

**Guido Kanschat**

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College Station, TX 77843

**1 Education**2004 *Habilitation* and *venia legendi*, Mathematics, University of Heidelberg, Germany1996 *Doctor rer. nat.* (PhD in Science), University of Heidelberg, Germany1992 *Diplom*, Mathematics, University of Bonn, Germany**2 Appointments**

2009–curr. Associate Professor, Texas A&amp;M University

2006–2009 Assistant Professor, Texas A&amp;M University

2005–2006 Research Associate (*Wiss. Ang.*), Department of Applied Mathematics, University of Heidelberg, Germany2000–2005 Assistant Professor (*Wiss. Assistent*), Dept. Appl. Math., Univ. Heidelberg, Germany

1999–2000 Visiting Assistant Professor, School of Mathematics, University of Minnesota

1999 Assistant Professor, Dept. Appl. Math., Univ. Heidelberg, Germany

1995–1999 Research Associate, IWR, Univ. Heidelberg, Germany

1986–1989 Software developer, Siempelkamp Engine Construction, Krefeld, Germany (part time)

**3 Grants and Awards**

2011 The Richard Stadelmann Faculty Senate Service Award

2010 One semester research grant at the Institute of Mathematics and its Applications, Minneapolis.

2009 KAUST Innovation Award, with R. Korty and D. Thomas

2008 BIRS Conference on Nonstandard Finite Element Methods in Computational Fluid Dynamics, with V. Girault (Paris VI), P. Mineev (U. Alberta) and J.-L. Guermond, 2010

2009 NSF-CBMS: Regional Conference on Adaptive Finite Element Methods, PI, with Wolfgang Bangerth (TAMU)

2008–2010 NSF(DMS): Tuning-free adaptive multilevel Discontinuous Galerkin methods for Maxwell's equations, PI, collaborative research with R. Hoppe (U. Houston) and T. Warburton (Rice U.)

2008–2012 King Abdullah University of Science and Technology Global Research Partnership Center "Institute for Applied Mathematics and Computer Science", investigator, (PI: Jim Calvin)

2007 The J. H. Wilkinson Prize for Numerical Software, with W. Bangerth and R. Hartmann

2007–2011 NSF-DNDO: ARI-LA: A Framework for Developing Novel Detection Systems Focused on Interdicting Shielded HEU, investigator (PI: Warren Miller)

2007–2009 NSF-DMS: Discontinuous Galerkin Methods for PDEs with Heterogeneous Coefficients, co-PI, with Jean-Luc Guermond (TAMU), PI, and Raytcho Lazarov (TAMU)

2006 Deal.II becomes part of the SPEC CPU2006 Benchmark

2000–2003 DFG *Schwerpunktprogramm ANumE*, co-Pi, Rolf Rannacher, PI, 2000–20031999 DFG *Habilitationsstipendium* (postdoctoral scholarship), 5 months

1992–1995 DFG Graduate Scholarship

## 4 Publications

### 4.1 Articles in refereed journals

- [1] S. E. Zedler, G. Kanschat, I. Hoteit, and R. Korty. A new approach for the determination of the drag coefficient from the upper ocean response to a tropical cyclone: a feasibility study. *J. Oceanography*, 2011. accepted for publication.
- [2] L. Rivera-Rivera, Z. Wang, B. McElmurry, R. Lucchese, J. Bevan, and G. Kanschat. Morphing a vibrationally-complete ground state potential for the hydrogen bond OC-HF. *Chem. Phys.*, 2011. in press.
- [3] B. Janssen and G. Kanschat. Adaptive multilevel methods with local smoothing for  $H^1$ - and  $H^{\text{curl}}$ -conforming high order finite element methods. *SIAM J. Sci. Comput.*, 33(4):2095–2114, 2011.
- [4] G. Kanschat and B. Rivière. A strongly conservative finite element method for the coupling of Stokes and Darcy flow. *J. Comput. Phys.*, 229:5933–5943, 2010.
- [5] J.-L. Guermond and G. Kanschat. Asymptotic analysis of upwind DG approximation of the radiative transport equation in the diffusive limit. *SIAM J. Numer. Anal.*, 48(1):53–78, 2010.
- [6] H. K. Hesse and G. Kanschat. Mesh adaptive multiple shooting for partial differential equations. Part I: Linear quadratic optimal control problems. *J. Numer. Math.*, 17(3):195–217, 2009.
- [7] B. Cockburn, G. Kanschat, and D. Schötzau. An equal-order DG method for the incompressible Navier-Stokes equations. *J. Sci. Comput.*, 40(1–3):188–210, 2009.
- [8] G. Kanschat and D. Schötzau. Energy norm a-posteriori error estimation for divergence-free discontinuous Galerkin approximations of the Navier-Stokes equations. *Int. J. Numer. Methods Fluids*, 57(9):1093–1113, 2008.
- [9] G. Kanschat. Robust smoothers for high order discontinuous Galerkin discretizations of advection-diffusion problems. *J. Comput. Appl. Math.*, 218:53–60, 2008.
- [10] G. Kanschat. Divergence-free discontinuous Galerkin schemes for the Stokes equations and the MAC scheme. *Int. J. Numer. Methods Fluids*, 56(7):941–950, 2008.
- [11] R. H. W. Hoppe, G. Kanschat, and T. Warburton. Convergence analysis of an adaptive interior penalty discontinuous Galerkin method. *SIAM J. Numer. Anal.*, 47(1):534–550, 2008.
- [12] B. Cockburn, G. Kanschat, and D. Schötzau. A note on discontinuous Galerkin divergence-free solutions of the Navier-Stokes equations. *J. Sci. Comput.*, 31(1–2):61–73, 2007.
- [13] W. Bangerth, R. Hartmann, and G. Kanschat. deal.II — a general purpose object oriented finite element library. *ACM Trans. Math. Softw.*, 33(4), 2007.
- [14] G. Kanschat. Block preconditioners for LDG discretizations of linear incompressible flow problems. *J. Sci. Comput.*, 22(1):381–394, 2005.
- [15] B. Cockburn, G. Kanschat, and D. Schötzau. A locally conservative LDG method for the incompressible Navier-Stokes equations. *Math. Comput.*, 74:1067–1095, 2005.
- [16] B. Cockburn, G. Kanschat, and D. Schötzau. The local discontinuous Galerkin method for linear incompressible fluid flow: A review. *Comput. & Fluids*, 34(4–5):491–506, 2005.

