Annual Report of the SFB F013

"Numerical and Symbolic Scientific Computing"

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1 Scientific Results of the Projects

1.1 Project F1301: "Service and Coordination Project"

The scientific part of Project F1301 is concerned with the coordination of scientific software and the graphical pre- and postprocessing. This includes in particular to provide new and to extend existing software concepts. Hereby, we concentrated on the further development of the numerical software package FEPP [D8]. In particular, two topics have been considered.

1.1.1 Hierarchical Visualization of 3D/2D Data

The extremely large size of todays data sets arising from computational mathematics poses increasing demands for performance (in the sense of graphics-performance) on interactive visualization systems. "Real-time" interaction interfaces have proven useful for the analysis of these data sets, but real-time performance has been difficult to achieve with such large amounts of data. That is why G. Kurka developed a visualization tool which is especially designed for the visualization of large unstructured data sets. In particular the hierarchical data structures provided by the numerical schemes are used to obtain the desired efficient performance. The results are documented in the SFB-Report [B39].

1.1.2 Parallelization Based on Distributed Data Algorithms

The numerical software package FEPP [D8] tackles a wide range of problems arising in mathematical physics. Consequently, various numerical schemes have to be provided including Finite and Boundary Element Methods. All these differences cause different needs for the distribution of data as well as for the parallel generation and solution of the discrete systems. M. Kuhn developed a unifying parallelization concept which minimizes those parts of the code which are specific for some strategy of parallelization. Hereby, we observe that all the parallel techniques under consideration lead to one and the same parallel iterative algorithm applied to particular vector types which correspond to the kind of data distribution. Then the most essential operation of the parallel iteration is the type-conversion of such vectors. This conversion is hidden in the preconditioner or, more precisely, in the smoother if multigrid is used as preconditioner. The calculation of scalar products is the only remaining operation which has to be overloaded correctly. Moreover, the concepts of operator overloading and inheritance provided by C++ are exploited. The methods are especially designed for massively parallel computers and workstation clusters. They are based on algorithms described in the book by G. Haase [A2].

1.1.3 Miscellaneous

Besides the scientific research, G. Kurka was concerned with the evaluation of available hardware components with respect to the special requirements of the SFB. That is, the performance of several architectures with respect to computing and visualization has been investigated. The results of a series of performance tests carried out as part of an evaluation of different graphics workstations are summarized in [B40]. The graphics performance was determined by Viewperf 5.1. Some results of a relatively simple graphics benchmark, which measures the raw performance with regard to Gouraud-shading are presented, too. In order to get a good estimation of the processing power under real world conditions, a multi-grid software package was executed on all machines.

1.2 Project F1302: "Solving and Proving in General Domains"

The subproject, also called "*Theorema*" aims at integrating computation and deduction in a system that can be used by the working scientist for building and checking mathematical models, including the design and verification of new algorithms. Currently, the system uses the rewrite engine of the computer algebra system *Mathematica* for building and combining a number of automatic/interactive provers (high-order predicate-logic, induction for lists/tuples and natural numbers, etc.) in natural deduction style and in natural language presentation. These provers can be used for defining and proving properties of mathematical models and algorithms, while a specially provided "computing engine" can execute directly the logical description of these algorithms.

In a first phase of the development cycle a number of provers have been written using the rewrite language of the computer algebra system *Mathematica*. We are now in a second phase of the development, in which these provers are integrated with each-other and with a common user interface, everything being implemented in *Mathematica* packages using a common style. Most of the components are already working: the user interface, the logical evaluator, the common mechanism for integrating provers, and the provers for high-order predicate-logic prover, for equational simplification, for induction on lists and on natural numbers. A special prover for sets, one for mathematical analysis, and one for functor-built domains are under development.

The provers can be used for defining and proving properties of mathematical models and algorithms, while a specially provided "computing engine" can execute the logical description of these algorithms directly. This requires a careful separation of the "object–level" and the "meta–level" of the language used.

The proofs produced by our system are presented in natural (English) language, similar to the one which is used in scientific textbooks. The external (notebook) representation of the proof is produced from an internal representation (the proof object) by a set of display packages, thus is an activity separated from the proof search. First a simple analyser generates the structure of the cells from the tree structure of the proof object, then the texts are displayed at the appropriate places. Support for various languages can be easily added by modifying the specific packages which display these texts.

1.3 Project F1303: "Proving and Solving over Reals"

A theory for approximate quantifiers has been developed by Stefan Ratschan, in order to model the situation that constraint parameters are often known up to a certain accuracy, as it often happens in applications in industry/engineering. He also defined a constraint programming language for this concept and implemented it, together with new algorithms solving these constraints.

The problem of solving algebraic equations in real 3-space in terms of rational function, which can also be phrased as the problem of rational parametrization of real algebraic surfaces, has been partially solved by Josef Schicho. His method solves, in some sense, almost all surfaces for which a complex parametrization is possible.

Several results have been obtained in connection to quantifier elimination based on cylindric algebraic decomposition. This method was originally invented by G. Collins already 25 years ago, but it is still the fastest method for the solution of general constraints with quantifiers. One of the main steps, the so-called projection phase, is based on resultant techniques for multivariate polynomials. In the project, an effort was made to enrich these polynomials with some additional structure in order to speed up the algorithm. A prototype of this new method has been implemented by Antonin Tesacek. Experiments have shown that one can indeed cut down the number of projected polynomials significantly.

On the other hand, Pau and Schicho achieved partial results towards a generalization of the CAD method to the case of trigonometric functions, which occur often in applications in mechanical engineering and control theory. The idea is to use the well-known "tanhalf" transformation, transforming an angle to the tangent of its half. The main problem is to deal with the case where the tangent is infinity, in a systematic way that is compatible with the theory of cylindric algebraic decompositions.

1.4 Project F1304: "Symbolic-Numerical Computation of Algebraic Curves and Surfaces"

In this first year of the project we have investigated new topics in parametrization of algebraic curves and surfaces, and we have also extended the scope of the project to include generalizations of algebraic elimination methods to elimination methods for differential polynomials.

1.4.1 Parametrization of Curves and Surfaces

Rationally parametrized algebraic curves and surfaces are of high importance in computer aided geometric design. Not every curve or surface can be rationally parametrized (i.e. over the given ground field). In previous work, both we and also other authors have investigated and designed decision methods for determining whether such geometric objects can indeed be parametrized over an algebraically closed field. For an overview compare [B54]. For practical applications this is not optimal. If we are considering a real algebraic curve, then we actually want to have a parametrization of this curve over the real numbers. In [B51] we show that every real curve, which can be parametrized over the complex numbers, can in fact also be parametrized over the real numbers, and we give an algorithms for actually determining such a parametrization over the reals.

We have reported on these new developments in various lectures [B54], [C67], [C66], [C65], [C62]. F. Winkler was invited for 1 month as a Visiting Academic to the University of Sydney to explain these new techniques to the Computational Algebra Group of Prof. John Cannon. Prof. Cannon with his group is the author of the widely used computational algebra system Magma.

More recently we have investigated the rational parametrization of certain surfaces important for computer aided geometric design, namely so-called canal or pipe surfaces. We are able to carry over many of the methods for curves to methods for this class of surfaces.

1.4.2 The Software System CASA

The software system CASA for computer aided computation on algebraic curves and surfaces has undergone a detailed analysis [B23]. We are currently starting to provide the possibility of parallel computation in CASA. F. Winkler has reported on our systems work in [C64], [C68].

1.4.3 Differential Polynomials and Symmetries of PDEs

Together with Dr. Fritz Schwarz (GMD Bonn/St.Augustin) we are investigating the application of canonical bases for differential polynomial ideals, so-called Janet bases, to the analysis of symmetries of partial differential equations of low order. Such symmetry analysis is available for ordinary differential equations, and E. Hillgarter in his ph.d. thesis work is extending these methods to PDEs. Another ph.d. student, R. Hemmecke, compares the different approaches to the problem of canonical bases for differential polynomial ideals.

1.5 Project F1305: "Symbolic Summation and Combinatorial Identities"

1.5.1 MacMahon's Partition Analysis

In his famous book "Combinatory Analysis" MacMahon introduced partition analysis as a computational method for solving problems in connection with linear homogeneous diophantine inequalites and equations, respectively. For several decades this method has remained dormant. Only recently, G.E. Andrews (PennState, USA; guest professor at RISC in April/May 1998) has observed that partition analysis is ideally suited for being supplemented by modern computer algebra methods. So Andrews, together with P. Paule and A. Riese developed a Mathematica package `Omega` which can be used as a tool for solving problems with constraints in form of linear diophantine inequalities. A similar package with respect to linear diophantine equations is in preparation. — As worked out by Andrews and Paule, a variant of partition analysis can be applied also to hypergeometric multisum identities. Examples range from the preprocessing for automatic theorem proving to enumeration problems in statistical physics.

