Present Position:	**full professor, Professor of Mathematics**
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Document prepared by Rolf Jeltsch for the occasion of the evaluation of the Mathematics Department for the time period 1999 - 2007, extended version.

Main research areas

Numerical Analysis (from theoretical investigations to engineering applications,) parallel computing, computational sciences. Special field of interests are numerics of hyperbolic conservation laws with applications in Euler equations of gas dynamics, compressible Navier-Stokes including large Eddy Simulation (LES) and chemistry, shallow water equations, magneto-hydrodynamical equations (MHD). Large scale computational and engineering problems such as simulation of accelerator beams, climate modeling, optimizing three dimensional turbine blades, modeling circuit breakers

Degrees and employment history

Ph.D. in mathematics 1972 at ETH Zürich;

Positions

1972-73 Killam postdoctoral fellow Dalhousie U, Canada;
1973-75 adj. ass. prof. University of California Los Angeles, UCLA, US;
1975-76 ass. prof. University of Kentucky, US;
1976-77 docent, Ruhr University in Bochum, Germany;
1977-79 associate prof. Ruhr University in Bochum, Germany;
1979-89 full prof. in Mathematics and director of the Institute for Geometry and Practical Mathematics of the University of Technology RWTH Aachen, Germany;
since 1989 full professor at ETH Zürich, Switzerland

Extended visits

1978 Stanford University, US, 6 month
1978 Helsinki Univ. of Technology, Finland, 2 month
1981 Helsinki Univ. of Technology, Finland, 3 weeks
1985 Helsinki Univ. of Technology, Finland, 1 month
1985 Stanford University, US, 1 month
1990 Helsinki Univ. of Technology, Finland, 2 month
1998-99 University of Queensland, Brisbane, Australia, 6 month
2004 The University of Auckland, Auckland, New Zealand, 2 month
2004-2005 University of Chile, Santiago de Chile, Chile, 2 month
2005 Escuela Poltecnica Nacional, Quito, Ecuador, 2 weeks

Honors and awards

Fellow of the National Mathematical, Centre, Abuja, Nigeria , Meritorious Service Award, 27 July, 2000
Foreign member of the Finnish Academy of Science and Letters, Finland, 15 April 2002
Honorary degree from the North University of Baia Mare, Romania, 10 October 2002
Honorary degree from the Univeristy of Technology Helsinki to be awarded 2 April 2008

Awards by my Ph.D. students

Manuel Torrilhon:
- Silver Medal for Ph.D. at ETH
- EURYI Award (this is a prize EUR 941,727 approximately 1.5 MCHF)

Andreas Adelmann:
First recipient of NERSC's Luis Alavarez Postdoctoral Fellowship in Computational Science, 2002 - 2003, see http://www.nersc.gov/news/newsroom/adelmann052902.php

Research since 1999

Completed Projects

A Genuninely Multi-Dimensinal Scheme for the Navier-Stokes Equations and its Application to LES with a Scale-Residual Model

A genuinely multi-dimensional numerical finite-volume method for solving mixed hyperbolic-parabolic equations has been developed and is applied to Navier-Stokes equations. It has been used for turbulent flow simulations using the method of Large Eddy Simulation (LES). A new model for LES has been developed. If a numerical scheme of low approximation order is used for the flow simulation, the numerical error can come up for the smallest scales of the solution to the same order of magnitude as the modelling term. The proposed scale-residual turbulence model takes this influence of this numerical error into account by construcing an approximative modelling term from the local temporal evolution solution.
This research was performed by Jochen Maurer in his thesis.

Wave propagation in solids

The method of transport of M. Fey has been adapted for the computation of waves solids, in particular in elastic-plastic materials. In the case of elastic deformation where the stress components are linear in the strain components, the problem reduces to the wave equation with constant coefficients. However, when a plastic wave is considered, the equation of state connecting strain and stress components depends on the past of the conserved variables. In one space dimension on has to solve three hyperbolic equations together with two ordinary differential equations which relate the stress and the pressure. The ordinary differential equations are solved with a Runge-Kutta method. For linear elastic material the method has order 4, for plastic material order 3.
This research was performed by Guido Giese in his thesis.

Writing the method of transport as a Boltzmann Scheme Boltzmann Schemes for the Euler equations use the fact that the Euler equations are the moments of the Boltzmann equation when the distribution function is locally Maxwellian. The numerical method consists of two phases: first, a convection phase where the collisionless Boltzmann equation is solved, and second, a collision phase where the distribution is relaxed to the local Maxwellian distribution. Instead of taking a Maxwellian Ansatz one can let the distribution function be any function whose moments are consistent with the Euler equations. The resulting schemes have the following properties:
- they are unconditionally stable in L^1, in particular, density and pressure remain positive
- often, the numerical solution fulfills an entropy inequality

It is possible to choose the distribution function such that the information spreads along the Mach cone. The resulting Boltzmann scheme is the first order Method of Transport. By modifying the distribution function we obtain a second order method similar to the second order Method of Transport. Conditions have been found under which the first property holds. It has been shown that the second-order method of transport cannot be written as a kinetic scheme. However, a second-order modified method of transport can be written as a kinetic scheme implying that the method preserves positivity of the density and pressure and certain L^1 estimates are satisfied.
This research was performed by Susanne Zimmermann

Inverse Design using the Euler Equations

Computational Fluid Dynamics, CFD, is a fundamental tool for the simulation of flow devices such as diffusers, blade rows, etc. Classically devices are optimised by parametrisation of the shape. With one shape one makes a forward flow slope and then corrects the shape. This is iterated until one has convergence. In the Inverse Methods one would like to design devices by imposing, for example, the distribution of the pressure or the flow speed as boundary conditions and looking for the corresponding geometry. Towards this goal J.J. Keller developed the inverse Euler equations (ZAMP, 49 (1998)). In the case of two dimensional or axial-symmetric problems

an algorithm has been developed. It is shown that the equations are composed of a system of equations for the generation of the shape of the device and by equations describing the physics of the flow. This splitting allows to determine a set of physically relevant boundary conditions and to modify the equations for the shape generation in order to devise a more efficient numerical method. An algorithm had been developed.
This research was performed by Andrea Scascighini.