- [17] G. Kanschat. Multi-level methods for discontinuous Galerkin FEM on locally refined meshes. *Comput. & Struct.*, 82(28):2437–2445, 2004.
- [18] G. Kanschat. Preconditioning methods for local discontinuous Galerkin discretizations. *SIAM J. Sci. Comput.*, 25(3):815–831, 2003.
- [19] J. Gopalakrishnan and G. Kanschat. A multilevel discontinuous Galerkin method. *Numer. Math.*, 95(3):527–550, 2003.
- [20] B. Cockburn, G. Kanschat, and D. Schötzau. The local discontinuous Galerkin method for the Oseen equations. *Math. Comput.*, 73(246):569–593, 2003.
- [21] G. Kanschat and R. Rannacher. Local error analysis of the interior penalty discontinuous Galerkin method for second order elliptic problems. *J. Numer. Math.*, 10(4):249–274, 2002.
- [22] B. Cockburn, G. Kanschat, D. Schötzau, and C. Schwab. Local discontinuous Galerkin methods for the Stokes system. *SIAM J. Numer. Anal.*, 40(1):319–343, 2002.
- [23] S. Richling, E. Meinköhn, N. Kryzhevoi, and G. Kanschat. Radiative transfer with finite elements I. basic method and tests. *A&A*, 380:776–788, 2001.
- [24] B. Cockburn, G. Kanschat, I. Perugia, and D. Schötzau. Superconvergence of the local discontinuous Galerkin method for elliptic problems on cartesian grids. *SIAM J. Numer. Anal.*, 39(1):264–285, 2001.
- [25] G. Kanschat and F.-T. Suttmeier. A posteriori error estimates for nonconforming finite element schemes. *Calcolo*, 36(3):129–141, 1999.
- [26] G. Kanschat. A robust finite element discretization for radiative transfer problems with scattering. *East-West J. Numer. Math.*, 6(4):265–272, 1998.
- [27] C. Führer and G. Kanschat. A posteriori error control in radiative transfer. *Computing*, 58(4):317–334, 1997.

## 4.2 Articles submitted to refereed journals

- [28] S. Zedler, R. Korty, I. Hoteit, and G. Kanschat. The sensitivity of the simulated upper ocean response to a hurricane to very high grid resolution. 2011. submitted.
- [29] J. Ragusa, J.-L. Guermond, and G. Kanschat. A robust Sn-DG-approximation for radiation transport in optically thick and diffusive regimes. *J. Comput. Phys.*, 2011. revision submitted.
- [30] Allmaras M., D. P. Darrow, Hristova Y., Kanschat G., and Kuchment P. Detecting small low emission radiating sources. 2011. submitted.

