Winter semester 2013/14

Graduate Seminar on Scientific Computing

Prof. Dr. Carsten Burstedde

1 Summary

We will focus on efficient techniques for the numerical solution of partial differential equations (PDEs). Multiple and rather different aspects need to be considered to obtain a satisfactory time-to-solution for high-accuracy simulations.

- Implicit/explicit time integration
- Block preconditioners for coupled PDEs
- Mesh generation—differential geometry and computational topology
- Adaptive mesh refinement—concepts, approaches, theory
- Parallelization—concepts, problems, solutions

Basic knowledge on interpolation, numerical quadrature, and finite element methods for elliptic PDEs will be advantageous.

The seminar presentations (50 minutes) should be self-consistent and understandable without requiring specialized prior knowledge. A four-page written summary in LaTeX must be turned in by email or in print until Feb 15, 2014.

The seminar will take place on Mondays at 3:00pm s.t. in room 5.002, Wegelerstr. 6.

2 Topics

1. The BDF-2 method for solving parabolic PDEs
2. Exponential time integrators for parabolic PDEs [6]
3. Predictor-corrector Newmark integrators [3, 7]
4. Block preconditioning for the Stokes equation [4]
5. Mesh generation: Introduction and coordinate transformations [12]
6. Meshes: Second derivatives and conservation laws [12]
7. Meshes: Time-dependent transformations and application to PDEs [12]
8. Mesh quality measures [12]
9. Algebraic grid generation and transfinite interpolation [12]
10. Metric identities and the spectral element method [9]
11. Adaptive hexahedral elements and spectral elements [11]
12. A-posteriori error estimation for elliptic PDEs [8]
13. Distributed parallelization of hanging-node adaptive meshes [13]

References

[1] D. Braess, *Finite Elements. Theory, Fast Solvers, and Applications in Solid Mechanics*, Cambridge University Press, Cambridge, New York, 1997.

[2] A. N. Brooks and T. J. R. Hughes, *Streamline upwind/Petrov–Galerkin formulations for convection dominated flows with particular emphasis on the incompressible Navier–Stokes equations*, Computer Methods in Applied Mechanics and Engineering, 32 (1982), pp. 199–259.

[3] J. A. Cottrell, T. J. R. Hughes, and Y. Bazilevs, *Isogeometry Analysis*, John Wiley & Sons, Ltd., 2009.

[4] H. C. Elman, D. J. Silvester, and A. J. Wathen, *Finite Elements and Fast Iterative Solvers with applications in incompressible fluid dynamics*, Oxford University Press, Oxford, 2005.

[5] J. S. Hesthaven and T. Warburton, *Nodal Discontinuous Galerkin Methods: Algorithms, Analysis, and Applications*, vol. 54 of Texts in Applied Mathematics, Springer, 2008.

[6] M. Hochbruck and A. Ostermann, *Exponential integrators*, Acta Numerica, 19 (2010), pp. 209–286.

[7] T. J. R. Hughes, *The Finite Element Method*, Dover, New York, 2000.

[8] D. W. Kelly, J. P. d. S. R. Gago, O. C. Zienkiewicz, and I. Babuska, *A posteriori error analysis and adaptive processes in the finite element method: Part I – error analysis*, International Journal for Numerical Methods in Engineering, 19 (1983), pp. 1593–1619.

[9] D. A. Kopriva, *Metric identities and the discontinuous spectral element method on curvilinear meshes*, Journal of Scientific Computing, 26 (2006), pp. 301–327.

[10] ——, *Implementing Spectral Methods for Partial Differential Equations*, Springer, 2009.

[11] D. A. Kopriva, S. L. Woodruff, and M. Y. Hussaini, *Computation of electromagnetic scattering with a non-conforming discontinuous spectral element method*, International Journal for Numerical Methods in Engineering, 53 (2002), pp. 105–122.

[12] V. D. Liseikin, *Grid Generation Methods*, Springer, 2nd ed., 2010.

[13] H. Sundar, R. Sampath, and G. Biros, *Bottom-up construction and 2:1 balance refinement of linear octrees in parallel*, SIAM Journal on Scientific Computing, 30 (2008), pp. 2675–2708.

[14] H. M. Tufo and P. F. Fischer, *Terascale spectral element algorithms and implementations*, in Proceedings of the ACM/IEEE SC99 Conference on High Performance Networking and Computing, 1999.