In three space dimensions the approach with the inverse Euler equation does not work. The following algorithm has been developed for three-dimensional viscous/inviscid method for aerodynamic shape design of gas turbine blades. Prescribed data are the blade thickness and pressure loading distribution as well as the leading edge position. The corresponding blade shape and steady flow field are sought. The method is based on a finite volume discretization on a structured H-mesh. The resulting ordinary differential equations for the flow state and the (algebraic) pressure loading constraints form a DAE system. A half-explicit Runge-Kutta method is employed to solve this system: The flow state is advanced in time by a standard explicit Runge-Kutta scheme. At each stage the algebraic constraints are satisfied by updating the unknown circumferential positions of the blade surface nodes. The corresponding system of equations is small and sparse, as only the cells along the blade surfaces are involved. In comparison to the direct problem with known geometry the overhead per iteration is below 10 percent. In terms of number of iterations the method proves robust. This research was performed by Andreas Troxler.

Three Dimensional Simulations of High Intense Particle Beams in Complicated Accelerator Structures

An algorithm has been developed to do three dimensional simulations of particle beams in the complicated proton accelerator at the Paul Scherrer Institut (PSI).

The physical model is based on the collisionless Vlasov-Maxwell theory, justified by the low density ($\approx 10^9$ protons/cm^3) of the beam and of the residual gas. The probability of large angle scattering between the protons and the residual gas is then sufficiently low, as can be estimated by considering the mean free path and the total distance a particle travels in the accelerator structure.

In this model two forces are driving the particles: the so-called external forces which originate from the exterior magnetic and electric fields which guide, focus and accelerate the beam, modeled by a relativistic Hamiltonian and internal forces arising from the Coulomb interactions. Clearly the Coulomb interactions represent a nonlinear N^2 problem. The number of particles N is usually between 10^9 and 10^{14}.

The two forces are separated numerically with an operator splitting. The exterior forces acting on a single particle are treated with Lie Algebraic methods combined with Taylorseries expansions. The internal Coulomb interactions are approximated by solving the Poisson equation in an open domain. The particle-mesh method is used to interpolate the charge density on to a rectangular mesh. It is then Fourier transformed into Fourier space using FFT. The Hadamard-Product with the charge density and the Green's function in Fourier space are then subsequently transformed back to real space allowing us to compute efficiently the time-consuming convolution. The scalar electric field is obtained from the potential, by the use of a second-order finite difference scheme. Again by using interpolation, one finds the electric field in the continuum.

The rigorous, object-oriented, parallel design and the corresponding implementation eases the extendibility and portability of the code. The code runs on different Linux (Beowulf) Silicon Graphics and IBM SP-2 clusters. The use of parallel Fourier transforms to solve the Poisson problem, and the full parallelisation of the split operator integration method, allows the following range of problems to be tackled: 10 to 100 million particles on meshes up to $128^2 \times 2048$. The parallel efficiency is 87.5% on 32 Processors; even using 128 processors we still obtain 37.5% with no code optimization.
This research was performed by Andreas Adelmann

Numerical Scheme for a Free-boundary Problem and Astrophysical Flows A scheme has been developed to for a Cauchy problem for the porous medium equation where the initial data is as non-negative continuous function with compact support. The solution of such a problem has compact support for every time and hence an interface separating the regions where the solution is zero form those region where it is positive. This has been applied to astrophysical flow.
This research was performed by Simin M. Motamen.

Numerical Methods for Solving the ideal Magneto-Hydrodynamical equations The MHD equations form a system of hyperbolic conservation laws. The method of transport has been adapted to solve these equation. There is an additional problem with the MHD equations, namely that its solutions satisfy the inherent condition that the divergence of the magnetic field stays constant. One can choose a variant of the method of transport where a numerical approximation of the divergence stays numerically constant during the numerical time evolution. Hence the divergence error made during the discretization of the initial condition is not increased during the

integration. This concept has been extended to general systems of equations where a linear constraint, usually the divergence or a curl, is kept constant constant. This general framework allows to construct numerical methods that preserve exactly the discretized constraint on arbitrary grids by special fluxdistribution. It turns out that there is a duality between the equations preserving the divergence and the ones preserving the curl.
This research had been initiated by Michael Fey and a large portion was done by Manuel Torrilhon.

Efficient Numerical Methods for the Shallow Water Equations on the Sphere, SWES This work deals with the numerical core of global climate simulation and atmospheric general circulation models, AGCM. To develop new methods for this core the models are striped from the ocean circulation and, as one is not able to resolve even physically important sub grid phenomena, all sub grid scale parameterization of such phenomena, e.g. cloud formation, friction. In principle one considers the gasdynamical equations for the whole atmosphere of the earth with a possible addition of a conservation for water vapor content. Todays models decompose the atmosphere in 10 to 100 layers, each of which is modeled by the Shallow Water Equation on the Sphere, SWES. Hence the numerical core algorithm has to efficiently simulate the solution of the SWES.

A numerical method for SWES on spherical grids had been developed and tested. The grid chosen is not the orthogonal grid, e.g. the latitude-longitude mesh, such as not to have pole problem. The grid is the dual grid of a triangular grid which is sufficiently homogenous so that the dual grid consists of pentagons and hexagons only. Discrete operators which approximate the gradient and the vorticity. The reconstruction of scalars and vector fields from local information has been done. In order to get around the problem of a lack of regularity he introduces the use of radial basis functions. Two type of staggered grids so called C- and D-grids have been investigated.

A key component of any Atmospheric General Circulation Model is the algorithm for the advection on the sphere. One can think of the transport of wind-driven tracers. Such an algorithm has be shape-preserving, i.e. no new maxima or minima are introduced. Known methods have been adapted for advection on the sphere.