### 4.3 Articles in refereed conference proceedings

- [31] J. Gopalakrishnan and G. Kanschat. Multi-level preconditioners for the interior penalty method. In F. Brezzi, A. Buffa, S. Corsaro, and A. Murli, editors, *Numerical Mathematics and Advanced Applications: ENUMATH 2001*, pages 795–804, Milano, 2003. Springer Italia.
- [32] B. Cockburn, G. Kanschat, and D. Schötzau. LDG methods for Stokes flow problems. In F. Brezzi, A. Buffa, S. Corsaro, and A. Murli, editors, *Numerical Mathematics and Advanced Applications: ENUMATH 2001*, pages 755–764, Milano, 2003. Springer Italia.
- [33] R. Wehrse, E. Meinköhn, and G. Kanschat. A review of Heidelberg radiative transfer equation solutions. In P. Stee, editor, *Radiative Transfer and Hydrodynamics in Astrophysics*, pages 13–30. EDP Sciences, 2002.
- [34] G. Kanschat and F.-T. Suttmeier. A posteriori error estimates in the case of insufficient regularity of the discrete space. In B. Cockburn, G. E. Karniadakis, and C.-W. Shu, editors, *Discontinuous Galerkin Methods*, volume 11, pages 349–354. Springer, 2000.
- [35] G. Kanschat. Solution of multi-dimensional radiative transfer problems on parallel computers. In P. Bjørstad and M. Luskin, editors, *Parallel Solution of Partial Differential Equations*, volume 120 of *IMA Volumes in Mathematics and its Applications*, pages 85–96, New York, 2000. Springer.
- [36] R. Wehrse and G. Kanschat. Radiative fluxes and forces in non-spherical winds. In B. Wolf, O. Stahl, and A. W. Fullerton, editors, *Variable and Non-spherical Stellar Winds in Luminous Hot Stars*, pages 144–150. Springer, 1999.

### 4.4 Articles in conference proceedings (not refereed)

- [37] G. Kanschat. Preconditioning discontinuous Galerkin saddle point systems. In K. J. Bathe, editor, *Computational Fluid and Solid Mechanics 2003*, pages 2016–2018. Elsevier, 2003.
- [38] J. Gopalakrishnan and G. Kanschat. Application of unified DG analysis to preconditioning DG methods. In K. J. Bathe, editor, *Computational Fluid and Solid Mechanics 2003*, pages 1943–1945. Elsevier, 2003.
- [39] B. Cockburn, G. Kanschat, and D. Schötzau. The local discontinuous Galerkin method in incompressible fluid flow. In H. A. Mang, F. G. Rammerstorfer, and J. Eberhardsteiner, editors, *Proceedings of the Fifth World Congress on Computational Mechanics (WCCM V)*. Vienna University of Technology, 2002.
- [40] G. Kanschat. Parallel computation of multi-dimensional neutron and photon transport in inhomogeneous media. In H.-J. Bungartz, F. Durst, and C. Zenger, editors, *High Performance Scientific and Engineering Computing*, volume 8, pages 431–440. Springer, 1999.
- [41] G. Kanschat. New algorithms for radiative transfer in accretion disks and surroundings. In D. T. Wickramasinghe, G. V. Bicknell, and L. Ferrario, editors, *Accretion Phenomena and Related Outflows; IAU Colloquium 163*, pages 736–737, San Francisco, California, 1997. Astronomical Society of the Pacific.
- [42] G. Kanschat. Efficient and reliable solution of multi-dimensional radiative transfer problems. In F. Karsch, B. Monien, and H. Satz, editors, *Multiscale Phenomena and Their Simulation*, pages 245–249, Singapore, 1997. World Scientific.
- [43] G. Kanschat. Parallel adaptive algorithms for radiative transfer problems. In P. Fritzon and L. Finmo, editors, *Parallel Programming and Applications*, volume 45 of *Transputer and OCCAM Engineering Series*, pages 238–243, Amsterdam, 1995. IOS Press.

#### 4.5 Contributions in collections

- [44] G. Kanschat, E. Meinköhn, R. Rannacher, and R. Wehrse. The radiation field and its transfer equation. In G. Kanschat, E. Meinköhn, R. Rannacher, and R. Wehrse, editors, *Numerical Methods for Multi-Dimensional Radiative Transfer*, pages 1–18. Springer, 2008.
- [45] G. Kanschat. Solution of radiative transfer problems with finite elements. In G. Kanschat, E. Meinköhn, R. Rannacher, and R. Wehrse, editors, *Numerical Methods for Multi-Dimensional Radiative Transfer*, pages 49–98. Springer, 2008.
- [46] E. Meinköhn, G. Kanschat, R. Rannacher, and R. Wehrse. Numerical methods for multidimensional radiative transfer. In J. Jäger, R. Rannacher, and J. Warnatz, editors, *Reactive Flows, Diffusion and Transport*, pages 485–526. Springer, Berlin, 2006.

#### 4.6 Books (authored and edited)

- [47] G. Kanschat, E. Meinköhn, R. Rannacher, and R. Wehrse, editors. *Numerical Methods for Multi-Dimensional Radiative Transfer*. Springer, 2008.
- [48] G. Kanschat. *Discontinuous Galerkin Methods for Viscous Flow*. Deutscher Universitätsverlag, Wiesbaden, 2007.
- [49] H. G. Bock, F. Brezzi, R. Glowinsky, G. Kanschat, Y. A. Kuznetsov, J. Périaux, and R. Rannacher, editors. *ENU-MATH 97, Proceedings of the 2nd European Conference on Numerical Mathematics and Advanced Applications*, Singapore, 1998. World Scientific.

