolation of the discrete logarithm in Fq by Boolean functions and by polynomials in several variables modulo a divisor of q-1, Discrete Applied Mathematics 128 (2003), 193-206.
8. T. Lange and A. Winterhof, Interpolation of the elliptic curve Diffie-Hellman mapping, Lecture Notes in Computer Sciences 2643 (2003), 51-60.
9. W. Meidl and A. Winterhof, On the linear complexity profile of explicit nonlinear pseudorandom numbers, Information Processing Letters 85 (2003), 13-18.
10. W. Meidl and A. Winterhof, On the linear complexity profile of some new explicit inversive pseudorandom number generators, Journal of Complexity, to appear.
11. W. Meidl and A. Winterhof, On the autocorrelation of cyclotomic generators, Proceedings Fq7, to appear.
12. H. Niederreiter and A. Winterhof, On the distribution of points in orbits of PGL(2,q) acting on GF(q^n), Finite Fields and Their Applications 9, 458-471.
13. H. Niederreiter and A. Winterhof, Multiplicative character sums of nonlinear recurring sequences, Acta Arithmetica, to appear.
14. I. Shparlinski and A. Winterhof, A nonuniform algorithm for the hidden number problem in subgroups and cryptographic applications, Proceedings PKC 2004, to appear.
15. A. Winterhof, A note on the linear complexity profile of the discrete logarithm in finite fields, Proceedings WCCC, to appear.

Cooperations

Name	Institution	Topic	Publication
B. Codenotti	University of Chicago	Structured matrices	[1]
G. Dorfer	TU Vienna	Pseudorandom numbers	[2,3]
J. Gutierrez	Santander University	Linear complexity	[4]
E. Kiltz	University of Bochum	Cryptographic functions	[5,6]
T. Lange	University of Bochum	Cryptographic functions	[7,8]
W. Meidl	NU Singapore	Sequences	[9-11]
H. Niederreiter	NU Singapore	Pseudorandom numbers	[12,13]
I. Shparlinski	Macquarie University Sydney	Cryptography	[1,4,14]
A. Topozoglu	Sabanci University Istanbul	Pseudorandom numbers	in progress

Invited Talks

1. TU Graz, On some properties of nonlinear recurrence sequences
2. Remote University Hagen, On some properties of nonlinear pseudorandom numbers
3. Sabanci University Istanbul, Measures for pseudorandomnes
4. TU Vienna, Quality measures for nonlinear pseudorandom number generators

Contributed Talks

1. Fq7, Toulouse, Autocorrelation of the discrete logarithm
2. AAECC15, Toulouse, On the interpolation of the elliptic curve Diffie-Hellman problem
3. Combinatoric colloquium, Magdeburg, On cyclotomic orthomorphisms

Visits of Institutions

1. January- July, National University of Singapore, Tutorials on elementary and advanced coding theory, research with H. Niederreiter and W. Meidl
2. 27 September – 10 October, Sabanci University Istanbul, invited talk and research with A. Topozoglu
3. Winter term, University of Vienna, Lectures on coding theory

Leader of FWF Project

S8313 Number theoretic methods in cryptography and pseudorandom number generation (part of FSP83 Number theoretic algorithms and applications)

Students

Dr Winterhof is currently supervising a diploma thesis (Nina Brandstätter) and two PhD-theses (Anna Varbanova, Harald Schön).

Group “Analysis of Partial Differential Equations”

Group Leaders:

o.Univ.-Prof. Dr. Peter Markowich
a.Univ.-Prof. Dr. Christian Schmeiser (also employed half time by RICAM)

Further Researchers:

Dr. Antonio Leitao
Dr. Norayr Matevosyan

In this first year of RICAM, all the group members continued their research work started at previous affiliations, but some cooperations started immediately, e.g. Markowich-Matevosyan on free boundary problems, Engl-Markowich-Leitao, and also Leitao-Schmeiser on parameter identification problems in semiconductors. These cooperations will be continued in 2004 and probably extended to other RICAM members.

The group should be extended in 2004 by at least one more PostDoc.

A major effort in 2004 will go into the extension of the efforts in Mathematical Biology. In a special semester on mathematical modelling of cell motion and cell signalling, a number of (mathematical) biologists will be invited and an initiative will be started which should involve several groups at RICAM. A cooperation with a visitor program at the Wolfgang Pauli Institute (Vienna) on the same subject is planned; also, research directions started at the IPAM Special Semester on Inverse Problems will be continued in this context.
Furthermore, a joint summer school with the Viennese Wissenschaftskolleg “Differential Equations” and with the Graduiertenkolleg "Erhaltungsprinzipien in der Modellierung und Simulation mariner, atmosphärischer und technischer Systeme" in Hamburg are planned.