1.5.2 q-Hypergeometric Multisums

Previously H. Wilf and D. Zeilberger set up an approach for the automatic treatment (e.g., proving) of identities involving hypergeometric multisums. K. Wegschaider, in his dimploma thesis (advisor: Paule) turned this approach into concrete algorithmics and efficient implementation. Riese succeeded to translate Wegschaider's algorithm into a q-analogue which enables, e.g., automatic theorem proving for a very general family of q-hypergeometric identities (including the prominent class of the Rogers-Ramanujan type). In addition, Riese already came up with a prototype implementation in Mathematica.

1.5.3 Indefinite Summation

Around 1980 M. Karr developed a summation counterpart (for certain difference field extensions) to Risch-integration. Despite the fact that its domain of application is impressively general (e.g, including harmonic numbers that arise in the analysis of algorithms), Karr's method has not achieved the attention it deserves. Now C. Schneider (PhD student; advisor: Paule) developed a first Mathematica prototype that implements Karr's machinery in full generality. Schneider will be employed by the SFB in the very next future.

1.5.4 Additive Number Theory

B. Zimmermann (diploma student; advisor: Paule) has been invited by Andrews and A. Knopfmacher (Johannesburg, South Africa) to serve as a co-author for a joint paper dealing with certain statistics in connection with the partition of numbers. Zimmermann is about to finish his diploma studies; then he will become an SFB-collaborator.

1.5.5 Miscellaneous

In 1998 Wilf and Zeilberger received the Steele prize for work in summation theory; in his response [Notices of the AMS **45** (April 1998), 507–508] Zeilberger explicitly pointed to the significance of the work carried out by project group F1305. — The National Institute of Standards and Technology ("NIST", Gaithersburg, USA) is about to initiate the project of editing an updated version of the "Handbook of Mathematical Functions" (1964; Abramowitz and Stegun, eds.) which is the probably most frequently cited work in the scientific literature. Paule has been invited by NIST to serve as the editor for the new section on computer algebra.

1.6 Project F1306: "Coupled Field Problems: Advanced Numerical Methods and Applications to Nonlinear Magnetomechanical Systems"

The driving goal of this project is the ability to simulate large scale, real life applications involving different types of physical phenomena leading to different types of partial differential equations. More particular, we considered so far the coupling of mechanics and magnetics as occur in the design of sensors, actors and electric machines.

M. Schinnerl works on the design and implementation of iterative algorithms for coupled problems. He uses the adaptive multi-level finite element code FEPP [D8], which provides the frame-work for discretizing, solving and postprocessing. Thanks to the abstract formulation, his algorithms apply very similar for 2D as well as 3D problems. Some applications will be described below.

J. Schöberl is mainly concerned with the support of the components, especially the multigrid preconditioners [B49, B48] and a posteriori error estimators. The challange for him is the design, analysis and implementation of components which are robust with respect to geometry and material parameters, efficient as well as simple to use as part of a global problem. He strongly interacts with M. Schinnerl in the analysis of the global algorithms and the choice of components.

S. Reitzinger is working on algebraic multigrid methods. One reason is the requirement to handle also rather fine initial meshes of more than 100 000 grid points in 3d, where direct solvers are intractable. The other intention for him is to provide fast preconditioners, where geometric multigrid fails, or is too difficult to implement. He has good results for anisotropic problems, which are discretized by thin rectangles (2d) or prism (3d) [A4]. Geometric multigrid fails, unless proper coarsening or block smoothers are used. Also, what is more surprising, standard AMG (Ruge Stüben) fails for these problems, because the system matrices are far away from M-matrices. The key is to replace the element matrices by spectrally equivalent M-matrices, and build an AMG preconditioner based on this matrix. He successfully applied this technique to shielding problems and anisotropic local refinement towards edge singularities. S. Reitzinger and M. Kaltenbacher ported this AMG solver into the multi-field uni-grid finite element code CAPA [D3], where it is the only chance for efficient equation solving [D3].

One specific example of interest is the design of an iterative solver for magnetic field problems involving (non-linear) ferro-magnetic materials. Standard techniques are fixed point iterations as well as Newton's method. Both algorithms are special choices of preconditioned gradient methods for the associated convex minimization problem. By using a line-search step, convergence was obtained. Additionally, the need to solve the linear problem exactly, could be replaced by the application of just one preconditioning step. Comparing the fixed point approach with Newton's method, we obtained that the second one would need less non-linear iterations, but the leck of a robust preconditioner for the linearized problem made the first to the winner. Maybe, new AMG-methods of S. Reitzinger will change the ranking.

A stationary coupled field problem was investigated. An elastic ferro-magnetic coil with a small air gap is deformed due to magnetic forces at interfaces of the permeability. Thus the domain for the magnetic field problem as well as the field and the forces do depend on the mechanical deformation. This problem could be solved efficiently by a nested iteration. On each level of refinement just a few fixed point iterations are enough to capture the non-linearity.

The simulation of dynamical coupled magnetomechanical problems involve more physical phenomena. On one hand, motional electromagnetic forces lead to induction of currents in moving and conductive materials. On the other hand, current in a magnetic field causes mechanical forces (Lorentz forces). The interplay of all was simulated for 2d and very recently also for 3d problems. A practical application of the developed calculation scheme, the simulation of the transient behaviour of an EMAT (electro magnetical accoustic transducer), is used as benchmark problem. Here, the coil of a transmitting EMAT generates a strong permanent magnetic field covering a thin aluminium plate. A short burst of high frequency induces eddy currents in the plate, and the interaction of these currents with the overall stationary magnetic field of the permanent magnet leads to mechanical force. Thus, mechanical waves propagates in the plate and reach a receiving EMAT. Due to mechanical motion in the stationary magnetic field eddy currents are induced in the plate under the receiving EMAT. These eddy currents cause a transient magnetic field, which is measured by a receiving coil.

This benchmark is challenging for simulation. Up to now, we can run this problem efficiently in 2d. For the 3d simulations most components are available (H(rot) discretization and multigrid, handling of thin geometries), but here an adaptive space time discretization is a must and will be implemented next. This benchmark was chosen, because such an equipment was physically built up and analyzed by M. Schinnerl. For the 2d simulation a very good agreement between measurement and simulation could be obtained.

1.7 Project F1308: "Large Scale Inverse Problems"

In previous works, we have contributed to the convergence analysis of iterative regularization methods methods for nonlinear inverse problems such as inverse scattering problems, parameter identification problems and inverse heat conduction problems. For these applications, the most costly part in an implementation is the evaluation of the parameter-to-solution map, its derivative, and the adjoint of the derivative. Our aim in this project is to develop iterative methods that yield order optimal convergence rates with minimal computational effort and converge as fast as possible for exact data.

1.7.1 Convergence of Newton-type Methods in Inverse Scattering

Inverse scattering problems appear in many areas of science such as medical imaging, geophysical exploration, and nondestructive testing. They are particularly hard to solve since they are nonlinear and severely ill-posed. Due to this severe ill-posedness, we have shown for several inverse obstacle scattering problems that under realistic smoothness assumptions the best possible convergence rates are logarithmic in the data noise level. Under smoothness conditions that can be interpreted in terms of Sobolev spaces, we have established such logarithmic convergence rates for the iteratively regularized Gauß-Newton method, and our theoretical results were confirmed by numerical experiments in 2 space dimensions ([B25, B26]). Moreover, we have developed effective and highly accurate methods to evaluate the Fréchet derivatives of the direct problems, and provided an error analysis that allows an optimal choice of the discretization parameters during the Newton iteration.

Furthermore, we have started a cooperation with Project 1306 on inverse inhomogeneous medium problems.

1.7.2 Newton-type Methods for Parameter Identification Problems

Consider, e.g., the problem of identifying a distributed parameter $a = a(x)$ in the PDE

$$\begin{aligned} -\bigtriangledown (a \bigtriangledown u) &= 0 \qquad \text{in } \Omega \\ u &= g \qquad \text{on } \partial\Omega \end{aligned} \tag{1}$$

from measurements u^δ of u, modelled by the abstract operator equation $F(a) = u$ where F is the parameter-to-solution map. It can be shown that this parameter identification problem is ill–posed in the sense that a solution $a^\dagger$ does not depend continuously on the data u (actually u^δ) and therefore has to be regularized (see, e.g., the book of Engl, Hanke, and Neubauer).