Explicit FV solvers which use local data dependencies only had been investigated as such algorithms are known to scale best on parallel computers. In addition one wanted that mass and the potential vorticity are preserved in the discrete form. To obtain these requirements a vector-invariant formulation of the shallow water equation on the sphere had been chosen. An algorithm using higher order radial basis function approximations for the wind reconstruction is given which yields for a simulation up to five days as good results as other existing ones. Unfortunately all of the staggered grid formulations show inherent numerical modes which show up as instabilities as pentagonal artifacts after some time.
This research was performed by William B. Sawyer.

Solving High Dimensional Dirichlet Problems Numerically Using the Feynman-Kac Representation

Two different algorithms to solve high dimensional Dirichlet problems numerically are proposed. Both approaches are based on the stochastic representation of the solution in the form of the famous Feynman-Kac formula. Here, the solution to an elliptic second order partial differential equation (PDE) is given by the expectation over some functionals of connected stochastic differential equations (SDEs). For the Dirichlet problem, the boundary condition makes the solution of the PDE unique. Monte-Carlo simulations involve the numerical approximation of the solution of the SDEs and the approximation of the mathematical expectation by a finite mean. For the simulation in a bounded domain, however, the first exit time of the process solving the SDE from the domain also plays a crucial role. On the one hand, integration is stopped as soon as the process reaches the boundary and on the other hand, the boundary condition is to be evaluated at the first exit point of the process from the domain. The proposed algorithms not only succeed in the approximation of the first exit time but also give an accurate approximation for the first exit point. Both algorithms make use of the fact that approximations of the solution of the SDEs have to be accurate only in a weak sense. Nevertheless, the two methods have essential differences. The first method uses bounded approximations for the increments of the simulated Brownian motion. This allows us to prevent the resulting discrete random walk from leaving the closure of the domain and the walk to approach the boundary in a controlled way. We prove both, the expected number of steps and the accuracy of the resulting one step approximation in the weak sense. A series of numerical tests is included. The second method uses Eulers method to approximately integrate the SDEs. Using normally distributed random variables to model the Brownian increments, the resulting discrete random walk is no longer restricted to the closure of the domain, but, might leave it within every step. An a posteriori test accounts for additional errors arising by the presence of boundaries. Corresponding exit times and exit points are sampled from analytical densities. Results from numerical experiments show that weak order one convergence of the Euler scheme is restored. Additionally, our results show the superiority of the proposed algorithm compared to other methods. Both methods are ideally suited for parallel simulations. Numerical tests in dimensions as high as 128 were run on the Beowulf cluster at ETH. This research was performed by Fabian Buchmann.

Approximation Schemes for SDEs with discontinuous coefficients

In this project numerical methods for solving stochastic differential equations, SDEs, with a drift term μ and a diffusion σ are considered. In applications drift and diffusion may not be smooth. One finds examples in mathematics of finance where typically jumps happen when a certain action is taken at a certain process threshold. There are also applications in physics and biology, for example permeable membranes or pottential cells arranged in lattices.
The project is concerned with discontinuous coefficient μ. It is known that with discontinuities only weak solutions exist. one wants to approximate such solutions which then can be used to compute certain properties, e.g. meanvalue of $g(solution)$, an infimum, and the distribution.
When computing the solution one would like to make no more assumptions as are needed for existence of a weak solution. This basically rules out all methods except the Euler method. Liqing Yan has shown that the Euler method converges under very mild conditions. Note however that with the Euler method one computes the solution at discrete points with a stepsize h but one does not take into account the location of the discontinuities. The main aim of this work is to improve upon the Euler method especially for large values of h. This research was performed by Sibylle Katharina Arnold.

Mathematical modelling of Triple Flame Ring Behaviour

In this research the dynamicla propoerties of lifted round diffusion jet flame, stabilized over a fuel exit has been studied. The stabilization mechanism is described in terms of triple flame structure, forming at hte edge of the flame. This *triple flame ring* propagates along the line of stoichiometry and stabilizes the flame at the point, where the local negative velocity of the triple structure compensates the velocity of the jet. The global dependence of the flame base radius was introduced at zero order, allowing the triple flame description in the vincinity of iso-stoichiometric surface. Zero Mach number combustion equations have been introduced to describe the flow. Even if the density changes due to the velocity variations are neglected, the variations referred to the temperature increase in the vincinity of the flame front are taken into account; small density variations are allowed and the impoact on the flame velosity has been studied. The flame front is assumed to be parabolic of unknown curvature, which is then found as a funciton of chemical properties. Closed expressions have been found for the flame velocity as a function of the mixture fraction gradient and of small heat release. Comparisons with direct numerical simulations of J. Boulanger, L. Vervisch, J. Reveillon and S. Ghosal had been made.
This research was performed by Marina Savelieva

High-Order Semi-Lagrangian Numerical Methods for Large-Eddy Simulations of Reacting Flow

Large Eddy Simulation (LES) has recently proven to be an accurate tool for the simulation of highly turbulent reacting flows. This project is focused on the improvement of this computational technique, as well as its application to the optimization of liquid fuel and premixed fuel combustion chambers. The numerical difficulties of such simulations, where the key combustion physics occur over length scales much smaller than the computatinal grid spacing are being solved using: (a) a coarse-grid simulation with extremely low dissipation known as the Forward Semi-Lagrangian Method (FSL), based on a newly discovered family of interpolation basic functions of high-accuracy and compact support (named Z-splines), and (b) a dynamic turbulence model based on a transport equation for the subgrid kinetic energy. Realistic combustion processes are simulated using a model with a reduced number of transport e quations, developed by Sevket Baykal from the LTNT of the ETH Zurich.
This research was performed by Julian T. Becerra Sagredo

Key publications before 1999

- Largest Disk of Stability of Explicit Runge-Kutta Methods, BIT 18, 500-502, 1978, jointly with O. Nevanlinna.
- An Optimal Fraction Free Routh Array, International Journal of Control 30, 653-660, 1979.
- Stability of Explicit Time Discretizations for Solving Initial Value Problems, Numer. Math. 37, 61-91, 1981, jointly with O. Nevanlinna.
- Stability and Accuracy of Time Discretizations for Initial Value Problems, Numer. Math. 40, 245-296, 1982, jointly with O. Nevanlinna.
- Accuracy Barriers of Difference Schemes for Hyperbolic Equations, SIAM J. Numer. Anal. 24, 1987, 1-11. Jointly with J.H. Smit.

