A Geometric Partitioning Scheme for the Direct Parallel Solution of Steady CFD Problems on Staggered Grids

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Abstract

When solving stationary flow problems, it is often advantageous to use Newton-like methods rather than performing long time integrations. In such an approach, linear systems with the large and sparse Jacobian matrix have to be solved. In the case of some classical structured-grid finite volume schemes (so-called Arakawa grids), the Jacobian of the incompressible Navier-Stokes equations is a special type of saddle point matrix. Using sparse direct solvers, one can use fill-reducing orderings to speed up the factorization process, e.g., PT-Scotch [1]. In general, such a black box approach cannot exploit the special properties of the saddle point system, i.c., that the Jacobian is related to a stable solution of the Navier-Stokes equations. In [2] a fill-reducing ordering technique was proposed, which leads to a stable factorization without the need of pivoting during the numerical factorization. In this work, we turn to parallel sparse direct solvers and examine the effect of the partition shapes on the efficiency of such methods. A novel geometric partitioning is proposed that leads to a reduction of the size of the Schur-Complement compared to Cartesian or octree-based partitioning. The new ordering may also be beneficial for preconditioning techniques based on domain-decomposition.

References

1. C. Chevalier and F. Pellegrini. PT-SCOTCH: a tool for efficient parallel graph ordering. Parallel Computing 34 (2008), 318-331.
2. A.C. de Niet and F.W. Wubs. Numerically stable LDLT-factorization of F-type saddle point matrices. IMA Journal of Numerical Analysis, 29 (2009) 208-234.