

Guido Kanschat

Professor (W3)

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IWR

Universität Heidelberg

Im Neuenheimer Feld 368

D-69120 Heidelberg

1 Education

2004 *Habilitation* and *venia legendi*, Mathematics, University of Heidelberg, Germany

1996 *Doctor rer. nat.* (PhD in Science), advisor Rolf Rannacher, University of Heidelberg, Germany

1992 *Diplom*, Mathematics, advisor Jens Frehse, University of Bonn, Germany

2 Appointments

2012– Professor, Universität Heidelberg

2012–2013 Professor, Texas A&M University (on leave)

2009–2012 Associate Professor, Texas A&M University

2006–2009 Assistant Professor, Texas A&M University

2005–2006 Research Associate (*Wiss. Ang.*), Universität Heidelberg

2000–2005 Assistant Professor (*Wiss. Assistent*), Universität Heidelberg

1999–2000 Visiting Assistant Professor, University of Minnesota

1999 Assistant Professor, Universität Heidelberg, Germany

1995–1999 Research Associate, IWR, Universität Heidelberg, Germany

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

3 Awards

2011 The Richard Stadelmann Faculty Senate Service Award

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

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

4 Grants

- 2016–2019 PLACE — Partizipation langfristig absichern, Chancen erweitern. Joint project of Heidelberg University and PH Heidelberg. Minister of Science and Art, Baden-Württemberg, proposal co-author.
- 2016–2018 exa-DG. Project within SPPExa program of DFG, with W. Wall, K. Kormann, M. Kronbichler (TUM).
- 2015–2019 heiEducation. Joint project of Heidelberg University and PH Heidelberg within “Qualitätsoffensive Lehrerbildung”, Federal Minister of Education and Research (BMBF), proposal co-author.
- 2014 International guest professorship for Béatrice Rivière, from excellence initiative funds at Heidelberg University.
- 2010 One semester research grant at the Institute of Mathematics and its Applications, Minneapolis.
- 2010 BIRS Conference on Nonstandard Finite Element Methods in Computational Fluid Dynamics, with V. Girault (Paris VI), P. Mineev (U. Alberta) and J.-L. Guermond.
- 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)
- 2007–2011 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, 2000–2003
- 1999 DFG *Habilitationsstipendium* (postdoctoral scholarship), 5 months
- 1992–1995 DFG Graduate Scholarship

5 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 Augsburg, Germany
- I. Hoteit, King Abdullah University of Science and Technology, Saudi Arabia
- B. Janssen, KTH, Sweden
- R. Korty, Texas A&M University, USA
- R. Lazarov, Texas A&M University, USA
- R. Lucchese, Texas A&M University, USA
- Anna Marciniak-Czochra, Universität Heidelberg, Germany
- 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

6 Publications

6.1 Articles in refereed journals

- [1] G. Kanschat and Y. Mao. Multigrid methods for \mathbf{H}^{div} -conforming discontinuous Galerkin methods for the Stokes equations. *J. Numer. Math.*, 23(1):51–66, 2015.
- [2] G. Kanschat and N. Sharma. Divergence-conforming discontinuous Galerkin methods and C^0 interior penalty methods. *SIAM J. Numer. Anal.*, 52(4):1822–1842, 2014.
- [3] G. Kanschat and J. Ragusa. A robust multigrid preconditioner for S_N DG approximation of monochromatic, isotropic radiation transport problems. *SIAM J. Sci. Comput.*, 36(5):2326–2345, 2014.
- [4] V. Girault, G. Kanschat, and B. Rivière. Error analysis for a monolithic discretization of coupled Darcy and Stokes problems. *J. Numer. Math.*, 22(2):109–142, 2014.
- [5] S. Zedler, G. Kanschat, I. Hoteit, and R. Korty. Estimation of the drag coefficient from the upper ocean response to a hurricane: a variational data assimilation approach. *Ocean Modelling*, 68:51–71, 2013.
- [6] J. E. Morel, J. C. Ragusa, M. L. Adams, and G. Kanschat. Asymptotic P_N -equivalent S_{N+1} equations. *Transport Theory Stat. Phys.*, 42(1):3–20, 2013.
- [7] M. Allmaras, D. Darrow, Y. Hristova, G. Kanschat, and P. Kuchment. Detecting small low emission radiating sources. *Inverse Problems and Imaging*, 7(1):47–79, 2013.
- [8] S. E. Zedler, G. Kanschat, R. Korty, and I. Hoteit. A new approach for the determination of the drag coefficient from the upper ocean response to a tropical cyclone: a feasibility study. *J. Oceanography*, 68(2):227–241, 2012.
- [9] J. Ragusa, J.-L. Guermond, and G. Kanschat. A robust S_n -DG-approximation for radiation transport in optically thick and diffusive regimes. *J. Comput. Phys.*, 231(4):1947–1962, 2012.
- [10] 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.*, 390(1):42–50, 2011.
- [11] B. Janssen and G. Kanschat. Adaptive multilevel methods with local smoothing for H^1 - and H^{curl} -conforming high order finite element methods. *SIAM J. Sci. Comput.*, 33(4):2095–2114, 2011.
- [12] 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.
- [13] 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.
- [14] 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.
- [15] 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.
- [16] 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.