Key publications 1999 - present

- Reducibility and contractivity of Runge-Kutta methods revisited. BIT**46**, no. 3, 567–587. 2006. Jointly with Germund Dahlquist.
- On curl-preserving finite volume discretizations for shallow water equations. BIT**46**, 2006 suppl., S35–S53. Jointly with Manuel Torrilhon.
- Essentially optimal explicit Runge-Kutta methods with application to hyperbolic-parabolic equations. Numer. Math. **106**, 2007, no. 2, 303–334. Jointly with Manuel Torrilhon.
- *Hyperbolic Problems: Theory, Numerics, Applications, Seventh International Conference in Zürich, February 1998, Vol 1 and Vol 2* ISNM Vol 129 and 130, Birkhäuser Verlag, Basel, Boston, Berlin, 1999, Jointly with M. Fey (Ed.).
- *Proceedings of Sixth International Congress on Industrial and Applied Mathematics, ICIAM07, Zurich*, EMS publishing house 2008, Edited jointly with G. Wanner, in preparation.

Editor for journals and bookseries

- Associate editor of Journal on Computational and Applied Mathematics since January 1981 - 2000 (?)
- Editor of the book series: numerical Mathematics and Scientific Computation Oxford University Press 1995 - 2001. Resigned because of conflict of interest with respect my position in the EMS-publishing house.
- Associated editor of the Journal on Computing and Visualization in Science, Springer, since 1998.
- SIAM Computational Science and Engineering Book Series, member editorial board, since 2004
- Proceedings A of the Royal Society, member of the editorial board, since 2004

Conferences and invited addresses: Selected examples

2008

IIT Delhi, India, 9 January
Titel: *Leonhard Euler - his life, personality, discoveries and their impact today*

Jamia Millia Islamia, Delhi, 9 January
Titel: *Leonhard Euler - his life, personality, discoveries and their impact today*

13th Annual Conf. and 1st Intern. Conf. of Gwalior Academy of Mathematical Sciences Invited plenary, Agra India, 10 January Title: *Essentially Optimal Explicit Runge-Kutta Methods with Application to Hyperbolic-Parabolic Equations*

Lecture in College of Engineering BMAS, Agra, India, 12 January Title: *Leonhard Euler - his life, personality, discoveries and their impact today*

Colloquiums lecture Lisbon 7 February Title: *Finite volume methods for partial differential equations with intrinsic constraints*

SANUM Conference, Stellenbosch, 26 - 28 March. Invited lecture. Title: *Essentially Optimal Explicit Runge-Kutta Methods with Application to Hyperbolic-Parabolic Equations*

ONJP120 Perspectives in Numerical Analysis, Helsinki University of Technology, 27-29 May, invited lecture

Severobaikalsk Baikal Conference, 1-9 July, invited lecture
Title: *Numerical Solution of stiff Differential Equations: History and Modern development*

Conference on Modeling, Simulation and Optimization of Complex Processes, 21-15 July, invited lecture

Sixth International Conference of Numerical Analysis and Applied Mathematics 2008 (ICNAAM 2008), Kos, Greece, 16-20 Sept. invited lecture

Special addresses

- Speech on the occasion of the public accouncement of the **Abel Prize**,Oslo, 6 June 2002, 14.00 - 14.30. In this speech I had to thank on behalf of the world mathematical community Norway for the creation of the Abel Prize.
  See http://www.emis.unne.edu.ar/abel.html
- Invited talk on the occasion of becoming a Foreign member of the Finnish Academy of Science and Letters
  Title: *The European Research Area: a dream and the reality!*
  Helsinki, Finland, 15 April 2002.
- Speech at the opening of the GAMM Annual Meeting in Luxemburg, 28 March 2005. Topic: The policy of the European Union towards research, in particular the imminent founding of the European Research Council. This was also a reply to the speech of the Ministre de la Culture, de l'Enseignement Supérieur et de la Recherche, of Luxemburg who was to chair in April 2005 the meeting of the research ministers of EU where the seventh Frameworkprogramm had to be decided along with the introduction of the European Research Council.
  See GAMM Rundbrief , 2005, Heft 2, p 18 -20. and http://www.gamm-ev.de/
- OECD Global Science Forum Workshop on Mathematics in Industry
  Key opening lecture
  Title: *Mathematics-Industry: Experiences and Expectations*
  Heidelberg, 22 March 2007
- Euler Award Ceremony in Bejing
  Key lecture
  Title: *Leonhard Euler - his life, personnality, discoveries and the impact today*
  23 April 2007
- Lecture the series: Science in the Caf in the Singapore Science Centre
  Title: *Leonhard Euler - his life, personnality, discoveries and the impact today* 25 April 2007

Statistics of publications and presentations

This information is from the annual reports to be done for ETH. As the requested data by ETH is changing over the years the information is heterogeneous. Moreover it partly consists of the publication and lectures of the whole group in the chair.
To find the complete publication list of Rolf Jeltsch see on the home page www.sam.math.ethz.ch/∼jeltsch/

refereed publications	22
scientific publications	1
monographs	5
varias publications	36

lectures for scientific audience 1999, 2000	26
other lectures 2001, 2002	5
invited lectures for scientific audience, 2001 - 2007	59
other lectures for scientific audience, 2001 - 2007	20

Collaborations

ABB Switzerland AG
ALSTOM POWER (Schweiz) AG
Sulzer Chemtech AG
PSI, Paul Scherrer Institut, Villigen
SLF, Swiss Federal Institute for Snow and Avalanche Research Davos
Institute of Fluid Dynamics, ETH
Energy Science Center, ETH
Tbilisi State University, Tbilisi, Georgia
Helsinki University of Technology, Espoo, Finland
University of Victoria, Victoria, BC, Canada
University of Adelaide, Adelaide, Australia
University of Queensland, Brisbane, Australia

