Annual Progress Report for 2003 of the project P14953

Robust Algebraic Multigrid Methods and their Parallelization

The aim of the project, that started 1^{st} of October 2001, consists in the construction of robust, flexible and efficient Algebraic Multigrid (AMG) methods, their parallelization, and their applications to real life problems. The following progress has been made since the last Annual Report 2002:

1. Concerning our work on AMG methods for Stokes and Navier-Stokes (resp. Oseen) equations, our results on (algebraically) stable mixed finite elements (stabilized equal order elements) have been consolidated. We have presented them at the Copper Mountain Conference on Multigrid Methods [16] and in the paper [18] which has been accepted for publication (a preprint is available [17]).

2. New methods in this direction were obtained by the utilization of the element based AMG methods (AMGe) which have been recently developed by J.E. Jones, P.S. Vassilevski, et.al. (Lawrence Livermore National Labs, Livermore, USA). They provide topological information on coarse levels, which can be especially exploited for our mixed finite elements. Using these ideas we got methods, which seem to be generalizable to different element types and which allow also analytic examinations. M. Wabro has discussed this approach with J.E. Jones and P.S. Vassilevski during a short visit at the Lawrence Livermore National Labs, Livermore, USA. The results were presented at the GAMM-Workshop on "Multigrid Methods and Hierarchic Solution Techniques" [15] and at the "Workshop on Advances in Numerical Algorithms [13]. A paper is in preparation.

3. The results above (and more) were extended to M. Wabro's PhD thesis [14].

4. The construction of AMG preconditioners for problems discretized using the boundary element method (BEM) was documented in D. Pusch's diploma thesis [12] and appeared in the journal publication [7] (especially for 2D problems). Some of the results were presented by U. Langer at the annual GAMM conference [3] and published in [6]. Further results for large scale problems can be found in [5].

5. Our further work has been focused on matrices arising from 3D boundary element methods. Consequently, some adaptions to the Adaptive-Cross-Approximation method have been realized and, in order to perform numerical AMG experiments, implemented in the software package **PEBBLES**. First numerical results have been presented by D. Pusch at the IMAMM '03 conference [10]. The corresponding paper [4] will be published in the conference proceedings. Similar numerical results were presented at a special BEM workshop [11].

6. U. Langer and O. Steinbach have developed new parallel solvers for boundary element domain decomposition (DD) equations [8] and for coupled finite and boundary element DD equations [9]. AMG preconditioners for the discrete single layer potential and the discrete (modified) hypersingular subdomain operators as well as the subdomain finite element stiffness matrix are the basic components of these highly parallel solvers. U. Langer presented these results as invited talks at the 4th International Conference on "Large-Scale Scientific Computations" and the 15th International Conference on "Domain Decomposition Methods" (July 21 - 25, 2003, Berlin, Germany).

7. Multigrid-Newton-Methods for solving nonlinear magnetostatic problems are studied in C. Pechstein's diploma thesis that was also supported by this project via "Kleine Forschungsbeihilfe". The diploma examination is planed for March 2004.

8. Finally, multigrid methods have been applied to real life problems in electromagnetics. The results have been presented at the Chemnitz FEM Symposium [1] and are documented in F. Bachinger's diploma thesis [2] that was also supported by this project via "Kleine Forschungsbeihilfe". Two papers are in preparation.

All results, including the publications and the description of the software packages **AMuSE** and **PEBBLES**, as well as this report can be found on our project home-page

`http://www.numa.uni-linz.ac.at/Research/Projects/P14953.html`

References

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[2] F. Bachinger. Multigrid Solvers for 3D Multiharmonic Nonlinear Magnetic Field Computations. Diploma thesis, Johannes Kepler University Linz, 2003.

[3] U. Langer. Algebraic Multigrid Preconditioners for Sparse Approximations of Boundary Element Matrices. Annual GAMM Conference 2003, Abano Terme - Padua, Italy, joint talk with D. Pusch and S. Reitzinger, March 2003.

[4] U. Langer and D. Pusch. Algebraic Multigrid Preconditioners for Adaptive-Cross-Approximated Boundary Element Matrices. In *IMAMM '03 Conference*, 2003. accepted.

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[7] U. Langer, D. Pusch, and S. Reitzinger. Efficient Preconditioners for Boundary Element Matrices Based on Grey-Box Algebraic Multigrid Methods. *Internat. J. Numer. Methods Engrg.*, 58(13):1937–1953, 2003.

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[11] D. Pusch. Algebraic multigrid preconditioners for adaptive-cross-approximated boundary element matrices. Talk at BEM Workshop, Saarbrücken, October 2003.

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[14] M. Wabro. *Algebraic Multigrid Methods for the Numerical Solution of the Incompressible Navier-Stokes Equations*. PhD thesis, University of Linz, 2003. published by Universitätsverlag Rudolf Trauner.

[15] M. Wabro. Algebraic multigrid methods for the Oseen equations. Talk at the GAMM-Workshop on Multigrid Methods and Hierarchic Solution Techniques in Leipzig, BRD, August 2003.

[16] M. Wabro. Algebraic multigrid methods for the Oseen problem. Talk at the Copper Mountain Conference on Multigrid Methods in Copper Mountain, USA, April 2003.

[17] M. Wabro. Coupled algebraic multigrid methods for the Oseen problem. Technical Report 2003-02, SFB 013, University of Linz, 2003. SFB-Report.

[18] M. Wabro. Coupled algebraic multigrid methods for the Oseen problem. *Computing and Visualization in Science*, accepted.