In the following, the activities of the group members employed at RICAM are described in individual sections.

Dr Antonio Leitao

Introduction

Over the last 6 years Dr Leitao has been working mainly with inverse problems, in particular with problems modeled by PDE's and with iterative methods. In particular, list he has worked on the following topics: both linear and non-linear Cauchy problems (in particular of elliptic type), Mazya iteration, Mann Iteration, Backus-Gilbert method, Level-set methods, Landweber method, dynamic programming based regularization methods, parameter identification in semicondutor equations. Dr. Leitao was intentionally assigned to the PDE group in order to further strengthen cooperation between that group and the inverse problems group.

A secondary area of research of Dr Leitao is optimal control and dynamic programming.
His research in this area started 3 years ago. As a result, 2 papers and one monography (2001, ISBN 85-244-0171-0) on this subject have already been published.

Research 2003

In 2003 Dr Leitao focused on the following problems: level set methods (collaboration with O.Scherzer and O.Dorn), dynamic programming based regularization methods (collaboration with S.Kinderman), parameter identification in Semicondutor equations (collaboration with P.Markowich and H.W.Engl and M.Burger), optimal control in ressource management (collaboration with J.Baumeister), elliptic Cauchy problems (collaboration with M.Klibanov), symmetry group techniques for inverse problems (collaboration with N.Bila).

Publications

1. A.Leitao, O.Scherzer: On the relation between constraint regularization, level sets, and shape optimization, Inverse Problems 19 (2003), L1-L11
2. P.Kuegler, A.Leitao: Mean value iterations for nonlinear elliptic Cauchy problems, Numerische Mathematik 96 (2003), 269-293
3. J.Baumeister, A.Leitao, G.N.Silva: On the value function for control problems with infinite horizon, IMA Journal of Mathematical Control and Information, to appear
4. M.Burger, H.Engl, A.Leitao, P.Markowich: On inverse problems for semiconductor equations, Matematica Contemporanea, to appear
5. J.Baumeister, A.Leitao: Optimal exploitation of renewable resource stocks: Necessary conditions, IMA J Mathematical Control Information, to appear
6. F.Fruehauf, A.Leitao, O.Scherzer: Analysis of Regularization Methods for the Solution of Ill--Posed Problems involving Unbounded Operators and a Relation to Constraint Optimization, SIAM J Numerical Analysis, submitted
7. S.Kindermann, A.Leitao: On regularization methods based on dynamic programming techniques, J Mathematical Analysis and Applications, submitted

Cooperations

Name	Institution	Topic	Publication
J. Baumeister	Frankfurt University	Dynamic Programming	[3,5]
N. Bila	Linz University	Inverse Problems	in progress
O. Dorn	Univ. Carlos 3 de Madrid	Level-Sets	in progress
S. Kindermann	Linz University	Regularization Methods	[7]
M. Klibanov	UNC Charlotte	Carleman weight functions	in progress
P. Kuegler	Linz University	Cauchy Problems	[2]
O. Scherzer	Innsbruck University	Level-Sets	[1,6]
J. Zubelli	IMPA Rio	Parameter identification	in progress
	(Project supported by Brazilian research agency CNPq, for 24 months starting in Jan 2004)		

Invited Talks

1. Analysis of Level Set Methods (Chair D.Marchesin)
   VIII Workshop on Partial Differential Equations
   IMPA, Rio de Janeiro, 21 - 25 Jul, 2003
   http://www.fluid.impa.br/wedp03/

2. Inverse Problems for Semiconductor Devices (Chairs J.Zubelli and P,Markowich)
   24th Brazilian Mathematical Colloquium
   Special Session: PDE's in Industry and Engineering
   IMPA, Rio de Janeiro, 27/jul - 1/aug 2003

http://coloquio.impa.br/CBM24/Sessoes/EDP_Ind_Engenharia/index.html

3. On the value function for optimal control problems with infinite horizon (Chair A.Iusem)
   24th Brazilian Mathematical Colloquium
   Special Session: Optimization
   IMPA, Rio de Janeiro, 27/Jul - 1/Aug 2003
   http://coloquio.impa.br/CBM24/Sessoes/Otimizacao/index.html

Contributed Talks

1. On the relation between constraint regularization and level-set methods
   Analytic and Geometric Methods in Inverse Problems
   Helsinki, Finland, 25 - 29 Aug 2003
   http://www.math.hut.fi/inverseyear/openingconference/