The University of Auckland, Auckland, New Zealand
University of Chile, Santiago de Chile, Chile
Escuela Poltecnica Nacional, Quito, Ecuador
EULER Project (7 Partners)
LIMES Project (8 Partners)

External funding

1996 - 1999 Schweizerischer Bundesamt für Energiewirtschaft BEW
Large-Eddy-Simulation in der turbulenten Verbrennung
CHF 102'000

1998 - 2000 Swiss National Science Foundation (SNF)
Projekt Nr. 21-52251.97
Genuinely multidemensional schemes for steady state calculations of compressible inviscid flows
CHF 30'000

1999 Research project with ABB Kraftwerke
Software Tool for the Inverse Computation of 3-D Flows
CHF 100'000 for 1999
other CHF 190'000 if required

2000-2002 Limes (Large Infrastructure in Mathematics)
5FP Contract Nr. HPRI-CT-1999-50002
Contract between European Commission and European Mathematical Society
EURO 22'000

2000 - 2002 KTI Research project with Alstom power and BBT (Bundesamt fr Berufsbildung und Technologie)
Projekt nr. 4571.1 KTS
Software Tool for the Inverse Computation of 3-D Flows
BBT: CHF 219'711
Alstom Power: CHF 255'000

2000 - 2003 EU - Scientific Program IST
MACSI-net: Mathematics, computing and simulation for industry
BBW Nr. 00.0195-1
CHF 29'000

2001 GAMM 2001 Annual Meeting

Paul Scherrer Institut	CHF	3'000
Swiss National Science Foundation Congress Invited Speakers Nr. 21-63228.00	CHF	5'000
Swiss National Science Foundation SCOPES Nr NF 7CO-63289	CHF	10'000

2001 - 2003 ETH project
'Non-premixed turbulent combustion modeling using large eddy simulation and unsteady flamelet models'
jointly with K. Boulouchos, J. Gass, L. Kleiser, D. Poulikakos
CHF 300'000

2005 - 2007 KTI Project with ABB Switzerland and BBT (Bundesamt fr Berufsbildung und Technologie
Project Nr. 7399.1 EPRP-IW
Model for High Current Arc in Generator Circuit Breaker
jointly with Christoph Schwab and Ralf Hiptmair
BBT: CHF 331'600
ABB Switzerland: CHF 332'000

2005 International Conference on differential equations: from theory to computational science and engineering
Swiss National Science Foundation (SNF)
Project Nr. IB7120-111395 / SCOPES
CHF 3'000

2006 - 2009 Swiss National Science Foundation (SNF)
Project Nr. IB7420-111041
Supporting the Bologna Process in Applied Mathematics and Computer Science at the Tbilisi State University in Georgia
CHF 77'800

2007 International Congress on Industrial and Applied Mathematics
A. SUPPORT from associations

Swiss National Science Foundation (SNF) SCOPES Nr B7120-117341	CHF	10'000
Swiss National Science Foundation (SNF) Congress Invited Speakers Nr 20CO21-117242/1	CHF	30'000
IMU-CDE	CHF	2'000
EMS European Mathematical Society	CHF	3'300
ICIAM Organization	CHF	18'000
SMG	CHF	5'000
Zürcher Hochschulstiftung	CHF	10'000
Stifung der math. Wissensch. in der Schweiz	CHF	12'000

B. SPONSORING from private sector

Novartis	CHF	5'000
IBM	CHF	11'000
Mathworks	CHF	10'000
Demoscope	CHF	1'000
SwissLife	CHF	17'000
Comsol	CHF	25'000
Man Investments AG	CHF	25'000
Europcar	CHF	5'000
Merck and Co	CHF	6'000
Swissmem	CHF	5'000
LGT Capital Management	CHF	1'500
Hilti Corporation	CHF	2'000
Wolfram Research Europe Ltd	CHF	2'500
City and Canton Zrich	CHF	20'000
Google	CHF	10'000

PhD students since 1999

Jochen Maurer 1999
A Genuinely Multi-Dimensional Scheme for the Navier-Stokes Equations and Its Application to LES [Large-Eddy Simulation] with a Scale-Residual Model

Guido Giese 1999
A Genuinely Multi-Dimensional High-Resolution Scheme for the Elastic-Plastic Wave Equation

Susanne Zimmermann 2001
Properties of the Method of Transport for the Euler Equations

Andrea Scascighini 2001
A Numerical Method for the Design of Internal Flow Configurations Based on the Inverse Euler Equations

Andreas Adelmann 2002
3D Simulations of Space Charge Effects in Particle Beams

Simin Motamen 2002
Nonlinear Diffusion Equation: A New Numerical Scheme for the Free-Boundary Problem and Applications of Numerical Schemes to Astrophysical Flows

Marina Savelieva 2003
Mathematical Modelling of Triple Flame Ring Behaviour

Andreas Troxler 2003
A Differential-algebraic Approach to Inverse Aerodynamic Shape Design of Gas Turbine Blades

Manuel Torrilhon 2003
Zur Numerik der idealen Magnetohydrodynamik

Fabian Buchmann 2004
Solving High Dimensional Dirichlet Problems Numerically Using the Feynman-Kac Representation

William Sawyer 2006
Efficient Numerical Methods for the ShallowWater Equations on the Sphere

Sybille Arnold 2007
Approximation Schemes for the SDEs with Discontinuous Coefficients

Julian Sagredo 2007
High-Order Semi-Lagrangian Numerical Methods for Large-Eddy Simulations of Reacting Flow

Patrick Huguenot 2008
Axisymmetric High Current Arc Simulations in Generator Circuit Breakers based on Real Gas Magnetohydrodynamics Models

Present:
Julia Kowalski
Expected to finish in 2008

Harish Kumar
Expected to finsih in 2008

Miroslav Cada
Expected to finish in 2009

Paolo Corti

Postdocs since 1999

Michael Fey 7.14% 1993 -
Manuel Torrilhon 12 2003 - 9 2004
Vincent Wheatly 10 2005 - 12 2007
Robert Artebrant 9 2006 - 9 2007
Sybille Arnold 50% 10 2007 - 1 2008

Future research projects

Simulations for High Current Arc Plasmas The high-energy, high-current thermal plasma arc that develops between electric contacts in a gas circuit breaker during circuit interruption is a important phenomenon in the power transmission industry. The high temperature and pressure arc dissipates the tremendous amount of energy generated by the fault current, hence it protects the other parts of the circuit. Simultaneously this energy has to be transfered away from the contacts in order to protect the components of the circuit breaker. In order to interrupt the current, the arc must be weakened and finally extinguished.