#### 4.7 Software and software manuals

- [50] W. Bangerth, R. Hartmann, and G. Kanschat. `deal.II Differential Equations Analysis Library, Technical Reference`, 6.3 edition, 2010. first edition 1999.
- [51] W. Bangerth and G. Kanschat. Concepts for object-oriented finite element software – the `deal.II` library. Preprint 1999-43, SFB 359, Heidelberg, 1999.
- [52] W. Bangerth, R. Hartmann, and G. Kanschat. `deal.II`. <http://www.dealii.org/>, 1998.

#### 4.8 Miscellaneous

- [53] G. Kanschat and E. Meinköhn. Multi-model preconditioning for radiative transfer problems. Preprint 2004-33, SFB 359, Heidelberg, 2004.
- [54] G. Kanschat. *Discontinuous Galerkin Finite Element Methods for Advection-Diffusion Problems*. Habilitationsschrift, Universität Heidelberg, 2003.
- [55] G. Kanschat. *Parallel and Adaptive Galerkin Methods for Radiative Transfer Problems*. Dissertation, Universität Heidelberg, 1996. Preprint SFB 359, 1996-29.

#### 4.9 Journal articles in preparation

- [56] G. Kanschat, J. Ragusa, and J.-L. Guermond. A robust multilevel discontinuous Galerkin method for the radiative transport equation in diffusive regimes. 2011. in preparation.
- [57] G. Kanschat and Y. Mao. On the numerical stability of the Arnold-Falk-Winther smoother. 2011. in preparation.
- [58] V. Girault, G. Kanschat, and B. Rivière. Error analysis for a monolithic, conservative discretization of coupled darcy and stokes problems. 2011. in preparation.

## 5 Conferences and Minisymposia (Organization)

- BIRS Workshop on Nonstandard Finite Element Methods in Computational Fluid Dynamics, with V. Girault (Paris VI), P. Mineev (U. Alberta) and J.-L. Guermond, 2010
- CBMS Regional Conference in the Mathematical Sciences — Adaptive Finite Element Methods for Partial Differential Equations, College Station, June 2009
- ISC Workshop on Radiation simulation, College Station, with S. Nasiri, J. Ragusa, 2008
- International Conference on Modeling, Simulation and Optimization of Complex Processes in honor of the 60th birthdays of H. G. Bock and R. Rannacher, Heidelberg, with M. Braack, E. Kostina, J. Schloeder, 2008
- Minisymposium on fast solvers for saddle-point problems with applications in fluid dynamics at ICIAM 07 with M. Olshanskii, 2007
- Minisymposium on high-level software for the numerical solution of partial differential equations at ICIAM 07 with W. Bangerth, R. Kirby, 2007
- First international deal.II user workshop, 2006
- RadConf, interdisciplinary workshop on numerical methods for radiative transfer problems with R. Rannacher, R. Wehrse and E. Meinköhn, 2003
- Minisymposium on discontinuous Galerkin methods at “ENUMATH 01” with E. Süli, 2001
- International conference “ENUMATH 97” with H. G. Bock, R. Rannacher, 1997
- Workshop “Adaptive Finite Element Methods” with Ch. Führer, R. Rannacher, 1995
- Workshop “Natur-Wissenschaft”, modeling in environmental physics with R. Eils, J. Jäger, 1994

## 6 Student Advising

### 6.1 Advisor

- Y. Mao, PhD, current
- A. Sharp, MS, 2011
- B. Janssen, *Diplom, Univ. Heidelberg*, 2007
- Ch. Laux, *Diplom, Univ. Heidelberg*, 2006

### 6.2 Thesis co-advisor/mentor (Univ. Heidelberg)

- B. Janssen, PhD, Univ. Heidelberg, current
- H. Hesse, PhD, Univ. Heidelberg, 2008
- 4 *Diplom* (master): W. Bangerth (1999), R. Hartmann (1999), B. Lienerth (2004), A. Wild (2001)
- 2 *Staatsexamen* (bachelor): A. Kürbs (1998), I. Krause (2003)

### 6.3 External Referee

- R. Oyarzúa, Universidad de Concepción, Chile, 2010
- Lars Pesch, PhD, University of Twente, The Netherlands, 2007
- J. J. Sudirham, PhD, University of Twente, The Netherlands, 2005