Visits of Institutions

1. Chair: Dr. Alexandre Madureira
   Department of Applied Mathematics, National Laboratory of Scientific Computation
   Petropolis (Brazil), 29 Jul, 2003
   Talk: On the relation between constraint regularization and level-set methods

2. Chair: Dr. Oliver Dorn
   Departamento de Matemáticas, Universidad Carlos III de Madrid Madrid (Spain), 7 - 13 Sep, 2003
   Talk: On the relation between constraint regularization and level-set methods

3. Chair: Prof. Dr. Karl Kunisch
   Institute of Mathematics, University of Graz, Graz, 4 - 5 Dec, 2003
   Talk: On regularization methods based on dynamic programming techniques

4. Prof. Dr. H.W.Engl
   IPAM, UCLA, USA, 12 - 20 Nov, 2003
   Conference: Inverse Problems Workshop Series II
   http://www.ipam.ucla.edu/programs/invws2/

5. Chair: Prof. Dr. Raul Feijoo
   Department of Applied Mathematics, National Laboratory of Scientific Computation
   Petropolis (Brazil), 16 - 23 Dec, 2003
   Talk: Regularisation of inverse and ill-posed problems

6. Chair: Prof. Dr. J.Zubelli
   IMPA (Brazil), Rio de Janeiro, 5 – 17 Jan, 2004
   Short course: Inverse Problems: Regularisation and Level-Sets

Invited guests at RICAM

1. Dr Oliver Dorn
   Departamento de Matemáticas, Universidad Carlos III de Madrid
   Period of visit: 2 - 6 Jun 2003
   Talk: A level set method for shape reconstruction in medical and geophysical imaging (3 Jun 2003)

2. Prof Dr Johann Baumeister
   Department of Mathematics, Frankfurt University
   Period of visit: 6 - 10 Oct 2003
   Talk: Optimale Steuerung mit Impulskontrollen am Beispiel eines Besteuerungsproblems (RICAM Seminar, 6 Oct 2003)

Organization of Scientific Events

1. Workshop: Technological Applications of PDE's
   Florianopolis, Brazil, 2 - 6 February 2004
   http://www.ricam.oeaw.ac.at/people/page/leitao/ws-tapde04/
   Organizing Committee: A.Leitao, P.Markowich, I.Mozolevski, J.P.Zubelli
   Financial support: CNPq (http://www.cnpq.br/), IM-AGIMB (http://milenio.impa.br/)

Dr Norayr Matevosyan

Introduction

Over the last 4 years Dr Matevosyan has been working mainly on free boundary problems, in particular with Free Boundary problems (F.B.p.), in particular with contact points. In particular, he has worked on superconductivity phenomena in F.B.p-s with contact points, parabolic and fully nonlinear F.B.p-s with contact points, obstacle like two-phase F.B.p-s.

A secondary area of research of Dr Matevosyan concerns uniqueness theorems for harmonic functions. His research in this area started 5 years ago. As a result a paper on this subject has been published.

Research 2003

In 2003 Dr Matevosyan focused on the following problems: fully nonlinear F.B.p-s with contact points (collaboration with P. A. Markowich), tangential touch between free and fixed boundaries in obstacle like two-phase problems (collaboration with J. Andersson and H. Mikayelyan), orthogonal touch between free and fixed boundaries in obstacle like two-phase problems (collaboration with J. Andersson and H. Mikayelyan), regularity of the free boundary in obstacle like two-phase problems (collaboration with J. Andersson and H. Mikayelyan).

Publications

1. N. Matevosyan, Tangentioal touch between free and fixed boundaries, PhD thesis, KTH Stockholm
2. N. Matevosyan, P.A. Markowich: Behaviour of the free boundary near contact points with fixed boundary for nonlinear elliptic equations, Monatshefte fur Matematik, to appear

Cooperations

Name	Institution	Topic	Publication
N. Arakelian	Armenian Academy of Sci.	Harmonic functions	1
P. Markowich	Vienna University, RICAM	Free Boundaries	1
J. Andersson	KTH (Stockholm)	Free Boundaries	in progress
H. Mikayelyan	Leipzig University	Free Boundaries	in progress

Visits of Institutions

Prof. Dr. Henrik Shahgholian
Department of Mathematics, Royal Institute of Technology,
Stockholm, Dec. 2003