In this project we are attempting to model these phenomena. We consider the equations of magnetohydrodynamics, these describe the flow of plasma in the presence of a magnetic field along with evolution of that field. These equations are to be solved numerically in realistic, complex circuit breaker geometries using finite volume methods. The domain is initially filled with SF6. We begin our computations after anode and cathode are fully separated and a core of ionized gas exists between these two. The strong electric field between the contacts drives the high arc current, which dissipates large amount of energy further ionizing the gas and raising the pressure in the heating volume. When the current decays during the A/C cycle, the high pressure in the heating volume drives the plasma flow which extinguishes the arc.

In order to successfully simulate this process, we must establish what physical mechanisms are important in the flow. For example, the importance of radiation, turbulence and real gas effects must be studied. We must then assess what numerical methods can best be used to capture these mechanisms. Finally these methods will be implemented to develop a simulation tool that can be used to study the details of the operation of gas circuit breakers.
This project is done jointly with Christoph Schwab, Ralf Hiptmair, Manuel Torrilhon, Michael Fey, Vincent Wheatley, Patrick Huguenot Harish Kumar and Gisela Widmer.

Partick Huguenot has written up a thesis: Axisymmetric High Current Arc Simulations in Generator Circuit Breakers based on Real Gas Magnetohydrodynamics Models.

Multi-Phase Shallow Water Systems for Debris Flow In the last decade shallow flow models have been successfully applied to simulate debris flows, however these models fail in regimes of dominant sedimentation and separation of components. The aim of this project is to derive a debris flow model that accounts for these effects. In a first step existing models have been generalized to allow for varying mixture densities. The resulting system is conditionally hyperbolic. A rigorous analysis of has been carried out to ensure, that regions of complex characterstics in the phase space are irrelevant for realistic flow situations. In a final step the developed numerical solver will be implemented into a GIS environment to simulate flow over complex terrain. Real scale data of debris flow events in the Illgraben (VS) provided by the Swiss Federal Institute for Forest, Snow and Landscape Research motivates and verifies the theory.
This project is done jointly with Manuel Torrilhon and Julia Kowalski

Multidimensional Numerical Methods for the Regularized 13-Moment Equations Thermodynamics of gases provides a field theory with the main objective of determing fields of the basic variables, density, velocity and temperature. In order to obtain the fields one needs balance equations, namely the conservation of mass, momentum and energy and additional constitutive relations. The Euler-equations of gas dynamics are a classical choice. However these equations do not consider dissipative effects.

The moment equations, derived from extended thermodynamics in the context of kinetic gas theory, are dissipative, hyperbolic field equations for monatomic gases. The main idea is that for processes with rapid changes, e.g. shock tube experiments, more variables than in the classical Euler case, are needed to give an appropriate theoretical description. However, these higher moment equations yield a closure problem for the last moment. For this system of equations, the moment in the space derivative of one equation is subsequently needed for the time derivative in the next equation. This system of equations yields a closure problem, since the very last moment is not described in the system itself.

In recent work a new closure for the 13-moment equations has been presented. The regularized 13-moment equations are based on 13 moments which correspond to the density, velocity and temperature, as well as stress tensor and heat flux. Beside the conservation laws the system provides two additional equations for the stress tensor and the heat flux. It is the objective of this project to derive appropriate multidimensional numerical methods for their solution.

In a first step we have formulated a new method, using a third order logarithmic limiter. This method enables us to get better resolution, namely third order accuracy. We have tested this method in different numerical experiments. In the future we will expand this work to deal with the full set of regularized 13-moment equations.
This project is done jointly with Manuel Torrilhon, Michael Fey and Miroslav Cada

Developing a Divergence Preserving Finite Volume Method for Maxwell Equations

The Maxwell equations describe the motion of electric charges and electromagnetic field in a medium. This set of equations can be subdivided in two groups, a first one that describes the changes in time of the electromagnetic fields, and a second one - an intrinsic constraint - that couples the fields to the charges. The time dependence of the charge density is not explicitly given through a partial differential equation alone, as for the field equation. In the continuum we can couple the two sets of equations to derive the rules for the evolution of charge density. In the continuous case with a physical initial condition, using the evolution of the charge equation automatically satisfies the constraint. The opposite is also true: from the constraint we get the physical charge. Finite volume method that solves the field equations have to deal with non physical solutions, which can be eliminate through some artificial steps. This happens if the operators are discretized without taking into account the implicit characteristics that exist in the continuum. This feature has to be mimicked in the discrete case to have a physically relevant result. We are developing a formulation in the framework of the finite volume method of Torrilhon and Fey to obtain a numerical algorithm that retains the desired attributes, without imposing the physical constraint in some artificial way between each time step.
This project is done jointly with Manuel Torrilhon, Michael Fey and Paolo Corti

Multi-Scale Time Integration Methods

Stabilized explicit Runge-Kutta methods use more stages which do not increase the order, but, instead, produce a bigger stability domain for the method. In that way stiff problems can be integrated by the use of simple explicit evaluations for which usually implicit methods had to be used. Ideally, the stability domain is adapted precisely to the spectrum of the problem at the current integration time in an optimal way, i.e., with minimal number of additional stages. This idea demands for constructing Runge-Kutta methods from a given family of flexible stability domain. Typically, these are given by a disk, real or imaginary intervals.