### 6.4 Committees at A&M

- |                                 |                               |                               |
|---------------------------------|-------------------------------|-------------------------------|
| • Henan Wang, MS in MATH        | • Kainan Wang, PhD in MATH    | • Chang Gyu Kim, MS in INEN   |
| • Alex Chambers, MS in NUEN     | • Javier Polanco, PhD in MATH | • Yaqi Wang, PHD in NUEN      |
| • Chao Liu, MS in ATMO          | • Fang Wang, PhD in MATH      | • Ni Zhen, MS in NUEN         |
| • Pradeep Rao, PhD in MEEN      | • Seul Ki Kang, PhD in MATH   | • James Newlin, MEN in CVEN   |
| • Yuan Qu, PhD in STAT          | • Jaehun Lee, MS in PETE      | • Jarrod Edwards, PHD in NUEN |
| • Jennifer Webster, PhD in MATH | • K. Kappagantula, MS in MEEN |                               |

## 7 Invited Presentations and Research Visits

2012

- Theory and Application of Discontinuous Galerkin Methods, Oberwolfach (Feb)

2011

- Waves 2011, Simon Fraser U. (4.5 hour tutorial, Jul)
- Applied Mathematics Perspectives 2011, U. British Columbia (Jul)
- Workshop on Advances in Numerical Analysis and Scientific Computing, U of Houston

2011

- Waves 2011 Conference, Vancouver, BC (4.5 hr invited tutorial)
- Numerical Methods for Incompressible Fluid Flow, Vancouver, BC (invited lecture)

2010

- Institute for Mathematics and its Applications, Minneapolis (1 semester)
- deal.II tutorial at the IMA, Minneapolis
- deal.II User Workshop 2010, Heidelberg, Germany
- Universität Heidelberg (1 week), Germany
- SIAM Annual Conference 2010, Pittsburgh (minisymposium)
- DSPDEs 2010, Barcelona (minisymposium)
- King Abdullah University of Science and Technology (2 weeks), Thuwal, Saudi Arabia

2009

- Brown University, Providence
- Universität Kiel (1 week), Germany
- Universität Heidelberg (1 week), Germany
- ENUMATH 2009, Uppsala (minisymposium)
- MAFELAP 2009, London (2 minisymposia)
- University of British Columbia, Vancouver
- Simon Fraser University, Vancouver

2008

- Rensselaer Polytechnic Institute, Troy
- Universität Heidelberg (1 week), Germany
- Fraunhofer Institut Kaiserslautern, Germany
- RWTH Aachen, Germany
- Sandia National Lab, Albuquerque
- Virginia Tech, Blacksburg

2007

- BIRS Workshop on DG, Banff
- University of Alberta, Edmonton
- ICIAM07, Zürich, Switzerland (2 minisymposia)
- 3rd Scientific Computing Seminar, Kiel
- Universität Göttingen
- Universität Karlsruhe
- Universität Heidelberg
- Int. Conf. of Theor. and Numer. Fluid Mechanics III, Vancouver
- University of Texas, Austin
- Rice University, Houston

2006

- Max-Planck-Institut Leipzig
- Texas A&M University, College Station

2005

- McGill University, Montreal
- Universität Erlangen
- Universität Siegen
- University of Delaware
- Nanyang Technical University, Singapore
- University of British Columbia, Vancouver
- University of South Carolina (1 month)
- SIAM SEAS Meeting, Charleston (Minisymposium)
- University of Minnesota
- Technische Universität Braunschweig
- Universiteit Twente, Enschede
- Texas A&M University (2 weeks), College Station
- University of Houston
- The University of Reading
- Universität Kiel
- Universität Duisburg

2004

- University of Florida, Gainesville
- Universität Siegen
- Universität Göttingen
- ETH Zürich
- Universität Ulm
- ICOSAHOM04, Providence (Minisymposium)

2003

- Army High Performance Computing Research Center, Minneapolis
- ENUMATH03, Prague (Minisymposium)
- MIT Conference (Minisymposium)

2002

- Technische Universität Dresden
- Mathematisches Forschungsinstitut Oberwolfach
- Università di Pavia
- University of Minnesota

2001

- Chalmers Tekniska Högskola, Göteborg
- University of Minnesota, Minneapolis
- Rensselaer Polytechnic Institute, Troy
- ENUMATH01, Ischia Porto (Minisymposium)
- NUMDIFF 10, Halle(Minisymposium)

2000

- Colorado State University, Fort Collins

1998

- Institut Mittag-Leffler (2 weeks), Stockholm

1997

- Institute of Mathematics and its Application, Minneapolis (1 month)
- National Center for Supercomputer Applications (2 weeks), Urbana-Champaign
- Centre de Recherche en Calcul Appliqué, Montreal
- ETH Zürich

1996

- Universität des Saarlandes, Saarbrücken
- Universität Paderborn
- Australian National University (1 week), Canberra
- University of Sydney
- Zentrum für Interdisziplinäre Forschung, Universität Bielefeld
- Univerzita Karlova, Praha