Prof. Christian Schmeiser

Introduction

The recent research work of C. Schmeiser has been concentrated on kinetic and macroscopic models for the transport of ensembles of charged particles (in particular in semiconductor materials, see the book *Semiconductor Equations,* by P. Markowich, C. Ringhofer, C. Schmeiser, Springer, 1990). These models include semiclassical kinetic equations, nonlinear hyperbolic fluid systems and the classical drift-diffusion model. Typical questions are the well posedness of initial-boundary value problems, the qualitative behaviour of solutions, as well as the development of efficient numerical methods. C. Schmeiser has contributed to the qualitative analysis of the drift-diffusion model. A number of ad hoc modelling assumptions from the physical literature have been mathematically justified and extended by rigorous asymptotic analyses of singular limits.
The qualitative understanding also prompted the development of nonstandard numerical approaches particularly suited to the drift-diffusion model. Recent work on the drift-diffusion model includes a renewed attack on some longstanding open problems (Debye-length-to-zero-limit in the parabolic case) and the derivation of free boundary problems as singular limits.

Several contributions of C. Schmeiser are concerned with the transition from kinetic to macroscopic models. This problem has been analyzed for different applications: electron-phonon systems in semiconductors, ionization in semiconductors and in gases, radiative transfer.

A very recent research area of C. Schmeiser is mathematical modelling of chemotaxis. Kinetic transport equations and their connection to macroscopic models also

Research 2003

In 2003, C. Schmeiser worked on the following problems: Derivation of macroscopic limits for charge transport in semiconductors (cooperations with I. Choquet (Chalmers, Gothenburg), P. Degond (Univ. Paul Sabatier, Toulouse), C.D. Levermore (Univ. of Maryland)). Quasineutral limit of the semiconductor drift-diffusion model (cooperation with S. Wang (Univ. Wien)). Modelling of chemotaxis, in particular derivation of drift-diffusion models form kinetic transport equations (cooperations with Y. Dolak (WK, Wien), F. Chalub (Univ. Wien), P. Markowich, B. Perthame (ENS, Paris)). Convergence to equilibrium for spatially nonhomogeneous kinetic equations (cooperations with K. Fellner (WK, Wien), L. Neumann

(WK, Wien), F. Popaud (Univ. Nice), V. Miljanovic (WK, Wien)). Analysis of a nonlinear dispersive model problem for two species gases of charged particles (cooperation with K. Fellner (WK, Wien)). Velocity saturation limit of a semiconductor drift-diffusion model (cooperation with J. Haskovec (Univ. Prague)).

Publications

1. I. Choquet, P. Degond, C. Schmeiser, Hydrodynamic model for charge carriers involving strong ionization in semiconductors, Comm. in Math. Sci. 1 (2003), 74-86.

2. C. Schmeiser, S. Wang, Quasineutral limit of the drift-diffusion model for semiconductors with general initial data, Math. Models and Meth. in Appl. Sci. 13 (2003), 463-470.

3. I. Choquet, P. Degond, C. Schmeiser, Energy-transport models for charge carriers involving impact ionization in semiconductors, Transp. Th. and Stat. Phys. 32 (2003), 99-132.

4. P. Degond, C.D. Levermore, C. Schmeiser, A note on the Energy-Transport limit of the semiconductor Boltzmann equation, in Transport in Transition Regimes, N. Ben Abdallah, A. Arnold, P. Degond, I. Gamba, R. Glassey, C.D. Levermore, and C. Ringhofer (eds.), IMA Vol. in Math. and its Appl. 135, Springer-Verlag, 2003.

5. Y. Dolak, C. Schmeiser, A kinetic theory approach to resolving the chemotactic wave paradox, in Mathematical Modelling & Computing in Biology and Medicine, (V. Capasso Ed.), ESCULAPIO Pub. Co., Bologna, 2003.

6.K. Fellner, L. Neumann, C. Schmeiser, Convergence to global equilibrium for spatially inhomogeneous kinetic models of non-micro-reversible processes, to appear in Monatsh. Math.

7. K. Fellner, F. Poupaud, C. Schmeiser, Existence and convergence to equilibrium of a kinetic model for cometary flows, to appear in J. Stat. Phys.

8. F. Chalub, P.A. Markowich, B. Perthame, C. Schmeiser, Kinetic models for chemotaxis and their drift-diffusion limits, to appear in Monatsh. Math.

9. K. Fellner, C. Schmeiser, Burgers-Poisson: a nonlinear dispersive model equation, to appear in SIAM J. Appl. Math.

10. V. Miljanovic, C. Schmeiser, On a semiconductor model including recombination via distributed traps, manuscript, TU Wien.

11. F. Chalub, P.A. Markowich, B. Perthame, C. Schmeiser, On the derivation of drift-diffusion models for chemotaxis from kinetic equations, ANUM Preprint 14/02 (http://www.anum.tuwien.ac.at/preprints.htm).