In this project the results for real line spectra, are generalized to more general spectra in the form of a thin region. In thin regions the eigenvalues may extend away from the real axis into the imaginary plane. Semi-discretizations of hyperbolic-parabolic equations are a relevant application which exhibit a thin region spectrum. As a model, linear, scalar advection-diffusion is investigated. The second order stabilized explicit Runge-Kutta methods derived from the stability polynomials are applied to advection-diffusion and compressible, viscous fluid dynamics in numerical experiments. Due to the stabilization the time step can be controlled solely from the hyperbolic CFL condition even in the presence of viscous fluxes.
This project is done jointly with Manuel Torrilhon

The Stability of Numerical Simulations of Complex Stochastic Differential Equations

When dealing with some simulations of SDEs, a loss of accuracy almost independent of the time-step refinement and number of paths can occur after a relatively short time for many methods. An example of a hard-necked SDE is the one given in [1], which numerical solution behaves badly after approximatively $t = 0.3$. Splitting of drift methods as introduced in [2] have been tried on this process and seemed to improve the stability of the results, but not to the desired extent. The goal of this dissertation is thus to develop some new techniques to deal with the unstable behavior of certain SDEs. In particular, the objectives are:

to find regularization and splitting techniques which allow numerical solutions of SDEs to remain stable for long time integrations. to study stochastic gauges and their relationships to integrability conditions. Apparently, choices of gauges which preserve positivity of the weights are not as arbitrary as in [1]. It is likely these gauges must be considered to be Lagrange multipliers which must be chosen according to integrability conditions [3,4] of the resulting SDE system with constraints. to study the behavior of oscillating SDEs and to find appropriate integration methods as in [5]. The [1] problems are not highly oscillating but the long time oscillating behavior is not well behaved.
This project is done jointly with Wesely Petersen and Christian Perret.

Suitability of IBM/Sony CELL processors for scientific computation

In the CSE project the suitability of IBM/Sony CELL processors for scientific work is tested.
This project is done jointly with Wesley Petersen, Jörg Waldvogel, Matthias Troyer, Anton Gunzinger, George Lake and students of CSE.

Barriers to the accuracy of stable difference schemes for hyperbolic partial differential equations When solving hyperbolic initial boundary value problem using difference methods one is interested in stable schemes only. Gustafsson, Kreiss, Sundstrm have shown that, instead of studying the two point boundary value problem with variable coefficients it is enough to consider the constant coefficient equation on a half plane. Even for systems this problem can be reduced to the study of several scalar advection equations with constant coefficients. A sufficient condition for the stability of the interior scheme as well as for the stability of the boundary scheme is that the characteristic polynomial associated with the scheme has all roots bounded by one and the roots of modulus one are simple. These stability requirements limit the accuracy a scheme can have. It has been conjectured that the order of accuracy is bounded by twice the number of stencil points on one side of the characterist the 'newest' point. For one step schemes this conjecture has been proved in 1987. Now one treats explicit and implicit two-step schemes.

Teaching

Each semester the following lectures have been taught:
- one from the following: Numerische Mathematik 4G; Analysis III 2V + 1U;Numerische Mathematik I 4V + 2U; Stat. and Numerische Meth. for chemical engineers 1V + 2U *; Numerische Mathematik II 2V+1U; Numer. Math. for CSE 4V + 2U; Numerik PDGl. II for mathematicians and CSE 3V + 1U; Analysis III for maschine construction engineers and CSE2V + 2U
- Fallstudien (case studies) (with K. Nipp, W. van Gunsteren)
- Seminar über Numerik 2S (SS 99, Ws 99/00)
* new script has been written

Other profession oriented activites

Involvement in societies:

ICIAM International Council for Industrial and Applied Mathematics

2000- 2005 Representative of EMS, voting member

2000- 2007 Representative of SMG, non-voting member

Congress Director of ICIAM 2007 held in Zürich, 16 - 20 July, 3200 participants

2005- 2007 President-elect

2007- present President

EMS European Mathematical Society

1994-2004 Council member

1994-1998 Member of the electronic publishing committee

1997-1998 Member of the executive committee

1998- Member of the applied mathematics committee

1999-2002 President

2004-present Committee on meetings

European Mathematical Foundation

The EMS founded under my presidency the *European Mathematical Foundation*. This foundation is strongly linked to the EMS and has its seat at the Seminar for Applied Mathematics at ETH. Its major operation is to run a publishing house which is called *EMS Publishing House*, see http://www.ems-ph.org/
By now it produces 11 periodicals and its financial assets at the end of 2006 have been EUR 647'700 (approximately CHF 1'042'000 at the exchange rate of 19 Jan 2008.)

2001-2002 President of the board of trustees of the European Mathematical Foundation

2002 - present Member of the board of trustees of the European Mathematical Foundation

GAMM Society for Applied Mathematics and Mechanics

1996-2001 Member of the Executive Board

2005-2007 President

2008- present Vicepresident

2006-2008 Chair of the Richard-von-Mises Prize committee

SMS Societe Mathematiques Suisse

1998-1999 Secretary

2000-2001 Vicepresident

2002-2003 President

MACSI-net (European network on Mathematics Application, Computing and Simulation in Industry)

2000-2004 Member of the strategy board

IMU International Mathematical Union

1998 - present Member of the General Assembly representing Switzerland

2002-2006 Member of Committee for Electronic Information and Communication, DMathLib co-chair

OECD Global Science Forum

2006 - present Member of the steeringcommittee for the project Workshops on Mathematics in Industry

Organisation of major conferences:

Organization of the 'Seventh International Conference on Hyperbolic Problems, Theory, numerical methods and applications', ETH Zürich, February 9-13, 1998.

Organization together with L. Kleiser and M. Gutknecht, Annual meeting of GAMM, ETH Zürich, February 12-15, 2001

Conference Chair, jointly with G. Strang (president SIAM) and P. Deuflhard (local organizer) of the first EMS-SIAM conference. Title: 'Applied Mathematics in a Changing World' Berlin, 2-6 September 2001

Conference Chair, jointly with M. Thera (president SMAI) and M. Waldschmidt (president SMF) of a EMS-SMAI-SMF conference. Title: Applied mathematics - Application of mathematics' Nice 10-13 February 2003

Congress Director of ICIAM 2007, Zurich, 16-20 July 2007.