1994

- Technische Universität Braunschweig
- Universität Paderborn

## 8 Collaborators

- B. Ayuso, Universidad Autónoma de Barcelona, Spain
- W. Bangerth, Texas A&M University, USA
- J. Bevan, Texas A&M University, USA
- A. Bonito, Texas A&M University, USA
- B. Cockburn, University of Minnesota, USA
- V. Girault, Université Paris VI, France
- J. Gopalakrishnan, University of Florida, USA
- R. Hartmann, DLR, Braunschweig, Germany
- H. K. Hesse, Universität Heidelberg, Germany
- R. H. W. Hoppe, University of Houston, USA
- I. Hoteit, King Abdullah University of Science and Technology, Saudi Arabia
- B. Janssen, Universität Heidelberg, Germany
- R. Korty, Texas A&M University, USA
- R. Lucchese, Texas A&M University, USA
- B. McElmurry, Texas A&M University, USA
- E. Meinköhn, Universität Heidelberg, Germany
- P. Monk, University of Delaware
- I. Perugia, Università di Pavia, Italy
- R. Rannacher, Universität Heidelberg, Germany
- L. Rivera-Rivera, University of Missouri, USA
- S. Richling, Institut d' Astrophysique de Paris, France
- D. Schötzau, University of British Columbia, Vancouver, Canada
- Ch. Schwab, ETH Zürich, Switzerland
- F.-T. Suttmeier, Universität Siegen, Germany
- Z. Wang, Texas A&M University, USA
- T. Warburton, Rice University, Houston, USA
- R. Wehrse, Universität Heidelberg, Germany
- S. Zedler, Texas A&M University, USA

## 9 Research

With my research, I strive to improve the ability of applied sciences to simulate complex phenomena involving partial differential equations (PDE). In order to achieve this goal, my research focuses on discretization schemes and numerical solution methods, but involves mathematical modeling as well. In order to disseminate knowledge about efficient numerical schemes, I am actively developing scientific software. Furthermore, I am involved in interdisciplinary projects and provide consulting to researchers from different areas.

### 9.1 Software Development

The application and evaluation of new numerical methods requires efficient and flexible software tools. These should combine ease of operation with full control over every aspect of the solution process and runtime efficiency. Since no commercial software reaches these goals, I founded the DEAL project in 1992 with F.-T. Suttmeier (U. Siegen, Germany), developing object oriented concepts and first implementations, which are still used as base of software packages like Gascoigne and the Heidelberg Radiative Transfer Code. In 1998, these preparations led to the object oriented software library `deal.II` [13, 50–52] with W. Bangerth, Texas A&M, and R. Hartmann, DLR (German Aerospace Foundation)). It is publicly available ([www.dealii.org](http://www.dealii.org); several hundred downloads worldwide per month for the current version). It is probably the only freely available software tool combining adaptive meshes in two and three dimensions with multilevel support, *hp*-adaptivity, and vector elements. It was awarded the *J. H. Wilkinson Prize for Numerical Software* in 2007.

Currently, the `deal.II` project is actively being transformed by expanding the pool of regular developers beyond the original three. This enabled us to add message passing parallelization (with T. Heister, U. Göttingen), an application framework (with B. Janssen, U. Heidelberg and M. Secanell, U. of Alberta), high order adaptive multigrid ([3] with B. Janssen, U. Heidelberg) and higher order Nedelec elements (with M. Bürg, U. Karlsruhe) within very short time. Active development involves high level algorithms for parameter estimation and optimization and extension to spline elements in order to couple with CAD software.

### 9.2 Ocean models and data assimilation

The development of numerical methods for ocean models recently has become a main focus of my research. The complexity of the phenomena combined with the fact that despite all efforts, data is still sparse, requires the choice of numerical schemes which are very well adapted to the problem at hand together with effective statistical methods to assess model parameters.

With my postdoc S. Zedler (Institute for Applied Mathematics and Computational Science, Texas A&M) and I. Hoteit (King Abdullah U. of Science and Technology), I am studying methods for the determination of phenomenological friction coefficients between atmosphere and ocean surface under hurricanes. This problem is characterized by very sparse and unreliable data. Therefore, the use of statistical inversion methods becomes inevitable [1]. The methods developed here are currently being extended to the study of sedimentation processes in the deep ocean and their use to determine prehistoric deep sea current patterns (research proposal in preparation with D. Thomas, Department of Oceanography at Texas A&M).

Ensemble filtering methods (Kalman filters) have become common statistical methods for the solution of this kind of problems. In order to improve these, M. Jun, M. Genton (Department of Statistics, Texas A&M), and me have devised a PhD project to study the use of adjoint techniques known from finite element methods to eliminate spurious correlations of data points.