Certainly the most well-known and most widely used regularization method is Tikhonov regularization, which was also used and shown to be convergent for a parameter identification problem in a parabolic PDE in [B10]. An interesting alternative to Tikhonov regularization are iterative regularization methods, e.g., Newton type methods (see [B9, B31, B32, B30]. Since in the analysis of Newton type methods for well-posed problems, invariance properties play an important role, a convergence analysis of Newton type methods for ill-posed problems under such invariance conditions was developped in [B9, B30].

For a practical implementation, any regularization method has to be discretized. On the other hand, discretization, i.e., projection on a finite-dimensional space itself can have a regularizing effect: Finite dimensional problems — though they might be ill-conditioned — are always well-posed in the sense of stable dependence of the solution on the data.

We used this fact to construct a Newton type method for solving $F(a) = u$ based on regularization by projection, namely $a_{n+1} = a_n + s_n$, where s_n is the best-approximate solution of $P_{Y_n}F'(a_n)s_n = P_{Y_n}(u^\delta - F(a_n))$ and Y_n are finite dimensional nested subspaces whose union is dense in Y — in the setting of parameter identification problems they will be finite element spaces. At the beginning of the iteration the discretization defined by the spaces Y_n can be rather coarse, but has to be refined in the course of the iteration, so that the optimal convergence speed of Newton's method is not affected. However, the finer the discretization is , the more the instability of the underlying infinite-dimensional ill-posed problem takes effect. Therefore, in the (practically relevant) case of noisy data, the Newton iteration has to be stopped at some appropriately chosen index. A convergence analysis of this method together with some optimal a priori and a posteriori stopping rules was done in [B30]. There, we showed convergence as $n \to \infty$ in the noise free case as well as convergence as the data noise level goes to zero in the case of noisy data (including convergence rates under additional regularity conditions.)

1.8 Project F1309: "Hierarchical Methods for Simulation and Optimal Design with Applications to Magnetic Field Problems"

During the first eight months we concentrated on essentially two topics. Firstly handling of geometries which is also used for projects F1306, and F1308. Secondly on hierarchical optimization of an 2D test problem.

Hence Wolfram Mühlhuber concentrated on the development of an efficient way for generating and handling 3D geometries. In order to close the gap between commercial Computer Aided Design systems for generating the shape of a working piece and our own tools for mesh generation (NETGEN) and numerical analysis (FEPP) new ways of exchanging and handling the data had to be developed.

The new data interface for NETGEN is based on STEP (Standard for the Exchange of Product Model Data), an ISO standard. STEP itself can be seen as a toolkit in which application specific product data models, so called Application Protocols, can be described using basic building blocks, so called Integrated Resources, in a predefined way. ISO describes its goal as an unambiguous representation of computer interpretable product information throughout the life of a product. That is why these Application Protocols cover a wide range of fields, e.g. design, geometry of parts, product information and documentation, manufacturing information, results of testing and quality control, a. s. o. The interface implements a large subset of STEP AP 203 for its geometry exchange and supports most of the geometric primitives defined therein.

In order to fully integrate the read geometry data into the existing software a completely new internal geometry representation model for both software products had to be developed. On the contrary to NETGEN's former geometry interface which was based on an Constructive Solid Geometry approach, the new geometry model implements a Boundary Representation approach, which is also used by most commercially available CAD programs.

Various tests using CAD files of different real life production geometries which were originally made available by various CAD program developers for testing their own software products were successfully performed.

In his diploma thesis to be finished in spring 1999 Klemens Hauser treated an 2D test example for the hierarchical optimization. This problem consist of a conductor with infinite length perpendicular to the x-y-plane, where we want to maximize the square of the magnetic field in x-direction in a point of measuring subject to a minimal distance to this point. For this problem we can prove existence and uniqueness of the optimal solution (first order and second order sufficient Kuhn-Tucker-conditions). Numerical experiments reflected the superiority of the hierarchical nested optimization method over the classical way to treat it, namely, where the grid size in the beginning is controlled by the error estimator for solving the underlying PDE.

1.9 Project F1310: "Estimation of Discontinuous Parameters in Differential Equations"

1.9.1 Denoising of Images

In this topic, Esther Radmoser, Otmar Scherzer (Institut für Industriemathematik), Joachim Schöberl (Institut für Analysis und Numerik), Joachim Weickert (Lehrstuhl für Bildverarbeitung, Univ. Mannheim) have been involved.

So far, we have treated a modern approach for the denoising of images, namely regularization by bounded variation. In contrast to other filtering strategies this approach conserves edges during filtering of noisy data. Moreover, this approach is extendable for the reconstruction of discontinuous features in general inverse problems, which is relevant for the further development of the project. Regularization with functions of bounded variation leads to a non-differentiable optimization problem, which is numerically difficult to realize. We use numerical algorithms to solve this problem in an efficient way, as they where originally developed for solving nonlinear differential equations. Moreover, we investigate analytically the choice of the many different parameters which appear in this minimization problem (cooperation with Joachim Schöberl).

Together with Joachim Weickert from the University of Mannheim, Germany, we have shown an important connection between nonlinear diffusion filtering and (iterative) regularization techniques. Besides of the theoretical importance of these results, this work enables us to develop new algorithms for the detection of discontinuities of solutions of inverse problems.

This expertise is transferable to many problems in the field of signal and image processing.

1.9.2 Construction of Wavelets on the Interval — a Matrix Analysis

In this topic, Frédéric Chyzak (INRIA Rocquencourt, France), Peter Paule, Burkhart Zimmermann (RISC), Otmar Scherzer, Armin Schoisswohl (Institut für Industriemathematik) have been involved.

Many problems in signal and image processing and in partial differential equations can be handled efficiently with wavelets on the interval. In contrast to wavelets on the (unbounded) real line, the construction of wavelets on a bounded interval is much more complex. In this part of the project we deal with a *systematic approach* for *contructing wavelets on an interval* to be able to optimally choose wavelet-basis-functions for particular problems.

Based on the fundamental works by Cohen, Daubechies and Vial (*Wavelets on the Interval and fast Wavelet Transforms*, ACHA 1993), and Meyer (*Ondelettes sur l'intervalle*, Rev.Mat.Iberoam., 1991) we developed an algorithm for the construction of orthogonal wavelet-bases on an interval that uses only methods of linear algebra. This approach allows the stable construction of wavelets on the interval using symbolic methods. Common approaches use numerical methods which are highly unstable.

1.10 Project F1311: "Structural Dynamics of Elasto-Plastic Multi-Body Systems: Integrated Symbolic and Numerical Computations"

The project started in October 1998.
Since we intend to develop a unified approach for problems of multi-body dynamics and of nonlinear continuum mechanics, a preliminary study has been performed with respect to the material description of the nonlinear field theories of mechanics. Refering to an undistorted reference configuration, a generalization of the principle of virtual work and of the Betti reciprocal theorem has been developed, first for static problems. In this study, performed by H. Irschik and A. K. Belyaev, Finger's virial has been introduced into a tensorial formulation utilizing Da Silva's astatic tensors of deformable bodies.
We furthermore intend to include plasticity by means of an analogy between plastic strains and thermal expansion strains. In order to include geometric nonlinearities, we therefore developed an extension of Maysel's formula of thermoelasticity to the nonlinear material description mentioned above. In these studies, performed by W. Brunner, J. Gerstmayr, H.J. Holl, H. Irschik, U. Pichler, we made use of the previously developed generalisation of the principle of virtual

work. Both, isotropic and anisotropic bodies have been studied, and thermally loaded beams with a v. Kármán type of nonlinearity have been considered as example problems. As a further result of these considerations, we performed a symbolic and numerical computational study on bifurcation and jump phenomena in thermally loaded beams. In our present investigation these structural elements are subjected to large rigid body movements, additionally to their deformation from the undistorted reference configuration.

2 Coherence within the SFB

- **Visualization Library:**
  Any project using the field simualtion of FEPP can make use of the visualization library developed by G. Kurka in Project F1301. These are, in particular, Projects F1306 and F1309.

- **Parallelization Library:**
  Any project using the field simualtion of FEPP can make use of parallel implementations of the algorithms developed by M. Kuhn in Project F1301. These are, in particular, Projects F1306 and F1309.

- **Theorema Software:**
  At the SFB–Workshop in Strobl all the SFB groups had the possibility to inspect the functionality of the *Theorema* software in live interactive presentations on the computer and to discuss various ways of interaction with the other sub-groups. The main conclusion was that the software will evolve into a version which should be useful for the current work of the mathematicians from the other disciplines in order to investigate mathematical models (e.g. by automating parts of the proofs, by direct execution of algorithm specifications, and by providing an intelligent environment for creating mathematica texts). Moreover, the work in this subproject will be directed towards analysing and integrating the proof techniques specific to the models which are currently used by the other subgroups: natural numbers, sets, real numbers, algebraic domains.