- [17] G. Kanschat. Robust smoothers for high order discontinuous Galerkin discretizations of advection-diffusion problems. *J. Comput. Appl. Math.*, 218:53–60, 2008.
- [18] 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.
- [19] 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.
- [20] 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.
- [21] W. Bangerth, R. Hartmann, and G. Kanschat. deal.II — a general purpose object oriented finite element library. *ACM Trans. Math. Softw.*, 33(4), 2007.
- [22] G. Kanschat. Block preconditioners for LDG discretizations of linear incompressible flow problems. *J. Sci. Comput.*, 22(1):381–394, 2005.
- [23] B. Cockburn, G. Kanschat, and D. Schötzau. A locally conservative LDG method for the incompressible Navier-Stokes equations. *Math. Comput.*, 74:1067–1095, 2005.
- [24] 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.
- [25] G. Kanschat. Multi-level methods for discontinuous Galerkin FEM on locally refined meshes. *Comput. & Struct.*, 82(28):2437–2445, 2004.
- [26] G. Kanschat. Preconditioning methods for local discontinuous Galerkin discretizations. *SIAM J. Sci. Comput.*, 25(3):815–831, 2003.
- [27] J. Gopalakrishnan and G. Kanschat. A multilevel discontinuous Galerkin method. *Numer. Math.*, 95(3):527–550, 2003.
- [28] B. Cockburn, G. Kanschat, and D. Schötzau. The local discontinuous Galerkin method for the Oseen equations. *Math. Comput.*, 73(246):569–593, 2003.
- [29] 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.
- [30] 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.
- [31] 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.
- [32] 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.
- [33] G. Kanschat and F.-T. Suttmeier. A posteriori error estimates for nonconforming finite element schemes. *Calcolo*, 36(3):129–141, 1999.
- [34] G. Kanschat. A robust finite element discretization for radiative transfer problems with scattering. *East-West J. Numer. Math.*, 6(4):265–272, 1998.
- [35] C. Führer and G. Kanschat. A posteriori error control in radiative transfer. *Computing*, 58(4):317–334, 1997.

6.2 Articles submitted to refereed journals

- [36] G. Kanschat and J. P. Lucero. A weakly penalized discontinuous galerkin method for radiation in dense, scattering media. *CMAM*, 2016. submitted.
- [37] G. Kanschat, R. Lazarov, and Y. Mao. Geometric multigrid for Darcy and Brinkman models of flows in highly heterogeneous porous media: A numerical study. *submitted*, 2016. <http://arxiv.org/abs/1602.04858>.

6.3 Articles in refereed conference proceedings

- [38] G. Kanschat and Y. Mao. Multiplicative overlapping Schwarz smoothers for h^{div} -conforming discontinuous Galerkin methods for the Stokes problem. In Th. Dickopf, M. J. Gander, L. Halpern, R. Krause, and L.F. Pavarino, editors, *Domain Decomposition Methods in Science and Engineering XXII*, volume 104 of *Lecture Notes in Computational Science and Engineering*, pages 285–292, 2016.
- [39] V. Girault, G. Kanschat, and B. Rivière. On the coupling of incompressible Stokes or Navier-Stokes and Darcy flows through porous media. In J. A. Ferreira, S. Barbeiro, G. Pena, and M. F. Wheeler, editors, *Modelling and Simulation in Fluid Dynamics in Porous Media*, volume 28 of *Springer Proceedings in Mathematics and Statistics*, pages 1–25, 2013.
- [40] 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.
- [41] 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.
- [42] 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.
- [43] 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.
- [44] 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.
- [45] 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.

6.4 Articles in conference proceedings (not refereed)

- [46] G. Kanschat. Preconditioning discontinuous Galerkin saddle point systems. In K. J. Bathe, editor, *Computational Fluid and Solid Mechanics 2003*, pages 2016–2018. Elsevier, 2003.
- [47] 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.
- [48] 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.
- [49] 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.
- [50] 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.
- [51] 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.

- [52] 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.

