Block-structured Adaptive Mesh Refinement Methods for Conservation Laws

Theory, Implementation and Application

Ralf Deiterding
Computer Science and Mathematics Division
Oak Ridge National Laboratory
P.O. Box 2008 MS6367, Oak Ridge, TN 37831, USA

E-mail: deiterdingr@ornl.gov

Structure of the lectures

Structure of the lectures

1. Fundamentals
   - Finite volume schemes for hyperbolic problems
   - Discussion of mesh adaptation approaches

Structure of the lectures

1. Fundamentals
   - Finite volume schemes for hyperbolic problems
   - Discussion of mesh adaptation approaches
2. Structured AMR for hyperbolic problems
   - Presentation of all algorithmic components
   - Parallelization

Structure of the lectures

1. Fundamentals
   - Finite volume schemes for hyperbolic problems
   - Discussion of mesh adaptation approaches
2. Structured AMR for hyperbolic problems
   - Presentation of all algorithmic components
   - Parallelization
3. Complex hyperbolic structured AMR applications
   - Shock-induced combustion
   - Fluid-structure interaction

Structure of the lectures

1. Fundamentals
   - Finite volume schemes for hyperbolic problems
   - Discussion of mesh adaptation approaches
2. Structured AMR for hyperbolic problems
   - Presentation of all algorithmic components
   - Parallelization
3. Complex hyperbolic structured AMR applications
   - Shock-induced combustion
   - Fluid-structure interaction
4. Further topics
   - Using the SAMR approach for multigrid methods
   - Practical implementation, discussion of SAMR systems

Useful references I

Finite volume methods for hyperbolic problems

- LeVeque, R. J. (2002). *Finite volume methods for hyperbolic problems*. Cambridge University Press, Cambridge, New York.
- Godlewski, E. and Raviart, P.-A. (1996). *Numerical approximation of hyperbolic systems of conservation laws*. Springer Verlag, New York.
- Toro, E. F. (1999). *Riemann solvers and numerical methods for fluid dynamics*. Springer-Verlag, Berlin, Heidelberg, 2nd edition.
- Laney, C. B. (1998). *Computational gasdynamics*. Cambridge University Press, Cambridge.

Structured Adaptive Mesh Refinement

- Berger, M. and Colella, P. (1988). Local adaptive mesh refinement for shock hydrodynamics. *J. Comput. Phys.*, 82:64–84.
- Bell, J., Berger, M., Saltzman, J., and Welcome, M. (1994). Three-dimensional adaptive mesh refinement for hyperbolic conservation laws. *SIAM J. Sci. Comp.*, 15(1):127–138.
- Berger, M. and LeVeque, R. (1998). Adaptive mesh refinement using wave-propagation algorithms for hyperbolic systems. *SIAM J. Numer. Anal.*, 35(6):2298–2316.

Useful references II

Adaptive multigrid (finite difference and finite element based in textbooks)

- Hackbusch, W. (1985). *Multi-Grid Methods and Applications*. Springer Verlag, Berlin, Heidelberg.
- Briggs, W. L., Henson, V. E., and McCormick, S. F. (2001). *A Multigrid Tutorial*. Society for Industrial and Applied Mathematics, 2nd edition.
- Trottenberg, U., Oosterlee, C., and Schüller, A. (2001). *Multigrid*. Academic Press, San Antonio.
- Martin, D. F. (1998). *A cell-centered adaptive projection method for the incompressible Euler equations*. PhD thesis, University of California at Berkeley.

Implementation, parallelization

- Hornung, R. D., Wissink, A. M., and Kohn, S. H. (2006). Managing complex data and geometry in parallel structured AMR applications. *Engineering with Computers*, 22:181–195.
- Rendleman, C. A., Beckner, V. E., Lijewski, M., Crutchfield, W., and Bell, J. B. (2000). Parallelization of structured, hierarchical adaptive mesh refinement algorithms. *Computing and Visualization in Science*, 3:147–157.

Useful references III

- Deiterding, R. (2005). Construction and application of an AMR algorithm for distributed memory computers. In Plewa, T., Linde, T., and Weirs, V. G., editors, *Adaptive Mesh Refinement - Theory and Applications*, volume 41 of *Lecture Notes in Computational Science and Engineering*, pages 361–372. Springer.
- Deiterding, R. (2003). *Parallel adaptive simulation of multi-dimensional detonation structures*. PhD thesis, Brandenburgische Technische Universität Cottbus.

Applications (from my own work)

- Deiterding, R. (2009). A parallel adaptive method for simulating shock-induced combustion with detailed chemical kinetics in complex domains. *Computers & Structures*, 87:769–783.
- Deiterding, R., Radovitzky, R., Mauch, S. P., Noels, L., Cummings, J. C., and Meiron, D. I. (2006). A virtual test facility for the efficient simulation of solid materials under high energy shock-wave loading. *Engineering with Computers*, 22(3-4):325–347.
- Pantano, C., Deiterding, R., Hill, D. J., and Pullin, D. I. (2007). A low-numerical dissipation patch-based adaptive mesh refinement method for large-eddy simulation of compressible flows. *J. Comput. Phys.*, 221(1):63–87.