  Additionally, several meetings were organized with the participation of only few groups, in order to facilitate a proper focus on the concrete research cooperation opportunities:

  - Meetings with Project F1305: We identified several proof techniques and computation methods which will be integrated in the *Theorema* software in relation to the treatment of the domains of natural numbers. Currently our induction provers are already capable to produce reasoning about simple summation formulae.
  - Meetings with Project F1303 and F1306: We selected a set of problems about the characterization of multidimensional system of equations using quantifier elimination in real closed fields and proving/computing by rewriting.

- **Proving Techniques:**
  An already existing software on symbolic quantifier elimination over the reals from Project F1303 has been successfully applied to a problem in numerical analysis posed in the frame of Project F1306. The possibility of similar applications is currently investigated by J. Schicho and J. Schöberl.

- **Geometry:**
  Initiated by Project F1304, a discussion on geometric problems has started with other

Projects (F1306, F1309). In particular we are discussing topologically correct numerical traces of curves, so-called α-shapes of curves, and also transformation problems in constructive solid geometry. See IPWG "Geometry".

- **Construction of Wavelets:**
  About half of the results achieved with respect to summation methods in Project F1305 are directly related to Project F1302 "Proving and Solving in General Domains". F. Caruso's work, namely the study of possible combinations of numeric and symbolic approaches to solving linear systems of equations over multivariate rational functions is globally related to the numerics groups of the SFB. - Substantial collaboration (a first joint paper is in preparation) was carried out between O. Scherzer (project F1310) and his student A. Schoisswohl, and the group of Paule. Namely, it turned out that certain parameters that are needed for the construction of wavelets can be computed in a purely symbolic fashion. This enables to generalize wavelet construction mechanisms; further developments involving also the group of U. Langer (Project F1306) are envisioned.

- **Inhomogeneous Medium Problem:**
  In cooperation between Project F1301, F1306 and 1308, we are working on the inhomogeneous medium problem. The direct problem and its derivative will be implemented using a FEM-BEM coupling (in 2 and later in 3 space dimensions). To effectively compute the solution for many directions of the incident wave, we plan to investigate an extrapolation method.

- **Parameter Identification Problem:**
  Currently the projection regularized Newton method for the parameter identification problem (1) is being implemented in the finite element package FEPP in a cooperation between Projects F1306 and F1308. To this end several algorithmic aspects have been considered, especially the solution of the the finite-dimensional linearized problem $P_{Y_n} F'(a_n)s_n = P_{Y_n}(u^\delta - F(a_n))$ in each Newton step. Here the question of the choice of the ansatz functions for s_n is of major relevance. The theory suggests the use of basis functions that lie in the range of $F'(a_n)^*$ and are therefore quite smooth (H^3, in our example). It turned out (and could also be theoretically supported) that the reformulation of the Newton step equation as a mixed variational equation makes it possible to release these smoothness conditions so that hat functions can be used to approximate s_n.

- **Handling of Constraints:**
  In a cooperation between Projects F1303, F1304, F1306, F1308, F1309 the handling of different types of constraints occurring in optimization problems as studied in F1309 are investigated. This involves

  - the elimination of constraints, simplification problem formulation via reduction of equality constraints generated by the describing geometry (F1309, F1303).
  - Check of feasible geometries (F1304, F1309).
  - Handling of the geometry and implementation of solvers (F1309, F1308, F1306).

- **Bounded Variation Regularization:**
  Cooperation between F1310 and J. Schöberl from Project 1306: Development of analytical results for bounded variation regularization in a multi-grid setting.

- **Symbolic Summation and Combinatorial Identities:**
  Cooperation between F1310 and P. Paule from Project F1305.

3 Transfer of Knowledge and Technologies

- **Software Competence Center Hagenberg:**
  The RISC working groups of the SFB (Professors Buchberger, Winkler, Paule) and the Institute for Industrial Mathematics (Professor Engl) initiated and lead a consortium for applying, in the frame of the "K-plus" program of the Austrian federal government, for the "Software Competence Center Hagenberg". The application was successful: On Dec 18, 1998, the Ministery for Science decided to launch this competence center in which 15 software companies and five institute of the University of Linz will cooperate in joint industrial research in a wide range of software topics. The joint expertise of the SFB partners was crucial for the success of this application and will also be crucial for the success of the future work of this competence center. Various synergies and mutual benefits can be expected from having both the SFB and the Software Competence Center organized at our University.

- **Industrial Applications of the** *Theorema* **Software:**

  - Wolfram Research Iternational (USA): Negotations are under way for integrating *Theorema* as a package on top of *Mathematica*. As a result of the negotiations, Wolfram Research became a partner in the consortium for the "Software Competence Center Hagenberg", which will be one of the first cases in which a US software company will settle in Upper Austria. Future negotiations will clarify to what extent marketing for *Theorema* will be integrated into the Wolfram marketing activities. Currently, Wolfram has close to a million users.
  - Uni Software Plus (Hagenberg): This company is interested in developing teachware for math education and intends to use the *Theorema* language as the basis for the entire development.

- **Mass Reduction of Injection Moulding Machines:**
  The methods and software developed in project F1306 have been used to finish the project *Mass Reduction of Injection Moulding Machines* successfully. Our industrial partner, ENGEL Group Schwertberg, was convinced by the adaptive error control therein and by the achieved mass reduction. The mass reduction bases on advanced optimization strategies which are part of project F1309. Especially the transfer of those new mathematical methods into industry has been honored by a research grant (Förderpreis) of the Allgemeine Sparkasse Oberösterrreich. The cooperation with ENGEL Group will be continued in a new project.

- **Design and Simulation of an Inductive Engine Speed Sensor:**
  The aim a cooperation with the BMW AG Steyr was the development of a sensor system which is able to measure the speed of a diesel engine as well as the angular position of the crankshaft accurately. In order to attain an optimal shape of the used ferromagnetic gearwheel, which is applied as pulse generator, a 2D FE simulation of the magnetic field was performed. Thereby, due to the high number of gearwheel teeth, a large FE model is necessary. By using a multigrid solver, which was developed in the Project F1306, the solution time of the whole simulation process could be reduced considerably.

- **Simulation of Rollers:**
  As part of Project F1306, solvers for contact problems have been developed by B. Hackl,

W. Hinterberger and J. Schöberl. These results have been used in a joint project with the VAI Linz. Hereby, the contact of rollers has been simulated numerically.

- **Image Processing:**
  The construction of wavelets on the interval offers new possibilities in the field of data compression. In this context we expect that the use of wavelets on intervals results in a significant reduction of artifacts of compressed images near the boundaries of images. In a current project with the company Kretztechnik AG, supported by the Upper Austrian government, data compression techniques in combination with multi-level algorithms for image processing are developed.

- **Pilotprojekt Kompetenzzentrum Mechatronik:**
  H. Irschik, A. K. Belyaev, M. Baldinger, H. Holl are involved in the project "Bindefestigkeitsprüfung des Lagerschalenverbundmaterials mittels geometrisch und physikalisch nichtlinearer elastoplastischer FE Rechnungen".

- **Simulation des Eckenumformprozesses in Blechen, elastoplastische Spannungs– und Dehnungsanalyse:**
  H. Irschik, A. K. Belyaev, H. Holl, S. Fischmeister are working on this project.

4 Inter-Project Working Groups (IPWG)

4.1 Computer Supported Proving

- **Members:**
  B. Buchberger (Leader), U. Langer, J. Schicho, J. Schöberl

- **Meetings:**

  - 3.4.98: Presentation of a solution of a prove problem occurring in numerical optimization by using quantifier elimination (Collins algorithm).
  - May 98: Introduction to problem solving technique used in numerical mathematics.
  - Several discussions on how to integrate existing implementations of provers for combinatorial identities as "black box provers" into the Theorema system.
  - Using Theorema provers to support proving in the area of combinatorics.
  - 25.6.98: "Proving and solving over reals and inverse problems". T. Hohage, B. Kaltenbacher, J. Schicho.
  - 30.7.98: "Symbolic methods in numerical analysis". B. Buchberger, J. Schicho, J. Schöberl.
  - 11.98,12.98,01.99: Joint work of J. Schicho and J. Schöberl on applications of symbolic proving methods in numerical analysis.

4.2 Special Functions

- **Members:**
  P. Paule (Leader), T. Hohage, M. Kuhn, O. Scherzer, A. Schoisswohl

- **Meetings:**

- Regularly: Collaboration between P. Paule, O. Scherzer, A. Schoisswohl on wavelet theory.
- 4.9.98: “Special functions in inverse problems”. T. Hohage, S. Kindermann, P. Paule.