6.5 Contributions in collections

- [53] 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.
- [54] 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.
- [55] E. Meinköhn, G. Kanschat, R. Rannacher, and R. Wehrse. Numerical methods for multidimensional radiative transfer. In W. Jäger, R. Rannacher, and J. Warnatz, editors, *Reactive Flows, Diffusion and Transport*, pages 485–526. Springer, Berlin, 2006.

6.6 Books (authored and edited)

- [56] G. Kanschat, E. Meinköhn, R. Rannacher, and R. Wehrse, editors. *Numerical Methods for Multi-Dimensional Radiative Transfer*. Springer, 2009.
- [57] G. Kanschat. *Discontinuous Galerkin Methods for Viscous Flow*. Deutscher Universitätsverlag, Wiesbaden, 2007.
- [58] H. G. Bock, F. Brezzi, R. Glowinsky, G. Kanschat, Y. A. Kuznetsov, J. Périaux, and R. Rannacher, editors. *ENUMATH 97, Proceedings of the 2nd European Conference on Numerical Mathematics and Advanced Applications*, Singapore, 1998. World Scientific.

6.7 Software and software manuals

- [59] W. Bangerth, T. Heister, and G. Kanschat. `deal.II Differential Equations Analysis Library`, *Technical Reference*, 8.0 edition, 2013. first edition 1999.
- [60] W. Bangerth and G. Kanschat. Concepts for object-oriented finite element software – the `deal.II` library. Preprint 1999-43, SFB 359, Heidelberg, 1999.

6.8 Miscellaneous

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

6.9 Publications in preparation

- [64] G. Kanschat. *MSRI Summer School on Geometric and Computational Spectral Theory*, chapter The Finite Element Approximation of Variational Eigenvalue Problems. AMS, 2015.
- [65] G. Kanschat and B. Rivière. A finite discretization for the linear biot model with strong divergence coupling. 2016. in preparation.

7 Conferences and Minisymposia (Organization)

- International Workshop on the Advances of Discontinuous Galerkin Methods, Heidelberg, with Nilima Nigam, December 2015
- PDFSoft 2014, Heidelberg, with P. Bastian, V. Heuveline
- 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

8 Student Advising

8.1 Advisor

- current: J. P. Lucero, N. Shakir, A. Bettendorf, S. Meggendorfer, J. Witte (Dr. rer. nat.); Ph. Siehr, P. Esser, M. Klingebiel, E. Miftari (M.Sc.); A. Aschauer (B.Sc.)
- 2014: Y. Mao (PhD), J. Vogel, E. Miftari H. Kaspari, P. Esser, M. Schubert, D. Stronczek (B. Sc.)
- 2013: V. Paus, (B.Sc.)
- 2011: A. Sharp (M.Sc.)
- 2007: B. Janssen, *Diplom, Univ. Heidelberg*
- 2006: Ch. Laux, *Diplom, Univ. Heidelberg*

8.2 Thesis co-advisor/mentor (Univ. Heidelberg)

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

8.3 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

9 Invited Presentations and Research Visits

2015

- 5th Chinese-German Workshop on Applied and Computational Mathematics, Augsburg (Sep)
- Joint workshop on Scientific Computing, Kyoto University, Japan (Sep)
- MSRI Summer School Geometric and Computational Spectral Theory, Montréal (Jun)
- BSSE Basel (May)
- Universität Stuttgart (Apr)
- 25 Years Cooperation in Applied Mathematics, Prague, Czech Republic (Apr)
- Short course on computational aspects of the finite element methods, Indian Institute of Space Science and Technology, Thiruvananthapuram, India (Feb)

2014

- Short course on computational aspects of the finite element methods, IIT Bombay, India (Mar)
- IISc Bengaluru, India (Mar)
- IIST Thiruvananthapuram, India (Mar)

2013

- Universität Göttingen (Nov)
- SISSA Trieste (1 week, Sep)
- deal.II User Workshop, College Station (Aug)

2012

- Louisiana State University (May)
- University of Delaware (Mar)
- 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

10 Research Statement

With my research, I strive to improve the ability of applied sciences to simulate complex phenomena involving partial differential equations (PDE) by creating new or improved mathematical methods, analyzing them, and providing efficient implementations. In order to achieve these goals, 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.