Organization together with T. Roesgen and M. Gutknecht, Annual meeting of GAMM, ETH Zürich, 16-20 July 2007.

Scientific committee member of major conferences:

Biennial conference series *Hyperbolic Problems, Theory, numerical methods and applications*. Member of the scientific committee for the years 1988, 1990, 1992, 1994, 1996,1998, 2000, 2002, 2006.

Biennial conference series *ENUMATH*. Member of the scientific committee 1997 Member of the program committee 1999, 2001, 2003, 2005, 2007, 2009.

Triennial conference Series *High Performance Scientific Computing, Hanoi*. Invited speaker 2000. Member of the scientific committee 2003, 2006, 2009.

International Congress of Applied Mathematics, Santiago de Chile, 13-17 March 2006 Member of the Steering Committee. This congress is planned to take place in Latin America every 4 years. It was organised by EMS-SIAM-UMALCA.

GAMM Annual meeting. Because I feel one should not be too frequently on the scientific committee of an annual meeting I tried to be on the scientific committee only every second year. As president, 2005-2007, one had to be on it every year.

Prizes Committees

Abel Prize. In 2002, as president of the EMS I was member of the group to give advise to the Norwegian Academy on how to set up the Abel Prize. In particular the EMS could propose two persons of which one would be picked by the Norwegian Academy to become a member of the Prize committee

ICIAM prizes 2011: Chair

CICIAM prizes1999: Member on the subcommittee for the CICIAM Maxwell prize

Richard-von-Mises Prize 2006: Chair

Richard-von-Mises Prize 2007: Chair

Richard-von-Mises Prize 2008: Chair

Henrici Prize 1999: Member of the committee

Henrici Prize 2003: Chair of the committee

Dahlquist Prize 1999: Member of the committee

Albert Pfluger Prize 1993 - 2007: Secretary of the committee

Member of Advisory Boards

Banach Center, Warsaw, Poland, Chair of the Scientific Council 2002-2005

Simula Research Center, Lysaker, Norway, 2002-2005

Johann Radon Institute for Computational and Applied Mathematics (RICAM), Linz, Austria 2003-2007

Johann Radon Institute for Computational and Applied Mathematics (RICAM), Linz, Austria 2008-2013

PSCI - Parallel and Scientific Computing Institute, Royal Institute of Technology, Stockholm and University of Uppsala, Sweden, 1999-2003

CIAM Center for Industrial and Applied Mathematics, 2007 - present

Evaluations

Stuttgart computing Center, HLRS, chair, Stuttgart 15 - 16 May 2000

Site committee University of Hawaii, Manoa, 10 -12 October 2001. This visit was made for the National Science Foundation of US. Chair of the site visiting team.

Imperial College London, Review of Undergraduate Teaching, 27 February 2004

6th FP Marie Curie Call FP6-2002-Mobility-1
Panel member, 2003

6th FP NEST Scientific Panel for New and Emerging Science and Technology
(NEST) panel memeber the last panel in the chair of the panel

VSNU Evaluation of the Mathematics Department of the Universities in the Netherlands, 24 -29 August 2003

Review panel of the Helmholtz Programme concerning *Scientific Computing* applications by Forschungszentrum Jülich (FZJ) and Forschungszentrum Karlsruhe (FZK) in Jülich, 5 May 2004

Panel for Engineering Sciences of the Swedish Research Council for evaluating Linnaeus Grants, supporting strong research environments at Swedish Universities. 2007 - 2008

European Research Council, ERC Advanced Grant (Physical Sciences & Engineering) Chair of the Panel PE1 - Mathematical foundations: all areas of mathematics, pure and applied, plus mathematical foundations of computer science, mathematical physics and statistics. Years 2009, 2011, 2013

Self assessment

Strong points

Teaching:

I have a large experience in teaching. Overall I taught more than 15'000 students. I am teaching courses since 1971 with interruptions only for a semester to finish the thesis, one year as postdoctortal fellow, a nine month period where I had a research grant by SNF, three sabbatical semesters, one semester when I had a back problem and a one year period to organize the ICIAM 2007 congress.

Heading institutions:

I have a large experience in heading institutions and running organisations. I am much helped by my ability to deal with people and a practical sense for organisational and financial matters.

1979 - 1989 I was head of the Institute of Geometry and Practical Mathematics at the RWTH Aachen. The Institute had some 15 - 20 members. In that period I was also the person in charge of the finances of the the group Mathematics (Fachgruppe Mathematik).

1989 - present: The duty of heading the Seminar for Applied Mathematics, SAM, is rotating in 2 year periods between the full professors of SAM. I am definitely the one who did the most 2 year periods.

1991-1993 Chair of the mathematics department.

1997 - present: Head of Student Studies CSE

2006 - Chair of the Committee for the resources of the department of Mathematics

President: EMS 1999-2002, SMG 2002-2003, GAMM 2005-2007, ICIAM 2007-2011

International networking:

I am extremely well connected with colleagues in Europe and the whole world, not only in the field of applied mathematics but all of mathematics. The reason is that I have been president of EMS with about 50 member societies in Europe and of ICIAM with more than 30 member societies world wide and have worked on many advisory boards, evaluation teams and on conference organisations.

Weak points:

My strongest weak point is that I feel that people are more important than theorems. Theorems can always be proved later, while persons in need can not wait. Hence I have difficulty to say 'No' if asked to help.

Additional remarks

For the complete list of publications see my webpage. Unfortunately I have not enough time to fill in all the activities done in the period 1999 - present. In particular I have not listed

- all the invited talks,
- all the conferences where I was on the scientific program committee,
- all the offices held at ETH or committees worked with
- all events organised myself
- all the evaluation panels I have been on
- talks and publications by co-workes of my group are not included

It is extremly timeconsuming to get all details of my activites accurately.