- **Lectures and Talks:**
  - F. Chyzak: Four lectures on holonomic functions were attended by SFB workers from different projects such as F1302, F1304, F1305, F1306, F1308, F1309, F1310, and F1311.

4.3 Hybrid Numeric-Symbolic Algorithms

- **Members:**
  E. Lindner (Leader), G. Haase, R. Pfau, C. Stangl, W. Windsteiger F. Winkler

4.4 Geometry

- **Members:** F. Winkler (Leader), G. Haase, E. Lindner, W. Mühlhuber, E. Radmoser, J. Schicho, J. Schöberl, C. Stangl
- **Meetings:**
  - 10.12.98: Hagenberg.

4.5 Direct and Inverse Field Problems

- **Members:**
  O. Scherzer (Leader), H. Engl, T. Hohage, B. Kaltenbacher, M. Kaltenbacher, M. Kuhn, F. Kickinger, U. Langer, E. Radmoser, M. Schinnerl, J. Schöberl
- **Meetings:**
  - 9.12.98: “Combination of FEPP and ITREG”. T. Hohage, M. Kuhn, J. Schöberl.
  - 14.1.99: “A saddle point variational formulation for the projection-regularized Newton method”. H. W. Engl, U. Langer, T. Hohage, B. Kaltenbacher, M. Kuhn, J. Schöberl.
  - 4.2.99: “Direct and inverse inhomogenuous medium problem”. H. W. Engl, U. Langer, T. Hohage, B. Kaltenbacher, M. Kuhn, J. Schöberl.

4.6 Environment PDEs

- **Members:**
  M. Kuhn (Leader), B. Buchberger, F. Kickinger, W. Mühlhuber, J. Schöberl, W. Windsteiger
- **Meetings:**
  - 30.9.98: Preparation of setting up a connection between Theorema and the visualization system Mesa (used by numerical group) in order to use Mesa for rendering 3D graphics from inside Theorema. F. Kickinger and W. Windsteiger.

4.7 Numerical Methods for Technical Problems

- **Members:**
  J. Schöberl (Leader), J. Gerstmayr, H. Holl, H. Irschik, M. Kaltenbacher , U. Langer, R. Lerch, W. Mhlhuber, R. Pfau, M. Schinnerl M. Kaltenbacher

5 Conferences

5.1 The 2nd Theorema Workshop

- June 29-30, 1998, RISC
- Exchanged information in the field of theorem proving.
- Participants: Aleksander Letichevsky, Glushkov Institute of Cybernetics Kiev, Sergey Krivoi, Glushkov Institute of Cybernetics Kiev, Andrei Voronkov, University of Uppsala, Alexander Vadimovich Lyaletski, Uni-Kiev, Marina Konstantinovna Morokhovets, Uni-Kiev, Yuri Vital'evich Koval, Uni Kiev, Lyudmila Vital'evna Koval, Uni Kiev, Dongming Wang, IMAG Grenoble, Laurent Henocque, CMI Marseille.

5.2 SFB–Workshop

- Strobl, September 21–25, 1998.
- 24 participants.
- Programme:
  - <u>Monday, 21.9.1998:</u>

13:30	Opening
13:55	Optimal Design
	C. Stangl: "Formoptimierung"
16:30	E. Lindner: "Einführung in restringierte nichtlineare kontinuierliche Optimierung"
	G. Haase: "Optimale Auslegung eines Spritzgussrahmens"
	W. Freiseisen: "Euler–Operatoren"

  - <u>Tuesday, 22.9.1998:</u>

09:05	Mehrgitterverfahren
	V. Korneev: "On Twolevel Methods Based on Aggregation"
10:40	J. Schöberl: "Theorem Proving in Hilbert Spaces"
14:00	Symbolic Scientific Computing
	B. Buchberger: "Theorem Proving"
14:55	J. Schicho: "Constraint Solving"
16:30	B. Buchberger: "Theorema"
17:20	T. Jebelean: "Theorema: Predicate Logic"

– Wednesday, 23.9.1998:

09:00	Symbolic Scientific Computing
09:05	D. Vasaru: "Theorema"
09:40	W. Windsteiger: "Theorema"
11:05	Geometry
11:10	W. Mühlhuber: "Importing Geometry from CAD Systems"
11:55	J. Schöberl: "NETGEN"
12:15	F. Kickinger: "AUTOGEN / Mesh Generation in Fluid Dynamics"
14:00	F. Winkler: "Real Parametrization of Algebraic Curves"
14:50	R. Hemmecke: "Computerdemo CASA system, version 2.3"
15:20	E. Hillgarter: "Symmetries in Differential Equations role of continuous symmetries and their Lie algebras for ODEs and PDEs"
16:35	G. Kurka: "An integrated visualization system for FEPP"
17:15	G. Kurka: "Exdasy: an extended data distribution system"

– Thursday, 24.9.1998:

09:20	O. Scherzer: "Inverse Problems"
11:05	B. Kaltenbacher: "Regularized Newton's method for nonlinear ill-posed problems"
11:35	E. Radmoser: "Denoising by bounded variation-regularization dedection of edges required"
13:30	Meeting of project leaders and computer commission.
17:00	B. Buchberger: "Problems for cooperation between numerics and symbolics"

– Friday, 25.9.1998:

09:05	P. Paule: "Symbolic summation and combinatorial identities hypergeometric series notation"
11:00	M. Kuhn: "Concepts for the Formulation of 3D Magnetic Field Problems"
11:25	J. Schöberl: "FEPP - Finite Element ++"
11:55	M. Schinnerl: "Setup of an Electro-Acustic-Mechanical-Transducer (EMAT)"

STATISTICAL APPENDIX

to the Annual Report to the SFB F013 (1998–2001)
1.4.98–31.12.98

A Monographs–PhD Theses–Diploma Theses

[A1] Buchberger, B., and Jebelean, T., Eds. *The 2nd International Theorema Workshop* (June 29-30 1998), Proceedings published as RISC-Report 98-10. Hagenberg, Austria.

[A2] Haase, G. *Parallelization of Numerical Algorithms for PDEs.* Teubner, 1999. In Preparation. See also http://www.numa.uni-linz.ac.at/Staff/ghaase/parvor_e/parvor.html.

[A3] Ratschan, S. *Approximative Constraint Logic Programming.* PhD thesis, University of Linz, 1998.

[A4] Reitzinger, S. Robust Algebraic Multigrid Methods in Magnetic Schielding Problems. Master's thesis, Johannes Kepler University Linz, 1998.

[A5] Tomuta, E. *An Architecture for Combining Provers and its Applications in the Theorema System.* PhD thesis, The Research Institute for Symbolic Computation, Johannes Kepler University, 1998. RISC report 98-14.

B Publications

[B1] Abramov, S., Paule, P., and Petkovšek, M. q-hypergeometric solutions of q-difference equations. *Discrete Mathematics* (1998).

[B2] Brunner, W., Gerstmayr, J., and Irschik, H. Symbolic and numerical computational studies on bifurcation and jump phenomena in thermally loaded beams. (in preparation), 1998.

[B3] Buchberger, B. Theorema: The Current Status. In *Proceedings of the Second International Theorema Workshop* (1998). RISC report 98-10.

[B4] Buchberger, B., Aigner, K., Dupre, C., Jebelean, T., Kriftner, F., Marin, M., Nakagawa, K., Podisor, O., Tomuta, E., Usenko, Y., Vasaru, D., and Windsteiger, W. Theorema: An Integrated System for Computation and Deduction in Natural Style. In *CADE 98 (International Conference on Computer Aided Deduction), Lindau, Germany* (July 5-10 1998). Workshop on integration of proving and computing.

[B5] Buchberger, B., Jebelean, T., and Nakagawa, K. Using the Predicate Logic Prover of Theorema for Formal Training in Mathematics. In *the 2nd International Theorema Workshop, Hagenberg, Austria* (June 29-30 1998). RISC-Report 98-10.

[B6] Buchberger, B., Jebelean, T., and Vasaru, D. Theorema: A System for Formal Scientific Training in Natural Language Presentation. In *Proceedings of ED-MEDIA 98 (International Conference on Educational Multimedia),Freiburg, Germany* (June 20-23 1998). pp. 174-179.

[B7] Buchberger, B., and Windsteiger, W. The Theorema Language: Implementing Object- and Meta-Level Usage of Symbols in the Theorema System. In *Proceedings of the Second International Theorema Workshop* (1998). RISC report 98-10.