### 9.3 Radiative transfer and neutron transport

Since my PhD thesis on parallel and adaptive finite element methods for radiative transfer problems, I have been working in close cooperation with colleagues in astrophysics and nuclear engineering. Neutron transport and radiative transfer problems are particularly demanding with respect to computer resources, since the computational domain is five-dimensional for the simplest model. Therefore, medium scale parallelization, adaptive mesh generation based on

optimal a posteriori error estimates and the application of efficient solution methods have to be implemented to obtain reasonably accurate simulation results at all [26, 27, 45, 55]. Recently, the experience gained in DGFEM has been applied to this project [5, 29]. Here, its features are used to achieve model adaptivity in the method, depending on the highly varying coefficients. Research is conducted with several colleagues in the Department of Nuclear Engineering at Texas A&M, funded by the Department of Homeland Security. I am planning on future research in nuclear reactor physics as well as in atmospheric radiative transfer, where new solution methods are needed to make accurate radiation computations feasible for weather and climate modeling.

#### 9.4 Mimetic Finite Element Discretizations

In many cases, physical problems have certain invariants, for instance manifested in mass or energy conservation. Instead of approximating these invariants “accidentally” while approximating the solution, mimetic finite element methods strive to produce solutions obeying these invariants exactly, or at least approximating them with higher accuracy. These methods are not only more acceptable in applied disciplines, they also can produce much better solutions in preasymptotic regimes.

I have been developing strongly divergence free discretizations for incompressible flow problems, mostly in collaboration with B. Cockburn (U. of Minnesota) and D. Schötzau (U. of British Columbia). These schemes use special, divergence-conforming elements and are based on earlier work on discontinuous Galerkin methods (DGFEM), in particular the LDG method. I am author of several publications on the a priori and a posteriori error analysis of these schemes [7, 8, 10, 12, 15]. Currently, I am working on the application to coupled free and porous media flow ([4, 58] with B. Rivière, Rice U. and V. Girault, Texas A&M); the discretization we obtain guarantees exact mass conservation, independent of material parameters, which had not been possible before. The same concepts are being applied to the applications in subsections 9.2 and 9.3 above.

I have been working intensely on DGFEM [20–22, 24], most recently with R. Hoppe (U. of Houston) and T. Warburton (Rice U.) on convergent adaptive methods [11]; currently, we are collaborating on a recently awarded NSF-grant to develop tuning-free DGFEM methods for Maxwell equations. In conjunction with a project with J.-L. Guermond and R. Lazarov (Texas A&M), these results are currently being extended to singularly perturbed problems.

#### 9.5 Linear Solvers

These discretizations are only as valuable as it is possible to solve the linear systems arising from them in reasonable time. In particular, efficient preconditioning techniques are required within quasi-Newton iterations in order to solve the nonlinear problems mentioned above efficiently.

Therefore, I have been developing efficient solvers for the discrete problems arising in the discretizations mentioned above. This includes the first multilevel preconditioners for a major group of DGFEM discretizations [9, 19, 31] (with J. Gopalakrishnan, U. of Florida) and their efficient application to the saddle point problems arising in incompressible flow [14, 17, 18]. These preconditioners perform excellently for higher order methods, on locally refined meshes and in advection-dominated regimes. In the analysis of these preconditioners I am currently focusing on the latter aspects. A recent project which funded by NSF-DMS involves multilevel methods for DG discretizations of Maxwell problems (with R. Hoppe, U. of Houston and T. Warburton, Rice U.) with a focus on local smoothing during adaptive mesh refinement cycles [57].

Solving radiative transfer problems in the diffusive regime has been a particular challenge for a long time [45, 53, 55]. Recently, we have developed a new multilevel scheme [56], which is much simpler and faster than commonly used methods.

## 10 Teaching record

Fall 11	Seminar in Applied Mathematics (MATH 664, “iterative solvers and preconditioning”, Texas A&M)
Spring 11	Engineering Calculus II (MATH 152) and Numerical Analysis (MATH 417, Texas A&M)
Spring 10	Differential Equations (MATH 308, Texas A&M)
Fall 09	Numerical Analysis (MATH 609, Texas A&M)
Fall 09	Differential Equations (MATH 308, Texas A&M)
Fall 08	Differential Equations, 2 sections (MATH 308, Texas A&M)
Spring 08	Linear Algebra and Vector Calculus (MATH 601, Texas A&M)
Fall 07	Differential Equations (MATH 308, Texas A&M)
Spring 07	Partial Differential Equations (MATH 602, Texas A&M)
Fall 06	Numerical Analysis (MATH 417, Texas A&M)
Winter 05/06	Finite elements with applications (course for PhD students in science) (U. Heidelberg)
Summer 05	Numerical Methods for Flow Problems (U. Heidelberg)
Winter 04/05	Numerical Analysis II (Partial Differential Equations) (U. Heidelberg)
Summer 04	C++ programming for numerical applications (U. Heidelberg)
Winter 03/04	C++ programming for numerical applications (U. Heidelberg)
Summer 03	C++ programming for numerical applications (U. Heidelberg)
Winter 02/03	C++ programming for numerical applications (U. Heidelberg)
Summer 02	C++ programming for numerical applications (U. Heidelberg)
Winter 01/02	C++ programming for numerical applications (U. Heidelberg)
Summer 2001	C++ programming for numerical applications (U. Heidelberg)
Winter 00/01	Iterative Solvers for Sparse Linear Systems (U. Heidelberg)
Spring 2000	Numerical Methods for Partial Differential Equations II (University of Minnesota)
Fall 1999	Numerical Methods for Partial Differential Equations I (University of Minnesota)
Summer 1999	Practical Introduction to object-oriented finite element software (U. Heidelberg)
Summer 1998	The Finite Element Method (advanced course) (U. Heidelberg)
Summer 1998	Practical Introduction to object-oriented finite element software (U. Heidelberg)