12. Y. Dolak, C. Schmeiser, Kinetic models for chemotaxis: Hydrodynamic limits and the back-of-the-wave problem, ANUM Preprint 5/03 (http://www.anum.tuwien.ac.at/preprints.htm).

13. L. Neumann, C. Schmeiser, Convergence to global equilibrium for a kinetic model for fermions, ANUM Preprint 7/03 (http://www.anum.tuwien.ac.at/preprints.htm).

14. J. Haskovec, C. Schmeiser, Transport in semiconductors at saturated velocities, manuscript, TU Wien.

Cooperations

Name	Institution	Topic	Publication
I. Choquet	Chalmers, Gothenburg	macroscopic limits	1, 3
P. Degond	UPS, Toulouse	macroscopic limits	1, 3, 4
S. Wang	Univ. Wien	quasineutral limit	2
D. Levermore	Univ. Maryland	macroscopic limits	4
Y. Dolak	WK, Wien	chemotaxis modelling	5, 12
K. Fellner	WK, Wien	to equilibrium	6, 7
		dispersive modeling	9
L. Neumann	WK, Wien	convergence to equilibrium	6, 13
F. Poupaud	Univ. Nice	convergence to equilibrium	7
F. Chalub	Univ. Wien	chemotaxis modelling	8, 11
P. Markowich	Univ. Wien, RICAM	chemotaxis modelling	8, 11
B. Perthame	ENS, Paris	chemotaxis modelling	8, 11
V. Miljanovic	WK, Wien	convergence to equilibrium	10
J. Haskovec	Univ. Prague	saturated velocities	14

Talks

1. On the Relation Between Kinetic Transport Models and Fluid Models for Chemotaxis, SIAM Conference on Applications of Dynamical Systems, Snowbird (2003), invited minisymposium talk.
2. Aspects of the Mathematical Modelling of Chemotaxis, International Workshop on Numerical and Symbolic Scientific Computing, Strobl (2003).
3. Models for the Chemosensory Movement of Leucocytes, workshop on Advances in Numerical Algorithms, Graz (2003), invited talk.
4. Macroscopic limits of kinetic models for chemotaxis, ÖMG Tagung 2003, Bolzano (2003).
5. Aspects of the Mathematical Modelling of Chemotaxis, RICAM Colloquium, Linz (2003).
6. Applications of the Desvillettes-Villani Approach to the Convergence to Equilibrium for Nonhomogeneous Kinetic Models, Oberwolfach (2003), invited talk.

Optimization and Optimal Control Group (Plans)

Group Leader:

O.Univ.-Prof. DI. Dr. Karl Kunisch

The group was established on January 1, 2004 (subject to sufficient budget in 2004), and is currently in the process making postdoc appointments. The future research – within the scope that was evaluated by the Board in the fall of 2003 - will depend to a large extent on the special research expertise of the PostDocs to be hired. Very promising applications were received and suggest that the following research areas can be addressed.

1) Optimal control in magneto-hydrodynamics: It has been established experimentally that electro-magnetic fields provide a tool to influence flow and, in turn, the heat and mass transfer in electrically conducting fluids. Thus magnetic fields act as controls on the fluid. An additional attractive feature for metallurgical or crystal growth applications is the contact-less form of this control. We intend to investigate control and optimal control theoretical techniques applied to the coupled systems of partial differential equations describing these phenomena. It appears that this field is just emerging and of intrinsic interest, both to the engineering community and researchers in optimal control. Attractive features for carrying out this research in Linz at RICAM include the fact that Prof. Langers codes for the Maxwell's equations and fluid dynamics codes could come to profitable use. Dr. Griesse is a potential PostDoc to work on this project. He currently works as a PostDoc in an SFB project in the research group of K. Kunisch at Graz.

2) A second focal area should be closed-loop optimal control. In recent years there was a major research effort on open-loop optimal control of fluids and the group in Graz has certainly contributed to its success. Open-loop control, however, is not capable of immediate reaction to disturbances to the system and is not of stochastic nature. We plan to attack the Hamilton Jacobi Bellman (HJB) equations providing the feedback gains for evolutionary equations. To overcome the tremendous numerical complexity of this problem in case of systems with high dimensional state-spaces (as is the case for discretized partial differential equations) we intend to utilize model reduction based on proper orthogonal decompostion or balanced truncation, for example. In addition, such kinds of problems lend themselves in a natural way for parallel implementations. Dr. Nguyen is a potential PostDoc to work on this project. He just completed his Ph.D. with Prof. Hoppe in Augsburg on numerical methods on conservation laws and level set methods.