[B8] Carstensen, C., Kuhn, M., and Langer, U. Fast parallel solvers for symmetric boundary element domain decomposition equations. *Numer. Math. 79*, 3 (1998), 321–347.

[B9] Deuflhard, P., Engl, H. W., and Scherzer, O. A convergence analysis of iterative methods for the solution of nonlinear ill-posed problems under affinely invariant conditions. *Inverse Problems 14* (1998).

[B10] Engl, H. W., and Zou, J. Stability and convergence analysis of Tikhonov regularization for parameter identification in a parabolic equation. *Report, Spezialforschungsbereich SFB013, University of Linz* (1998).

[B11] Frigaard, I., and Scherzer, O. The effects of yield stress variation on uniaxial exchange flows of two bingham fluids in a pipe. Submitted.

[B12] Frigaard, I., and Scherzer, O. Uniaxial exchange of two bingham fluids in a cylindrical duct. *IMA J. Appl. Math.* (To appear).

[B13] Gullikson, M., and Scherzer, O. An adaptive strategy for updating the damping parameters in an iteratively regularized gauss-newton method. Tech. rep., J. of Opt. Theory and Appl., To appear.

[B14] Haase, G. Multilevel extension techniques in domain decomposition preconditioners. In *Domain Decomposition Methods in Science and Engineering* (1998), Domain Decomposition Press, Bergen, pp. 359–367.

[B15] Haase, G., and Kuhn, M. Preprocessing for 2d FE/BE Domain Decomposition Methods. SFB Report 98-14, Johannes Kepler University Linz, SFB "Numerical and Symbolic Scientific Computing, 1998. Submitted for publication.

[B16] Haase, G., Kuhn, M., Langer, U., and Schöberl, J. Parallelization strategies for 3d magnetic field problems. Tech. rep., 1998. In Preparation.

[B17] Haase, G., and Lindner, E. Advanced iterative solvers and optimal design of industrial machine components. Institutsbericht 543, Institute of Analysis and Computational Mathematics, Johannes Kepler University Linz, July 1998. Submitted to Proceedings of ECMI 98.

[B18] Haase, G., and Lindner, E. Advanced iterative solvers and optimization. *ECMI Newsletter 24* (October 1998), 5 – 7.

[B19] Hanke, M., and Scherzer, O. Error analysis of an equation error method for the identification of the diffusion coefficient in a quasilinear parabolic differential equation. SIAM Appl. Math, To appear.

[B20] Hanke, M., and Scherzer, O. Numerical differentiation as an example for inverse problems. Submitted.

[B21] Heise, B., and Jung, M. Efficiency, scaleability and robustness of parallel multilevel methods for nonlinear pde's. *SIAM J. Sci. Comput.* (1998). Accepted.

[B22] Heise, B., Kuhn, M., and Langer, U. A mixed variational formulation for 3D magnetostatics in the space $H(\mathrm{rot}) \cap H(\mathrm{div})$. Tech. rep., 1997. Submitted 1998.

[B23] Hemmecke, R., Hillgarter, E., and W. Schreiner, F. W. An evaluation of the state of the casa system. *Techn. Rep. SFB 98–12* (1998).

[B24] Hofmann, B., and Scherzer, O. Local ill-posedness and source conditions of operator equations in hilbert spaces. *Inverse Problems 14* (1998), 1189–1206.

[B25] Hohage, T. Convergence rates of a regularized Newton method in sound-hard inverse scattering. *SIAM J.Numer.Anal.* (To appear).

[B26] Hohage, T., and Schormann, C. A Newton-type method for a transmission problem in inverse scattering. *Inverse Problems 14* (1998).

[B27] Holl, H., Irschik, H., Pichler, U., and Gerstmayr, J. Maysel's formula in nonlinear structural mechanics. To appear in Proceedings of Third International Congress an Thermal Stresses, Thermal Stresses 1999, Cracow, 1999.

[B28] Irschik, H., and Belyaev, A. K. Das Fingersche Virial verformbarer Körper und der Satz von Betti in der nichtlinearen Kontinuumsmechanik. (in publication), 1998.

[B29] Kabanikhin, S., Kowar, R., and Scherzer, O. On the landweber iteration for the solution of a parameter identification problem in a hyperbolic partial differential equation of second order. *J. Inv. Ill-Posed Problems 6*, 5 (1998), 403–430.

[B30] Kaltenbacher, B. On Broyden's method for nonlinear ill-posed problems. *Numer.Funct.Anal.Opt. 19* (1998).

[B31] Kaltenbacher, B. A posteriori parameter choice strategies for some Newton type methods for the regularization of nonlinear ill-posed problems. *Numer.Math. 79* (1998).

[B32] Kaltenbacher, B. A projection-regularized Newton method for nonlinear ill-posed problems and its application to parameter identification problems with finite element discretization. *SFB Report 98–13, University of Linz* (1998).

[B33] Kriftner, F. Theorema: The Language. In *Proceedings of the Second International Theorema Workshop* (1998). RISC report 98-10.

[B34] Kuhn, M. The application of coupled BE/FE formulations in technical magnetic field computations. *Computer Methods in Applied Mechanics and Engineering 157* (1998), 193–204.

[B35] Kuhn, M. Efficient parallel FEM–BEM calculations based on local parallelization and domain decomposition. In *Proceedings of ENUMATH 97* (Singapore, 1998), World Scientific Publishing, pp. 429–436.

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[B38] Kuhn, M. Symmetric coupling of FEM and BEM for 3d exterior magnetic field problems. In *Proceedings of ACOMEN 98* (Maastricht. The Netherlands., 1998), R. v.Keer, B. Verhegghe, M. Hogge, and E. Noldus, Eds., Shaker, pp. 489–496.

[B39] Kurka, G. A fast visualization system for adaptive grids. SFB Report 98-11, Johannes Kepler University Linz, SFB "Numerical and Symbolic Scientific Computing, 1998.

[B40] Kurka, G. Graphical and arithmetical benchmarking of workstations. SFB Report 98-09, Johannes Kepler University Linz, SFB "Numerical and Symbolic Scientific Computing, 1998.

[B41] Pichler, U., Irschik, H., and Gerstmayr, J. Maysel's formula of thermoelasticity extended to anisotropic materials at finite strain. (To appear in Proceedings of EUROMECH Colloquium 394, Graz, 1999), 1998.

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[B51] Sendra, J., and Winkler, F. Algorithms for rational real algebraic curves. *Techn. Rep. SFB 98–16* (1998).

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[B54] Winkler, F. Geometric algorithms based on computer algebra. *Proc. Mathematical Theory of Networks and Systems (MTNS'98), Padova* (1998).

C Talks

[C1] Buchberger, B. Computer Support for Inventing Groebner Bases Theory. IMACS Conference, Prague, Czech Republic, 1998-8-9.

[C2] Buchberger, B. Intensive Course on Groebner Bases (30 hours). Universitad de Oriente, Santiago, Cuba, 1998-10-5 / 14.

[C3] Buchberger, B. Overview on the Theorema System. International Theorema Workshop, RISC, Hagenberg, 1998-6-29.

[C4] Buchberger, B. Symbolic Computation: Ein Überblick. Universität Hamburg, Institut für Informatik, 1998-6-22.

[C5] Buchberger, B. Theorema: Automatisches Beweisen für Lehre und Forschung. Universität Leipzig, Mathematisches Institut, 1998-11-25.

[C6] Buchberger, B. Theorema: Computer-Supported Mathematical Proving. Annual Meeting of the Mathematics Department of the University of Wales, Gregynod,1998-6-19.

[C7] Buchberger, B. Theorema: Computer-Unterstuetztes mathematisches Beweisen, 1998-4-24. Universität Karlsruhe, Institut für Informatik.

[C8] Buchberger, B. The Theorema Project. Universidad de Oriente, Santiogo, Cuba, 1998-10-13.

[C9] Buchberger, B. The Theorema Project: An Introduction. Research Institute IRST, Trento, 1998-2-19.

[C10] Buchberger, B. The Theorema System, invited tutorial (together with Tudor Jebelean). MFCS'98 (International Conference on Mathematical Foundations of Computer Science), Brno, Czech Republic, 1998-8-8.

[C11] Buchberger, B. Theorema: Theorem Proving for the Masses Using Mathematica (invited keynote). Worldwide Mathematica Conference, Chicago, 1998-6-20.

[C12] Buchberger, B. Using Theorema for Mathematical Education (together with T. Jebelean). IMACS Conference on Applied Computer Algebra, Prague, Czech Republic, 1998-8-10.

[C13] Engl, H. W. Convergence rates for iterative regularization of nonlinear inverse problems. Special Session on Nonlinear Inverse Problems, AMS-Meeting, Baltimore, January 5-12, 1998.