## 11 Service

### 11.1 Professional Service

- Founding editor of “Archive for Numerical Software”

### 11.2 University

- Member of the Council on the Built Environment, 2011-
- Member of the Faculty Senate 2011-
- Member of the Council on Climate and Diversity, 2011-
- President GLBT Professional Network, 2011-
- Member of the Diversity Awards Committee, 2010
- Member of the search committee for the faculty ombudsperson, 2010
- Liaison of the Institute for Applied Mathematics and Computational Science at Texas A&M University to the Scientific Computing and Imaging Institute at the University of Utah, 2009–
- Texas A&M System Task Force on Export Control Policies, committee on employees and visitors, 2009
- Member executive committee of the faculty senate
- Member of the search committee for the Vice President and Associate Provost for Diversity, 2009
- Caucus leader of the College of Science in the faculty senate, 2008–2010
- Treasurer GLBT professional network, 2008–2010
- Member of the Faculty Senate and its committees on research and diversity, 2007–2010
- Aggie Allies member, since 2007

- Member of the IWR Parallel Computer Committee, U. Heidelberg, 2005–2006
- Member of the Selection Committee, Graduate School for Scientific Computing of the IWR, Heidelberg, 2005
- Head of the Applied Mathematics Student Computer Pool, U. Heidelberg, 2000–2006
- Head of System Administration, AG Numerik, Heidelberg, U. Heidelberg, 1999–2006.

## 12 Teaching Statement

One of my main goals in teaching is making students understand not only the techniques and facts of the topic at hand, but also its relations to topics already known. It is important to find a balance between concrete study of the current topic and mathematical abstraction, depending on the level of the course and the type of audience.

I tend to devote a considerable part of the course to pose the material in form of questions to be answered by the students. This way, students gain confidence in their acquired abilities and are encouraged to explore. Furthermore, they learn discussing about mathematical topics.

In the beginning of a course, I ask my students to form study groups of three to four members for preparation of their homework. This process is formalized by requiring every student to register with one group. My experience over the last years is that at least some of these groups continue discussing their work during the semester, which becomes visible through increased classroom participation and improving grades. Usually, stronger as well as weaker students profit from this system, the latter by explanations gotten from their peers, the former by a much deeper engagement in the material. Naturally, I point out the difference between joint preparation of homework and simple copying.

I have given courses on various topics in numerical analysis, where I make sure to link the presentation of the theoretical results to their practical implications. These courses are complemented by practical sessions, allowing students to see how the concepts taught actually work.

Additionally, I taught several mathematics classes populated predominantly by engineering students; here, the balance between mathematical theory on the one hand and application on the other is very important. While conveying some of the mathematical background, the use and judgement of the methods presented should be considered more important.

Between 2001 and 2004, I have developed and taught a course on C++ programming for numerical applications, which did not exist at the University of Heidelberg before. This course consists of practical sessions with tutorials interspersed. Its focus is on gaining programming experience and developing a good style and it is organised such that programming techniques are acquired as they are needed to complete a given project (e.g. a solver for a discretised PDE) at the end of the semester.

In 2011, I initiated discussions leading to the reorganization of undergraduate education in numerical analysis at Texas A&M University. I submitted a revised course description and syllabus for MATH 417 as a service class (now “Numerical Methods”) and a new course in numerical analysis for MATH and APMS majors (MATH 437 “Numerical Analysis I”). The latter is intended to be complemented by MATH 438 “Numerical Analysis II” after teaching the subject as a MATH 489.

## 13 Service Statement

I strongly believe that faculty participation in administration is very important for the efficient and effective operation of a university. While I do not expect to be able to compete with professional administrators when it comes to actually running a big institution, I see the value of my input in my experience with the actual teaching and research operation. Therefore, I consider it as my obligation as member of the faculty to assist where my advice is asked for. For instance, I served on two panels for the Dean of Faculties.

In order to have qualified opinions, I consider it necessary to be informed about proceedings at the university and acquire knowledge about the structure and decision making processes. I joined the Faculty Senate in 2007 in order to obtain this insight and be a contributing part of the campus community. I am also an active member of two faculty networks and officer of one of them.