10.1 Software Development

Modern mathematical simulation methods have reached a level of complexity and sophistication that makes it infeasible to have them reimplemented by graduate students over and over again. Instead, it has become an integral part of the work of researchers in scientific computing to provide efficient implementations of these methods. 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 (now U. Siegen) to provide such a platform. In 1998, this work led to the object oriented software library `deal.II` with W. Bangerth (Texas A&M) and R. Hartmann (DLR). It is open source and publicly available (www.dealii.org; several hundred downloads worldwide per month for the current version). 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 among others message passing parallelization with T. Heister (U. Göttingen) and M. Kronbichler (TUM), an application framework with B. Janssen (KTH Stockholm) and M. Secanell (U. of Alberta), high order adaptive multigrid with B. Janssen and higher order Nedelec elements with M. Bürg (KIT) within very short time. It combines adaptive meshes in two and three dimensions with multilevel support, *hp*-adaptivity, vector elements, and numerous optimizations for parallel computing. It was awarded the *J. H. Wilkinson Prize for Numerical Software* in 2007. Active development involves high level algorithms for parameter estimation and optimization and extension to spline elements in order to couple with CAD software. A team at TUM and I are working on new internal structures to make `deal.II` ready for exascale computing; the funding decision of DFG is expected in October 2015.

10.2 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.

Recently, we developed a new discontinuous Galerkin discretization method together with a robust multigrid solver for the single group approximation in a team consisting of mathematicians and a nuclear engineer (J.-L. Guermond, J. Ragusa, Texas A&M). It addresses many problems of existing methods and provides the robustness needed for realistic simulations. Constructive dialogue between the different research areas was a key stone in achieving these results. In a current PhD project, we are extending these concepts to atmospheres in local thermodynamical equilibrium with the long term goal to develop an accurate and detailed radiative transfer solver which is sufficiently fast to be coupled to hydrodynamic computations, such that it is feasible for super-nova simulations and weather and climate modeling.

10.3 Constrained 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, I 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 pre-asymptotic regimes. The

application area is coupled incompressible flow problems as for instance interfacing free flow regions with porous media or poroelasticity.

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. Recently, I extended these methods to coupled free and porous media flow with B. Rivière (Rice U.) and V. Girault (Paris VI); the discretization we obtain guarantees exact mass conservation, independent of material parameters, which had not been possible before. Currently, in cooperation with A. Marciniak-Czochra (Heidelberg U.) and A. Mikelić (U. de Lyon), these concepts are extended to poroelasticity with finite deformations for applications in organ and cell biology. Here, homogenization techniques from mathematical analysis are paired with tailored finite element spaces to approximate the delicate force balance between liquid and solid matter, which is manifested by a constraint on the divergence of the two fields.

I have been working intensely on the basic analysis DGFEM, most recently with R. Hoppe (U. Augsburg), N. Sharma (now UT El Paso), and T. Warburton (now Rice U.) on convergent adaptive methods for Maxwell and Stokes equations.

10.4 Multigrid 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 with J. Gopalakrishnan (Portland U.) and their efficient application to the saddle point problems arising in incompressible flow. 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.

In this area, I am focusing on multilevel domain decomposition methods leading to geometric multigrid methods with smoothers which obey the constraint structures outlined in section 10.3. Such methods have the advantages of robustness in case of singular perturbed problems and for higher order methods, and suitability for modern hardware architectures like multicore or graphics coprocessors. Indeed, they provide mathematically proven optimality in many interesting applications, including the radiative transfer and coupled flow problems described above. Further research will focus on efficient implementation of the local solvers on modern hardware, nonlinear multigrid, and the evaluation of their efficiency in complex geometries.

11 Teaching record

Note: additional student seminars since 2012 not listed

Summer 15	Linear Algebra II (U. Heidelberg)
Winter 14	Linear Algebra I (U. Heidelberg)
Summer 14	Mixed and Discontinuous Finite Element Methods (U. Heidelberg)
Winter 13	Numerical Analysis of Partial Differential Equations (U. Heidelberg)
Summer 13	Numerical Analysis of Ordinary Differential Equations (U. Heidelberg)
Winter 12	Introduction to Numerical Analysis (U. Heidelberg)
Spring 12	Numerical Analysis (MATH 417, Texas A&M)
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	C++ programming for numerical applications (U. Heidelberg)
Summer 03	C++ programming for numerical applications (U. Heidelberg)
Winter 02	C++ programming for numerical applications (U. Heidelberg)
Summer 02	C++ programming for numerical applications (U. Heidelberg)
Winter 01	C++ programming for numerical applications (U. Heidelberg)
Summer 2001	C++ programming for numerical applications (U. Heidelberg)
Winter 00	Iterative Solvers for Sparse Linear Systems (U. Heidelberg)
Spring 00	Numerical Methods for Partial Differential Equations II (University of Minnesota)
Fall 99	Numerical Methods for Partial Differential Equations I (University of Minnesota)
Summer 99	Practical Introduction to object-oriented finite element software (U. Heidelberg)
Summer 98	The Finite Element Method (advanced course) (U. Heidelberg)
Summer 98	Practical Introduction to object-oriented finite element software (U. Heidelberg)