[C14] Engl, H. W. Inverse problems in continuous casting and hot rolling of steel. Tagung "Inverse Problems in Engineering", Nagano, March 21-29, 1998.

[C15] Engl, H. W. Inverse problems in industrial applications. Research Chinese University of Hongkong, March 29 -April 8, 1998.

[C16] Engl, H. W. Iterative regularization of nonlinear inverse problems with applications to parameter identification. Conference on Inverse Problems, Vietri sur Mare, Italien, September 28 - October 2, 1998.

[C17] Haase, G. Optimization of machine support using advanced iterative solvers. August 1998.

[C18] Haase, G. Advanced iterative solvers in optimization. July 1998.

[C19] Haase, G. Mass reduction of injection moulding machines. November 1998.

[C20] Haase, G., and Lindner, E. Optimization of machine support using advanced iterative solvers. April 1998.

[C21] Hohage, T. Analytische Abhängigkeit des Feldes vom Rand bei Streuung an nichtglatten Gebieten. Seminar talk at the University of Göttingen, 7 December 98.

[C22] Hohage, T. Convergence of iterative regularization methods in inverse scattering. Oberwolfach, September 21-27, 1998.

[C23] Hohage, T. Convergence rates of a regularized Newton method for inverse scattering problems. PIERS98, Nantes, July 13-17, 1998.

[C24] Kuhn, M. Symmetric FE–BE formualtions for 3d magnetic field problems. Oberseminar, Stuttgart, Germany, July 22nd, 1998.

[C25] Kuhn, M. Boundary element methods in magnetic field computations. BEM Workshop, Saarbrücken, Germany, November 26–27, 1998.

[C26] Kuhn, M. Multigrid methods for magnetic field problems. 10th GAMM Multigrid Workshop, Bonn, Germany, October 4 – 8, 1998.

[C27] Kuhn, M. Symmetric coupling of FEM and BEM for 3d exterior magnetic field problems. ACOMEN 98, Ghent, Belgium, September 2–4, 1998.

[C28] Kuhn, M. Concepts for the formulation of 3d magnetic field problems. SCEE, Berlin, Germany, September 30 – October 02, 1998.

[C29] Langer, U. Scientific computing: Numerical methods and industrial applications. 10th Conference of the Europeen Consortium for Mathematics in Industry *"ECMI'98"*, Göteborg, Sweden, June 22–27, 1998.

[C30] Langer, U., and Kickinger, F. Algebraic multigrid method with pbp smoothing. *"Oberwolfach Seminar"*, Oberwolfach, Germany, April 26 - May 2, 1998.

[C31] Langer, U., and Kickinger, F. Advanced numerical methods and applications. IFIP Workshop *"Computational Scienece in the 21st Century"*, Patras, Greece, May 21 - 24, 1998.

[C32] Langer, U., and Kickinger, F. Algebraic multigrid method based on graph coarsening. 10th International GAMM Workshop on Multigrid Methods Bonn, Germany, October 5–8, 1998.

[C33] Langer, U., Kickinger, F., and Schöberl, J. Algebraisierung und Robustheit von Mehrgitterverfahren. Arbeitstagung *"Finite Elemente und Strukturmechanik"*, Bochum, Germany, June 18 - 19, 1998.

[C34] Lindner, E., and Haase, G. Advanced iterative solvers and optimal design if industrial components. June 22 – 27 1998.

[C35] Mühlhuber, W. Numerical solution of contact problems and applications. GAMM Workshop, Kiel, Germany, July 3 – 5 1998.

[C36] Mühlhuber, W. Importing geometries from CAD systems. SFB Workshop, Strobl, Austria, September 1998.

[C37] Paule, P. Automatic hypergeometric summation: The wz-engine in theory and practice. invited key lecture at the "Summerschool on Group Theory and Lie Algebras", Leiden, 1998.

[C38] Paule, P. Hypergeometric summation: Fine-tuning of the wz-engine. invited key lecture, Seminaire Lotharingien de Combinatoire, Strasbourg, 1998.

[C39] Paule, P. Hypergeometric summation: Tables and algorithms. invited lecture, DLMF Seminar Series, NIST, Gaithersburg, 1998.

[C40] Paule, P. qWZ-theory and bailey chains. invited talk, INRIA-Paris, 1998.

[C41] Paule, P. WZ theory: back to chapter I. invited lecture, Symbolic Computation Workshop, MSRI, Berkeley, 1998.

[C42] Ratschan, S. Approximate quantified constraint solving. University of North Carolina, September 1998.

[C43] Scherzer, O. A-posteriori estimates for nonlinear ill-posed problems. AMS-SIAM Summer Research Conference on Inverse Problems in Partial Differential Equations, Boston, USA, July 1998.

[C44] Scherzer, O. Inverse Problemen und deren numerische Lösung. Universtät Halle, Deutschland, November 11th 1998.

[C45] Scherzer, O. Inverse problems in nondestructive testing (with A. Neubauer. SIAM Annual Meeting, Organisation Minisymposium, July 17th 1998.

[C46] Scherzer, O. Iterative methods for the solution of nonlinear ill-posed problems. IICP'98 (inversion conference), Kopenhagen, Dänemark, August 9-15 1998.

[C47] Scherzer, O. Methoden zur Lösung von Inversen Problemen. ETH-Zürich, April 2nd 1998.

[C48] Scherzer, O. Methoden zur Lösung von Inversen Problemen. Universität Zürich, April 16th 1998.

[C49] Schicho, J. A survey on quantifier elimination. University of Innsbruck, June 1998.

[C50] Schinnerl, M. Numerical simulation of coupled field problems. SFB Workshop, Strobl, Austria, September 21–25, 1998.

[C51] Schinnerl, M. Multigrid methods for coupled nonlinear magneto-mechanical problems. SCEE Workshop on Scientific Computing in Electrical Engineering, Berlin, September 30–October 2, 1998.

[C52] Schöberl, J. Robust preconditioning for systems of pdes. Oberwolfach Seminar *Domain Decomposition and Multifield Theories*, April 26 – May 2, 1998.

[C53] Schöberl, J. Über Netzgenerierung und adaptive Mehrgitterverfahren in der Festkörpermechanik. Eingeladen am Institut für Leichtbau und Flugzeugbau, TU Wien, April 3, 1998.

[C54] Schöberl, J. Efficient contact solvers based on domain decomposition techniques. Numerical Methods in Computatinal Mechanics, Miskolc, Hungary, August 24–28, 1998.

[C55] Schöberl, J. Robust multigrid methods for parameter dependent problems. Mathematical Modelling and Computational Methods in Mechanics, Minisymposium Iterative Methods, University Praha, June 7–11, 1998.

[C56] Schöberl, J. Robust multigrid methods for parameter dependent problems. 10^{th} GAMM Workshop on Multigrid Methods, Bonn, October 5–8, 1998.

[C57] Schöberl, J. Automatic theorem proving in hilbert spaces. SFB Workshop, Strobl, Austria, September 21–25, 1998.

[C58] Schöberl, J. Robust multigrid methods for parameter dependent problems. Iterative Solution Methods for the Elasticity Equations, Nijmegen, The Netherlands, September 28–30, 1998.

[C59] Schöberl, J., and Haase, G. Some concepts of the finite element code fepp. 14^{th} GAMM Seminar Kiel on *Concepts of Numerical Software*, January 23–25, 1998.

[C60] Tomuta, E., and Buchberger, B. Combining Provers in the Theorema System. In *Sixth Rhine Workshop on Computer Algebra, March 31.–April 3, Sankt Augustin, Germany* (1998).

[C61] Windsteiger, W. The Theorema Language: Implementing Object- and Meta-Level Usage of Symbols. In *Workshop Calculemus 98, Eindhoven, Netherlands* (1998).

[C62] Winkler, F. Algebraic curves and symbolic computation. Talk at the School of Mathematics, Physics, Engineering and Computer Science, Macquarie Univ., Sydney, Australia, Nov. 1998.

[C63] Winkler, F. Algebraic geometry methods in symbolic computation. Talk at Dept. of Mathematics, Fudan Univ., Shanghai, China, July 1998.

[C64] Winkler, F. Casa — a system for computational algebra and constructive algebraic geometry. Talk at Workshop on "Automated Deduction in Geometry", Beijing Univ., Beijing, China, August 1998.

[C65] Winkler, F. Computer algebra meets geometry. Talk at Dept. of Computer & Information Sciences, Univ. of Delaware, USA, Sept. 1998.

[C66] Winkler, F. Optimal parametrization of algebraic curves. Talk at Conference "IMACS Conf. on Applications of Computer Algebra", Prague, Chech Republic, August 1998.

