DEVELOPMENT OF AN AGGREGATION-TYPE ALGEBRAIC MULTIGRID SOLVER FOR CFD PROBLEMS

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While the field of computational fluid dynamics (CFD) has focused mainly on steady simulations in the past, computers have become su_ciently powerful and a_ordable to perform detailed time-dependent simulations on increasingly large problems. The main computational cost in most flow solvers is that a large sparse linear systems must be solved. Modern Algebraic Multgrid (AMG) methods are capable of performing this task in a reasonable amount of time. AMG generates approximations of the linear system on coarser grids automatically. The coarser grid problem can be solved much more quickly, and can be exploited to speed convergence of the linear solver.

The project focused on the development of a computationally-light form of AMG, Aggregation-type AlgebraicMultigrid (AggMG). This AggMG setup technique uses a top-down approach, where the original problem is coarsened by recursive partitioning. The subdivisions then act as degrees of freedom on the smaller systems; this method o_ers the possibility to perform anisotropic coarsening, and will make adaptation of the solver to parallel easier.

To support the AggMG implementation, a new solver library, FlexMG (for Flexible MultiGrid) was written. This framework also supports Geometric Multigrid, being developed concurrently at the Université Libre de Bruxelles. The multigrid correction can then be used as a preconditioner for powerful Krylov subspace solvers, such as the generalized minimal residual method (GMRES).

AggMG performance in FlexMG was tested first in the turbulent flow solver, Sfeles. Accuracy of the AggMG solver was verified, and the performance of FlexMG compared to other solvers from published data. The memory required and solution time are similar to that of other multigrid linear solvers. Typical aggregates formed for a test case of a cylinder and the streamlines resulting from solution with FlexMG are shown below. With FlexMG, large direct numerical simulations (DNS) on two-phase flow have been performed that were previously impossible to run at VKI.

FlexMG was also integrated with COOLFluid, a modular VKI CFD multi-method code. The applicability of FlexMG to complex 3D geometries demonstrated, and it outperformed other single-level solvers. In conclusion, this project is the first step in the development of a powerful in-house linear iterative solver, and provides the framework for continued study and improvement of multigrid solvers for CFD problems.