[C67] Winkler, F. Parametrization of real algebraic curves. Talk at Dept. of Mathematics, Fudan Univ., Shanghai, China, July 1998.

[C68] Winkler, F. Symbolic geometric computation. Talk at the School of Mathematics and Statistics, The Univ. of Sydney, Sydney, Australia, Nov. 1998.

D Software Developments

[D1] The Theorema System. http://www.theorema.org.

[D2] Hohage, T. ITREG. C++ code for iterative regularization methods for nonlinear ill-posed problems, e.g., inverse scattering, inverse potential, and parameter identification problems in PDEs.

[D3] Lerch, R., Kaltenbacher, M., and Landes, H. *CAPA* manual, rel. 3.1, 1998.

[D4] Podisor, O. Compiler for Theorema.

[D5] Riese, A. Omega — a mathematica implementation of partition analysis. available via: `http://www.risc.uni-linz.ac.at/research/combinat/risc/software/` .

[D6] Riese, A. Ratdiff — a mathematica implementation of mark van hoeij's algorithm for finding rational solutions of linear difference equations. available via: `http://www.risc.uni-linz.ac.at/research/combinat/risc/software/` .

[D7] Schöberl, J. *NETGEN*: An advancing front 2d/3d mesh generator based on abstract rules. *Comput. Visual. Sci.* (1997), 41–52. See also: http://www.numa.uni-linz.ac.at/Staff/joachim/netgen/usenetgen/usenetgen.html.

[D8] Schöberl, J. Objektorientiertes Finite Element Programm *FEPP*, 1997. Programmdokumentation via http://nathan.numa.uni-linz.ac.at/Staff/joachim/cpp/doc/index.html.

E SFB–Reports

98–1 Tomuta, E. and Buchberger, B.: *Combining Provers in the Theorema System.* April, 1998. Herausgeber: P. Paule, F. Winkler

98–2 Schicho, J.: *Rational Parameterization of Real Algebraic Surfaces.* April 1998. (also RISC-Rep 98-01) Herausgeber: N.N.,N.N

98–3 Ratschan, S.: *Approximative Logic - An Overview.* April 1998. (also RISC-Rep 98-08) Herausgeber: N.N.,N.N

98–4 Buchberger, B.: *Theorema: Theorem Proving for the Masses Using Mathematica.* June 1998. Herausgeber: P. Paule, F. Winkler

98–5 Buchberger, B., Jebelean, T. and Vasaru D.: *Theorema: A System for Formal Scientific Training in Natural Language Presentation.* June 1998. Herausgeber: P. Paule, F. Winkler

98–6 Buchberger, B., Aigner, K., Dupré, C., Jebelean, T., Kriftner, F., Marin, M., Nakagawa, K., Podişor, O., Tomuţa, E., Usenko, Y., Văsaru, D. and Windsteiger W.: Theorema*: An Integrated System for Computation and Deduction in Natural Style.*
July 1998. Herausgeber: P. Paule, F. Winkler

98–7 Buchberger, B. and Windsteiger W.: *The* Theorema *Language: Implementing the Object- and Meta-Level Usage of Symbols.*
July 1998. Herausgeber: P. Paule, F. Winkler

98–8 Tomuta, E.: *An Architecture for Combining Provers and its Applications in the Theorema System.*
July 1998. Herausgeber: P. Paule, F. Winkler

98–9 Kurka, G.: *Graphical and Arithmetical Benchmarking of Workstations.*
September 1998. Herausgeber: U. Langer, J. Volkert

98–10 Engl, H.W. and Zou, J.: *Stability and Convergence Analysis of Tikhonov Regularization for Parameter Identification in a Parabolic Equation.*
October 1998. Herausgeber: B. Buchberger, U. Langer

98–11 Kurka, G.: *A fast Visualization System for Adaptive Grids.*
October 1998. Herausgeber: U. Langer, J. Volkert

98–12 Hemmecke, R., Hillgarter, E., Schreiner, W. and Winkler, F.: *An Evaluation of the State of the CASA System.*
October 1998. (also RISC-Rep. 98-16) Herausgeber: B. Buchberger, P. Paule

98–13 Kaltenbacher, B.: *A Projection-Regularized Newton Method for Nonlinear Ill-Posed Problems and its Application to Parameter Identification Problems with Finite Element Discretization.*
November 1998. Herausgeber: H.W. Engl, U. Langer

98–14 Haase, G. and Kuhn, M.: *Preprocessing for 2D FE–BE Domain Decomposition Methods.*
December 1998. Herausgeber: U. Langer, J. Volkert

98–15 Reitzinger, S.: *Algebraic Multigrid and Element Preconditioning.*
December 1998. Herausgeber: U. Langer, O. Scherzer

98–16 Sendra J.R. and Winkler, F.: *Algorithms for Rational Real Algebraic Curves.*
December 1998. Herausgeber: B. Buchberger, P. Paule

F Scientific Meetings

- **Approximate quantifier elimination:** Raleigh, North Carolina, September 1998 Joint work of Stefan Ratschan and Hoon Hong in approximate quantifier elimination

- **Summer School on Real Algebraic Geometry:** Trento, Italy, September 1998. Attendance of Antonin Tesacek

- **International Conference ISSAC'98:** Rostock, Germany, August 1998. Presentation of research results by Josef Schicho.

- **Cooperation with Fudan University, Shanghai, China:** July 21 – August 7, 1998. F. Winkler has visited Shanghai and Beijing. Cooperation with the research group of Prof.

Xin Dingjia of Fudan University in Shanghai, China, on problems in computational algebraic geometry and coding theory. Participation in and talk at the workshop "Automated Geometric Deduction" at the University of Beijing.

- **University of Delaware, Newark De, USA:** September 13 – 20, 1998. F. Winkler has visited the University of Delaware Cooperation with the computer algebra research group at the Univ. of Delaware.
- **University of Sydney, Sydney, Australia:** November 3 – 26, 1998. F. Winkler has been invited by Prof. John Cannon of the Department of Mathematics to discuss our results on parametrization of curves with the research group on computational algebra of the Univ. of Sydney.
- **GMD Bonn/St.Augustin, Bonn, Germany:** November 15 – 19, 1998 In the frame of our cooperation with the research group of Dr. Fritz Schwarz from the Gesellschaft für Mathematik und Datenverarbeitung (GMD) in Bonn/St.Augustin, E. Hillgarter has visited there and discussed our research on symmetry analysis of PDEs.
- 35^{th} **Annual Technical Meeting, Society of Engineering Science:** Pullman, Washington, September 1998. Special symposium organized by H. Irschik. Presentation of research results by A.K. Belyaev.

G Guests

- **Prof. Dr. W. Hackbusch:** Universität Kiel, 5.5.–7.5.98.
- **Prof. Dr. K. Radbruch:** Universität Kaiserslautern, 3.6.98.
- **Dr. T. Rossi:** University Jyväskylä, 13.6.–21.6.98.
- **Prof. Dr. C. Douglas:** University of Kentucky, Yale University, 15.6.–27.6.98.
- **Prof. Dr. G. Molnarka:** University of Györ, 13.7.–17.7.98.
- **Dr. B. Kiss:** University Györ, 13.7.–17.7.98.
- **Dr. A. Krebsz:** University Budapest, 13.7.–17.7.98.
- **Dr. M. Gander:** Ecole Polytechnique Paris, 4.8.–6.8.98.
- **Prof. Dr. V.G. Korneev:** Rensselaer Polytechnic Inistitute (USA), 21.9.–26.9.98.
- **Prof. Dr. T. Sakkalis:** Agricultural Univ., Athens, Greece, October 11–12, 1998. Prof. Sakkalis is a well-known research in mathematical problems in computer aided design. We have discussed his new approach to topologically correct numerical traces of algebraic curves, the so-called α-shapes.
- **Univ.-Doz. Dr. A. Rieder:** Universität des Saarlandes, 12.-17.10.1998.
- **Dipl.-Ing. J. Gerhard:** University of Paderborn, 15–21 November 1998. 2 talks on "Towards a cost analysis of Gosper's algorithm".
- **H. Hauser:** University of Innsbruck, November 1998. Talk: ""Resolution of Singularities".
- **T. Salame:** GMD Bonn, January 1999. Candidate for open SFB position.

H Lectures

- **Parallelization of Numerical Algorithms:** July 1998, University of Freiburg, Germany. Lectures by G. Haase and exercises by M. Kuhn.
- **Regularization Methods for Inverse Problems:** October 19-23, 1998, University of Kaiserslautern. Heinz W. Engl, Thorsten Hohage.