CONVERGENCE ACCELERATION TECHNIQUES FOR AN IMPLICIT FINITE VOLUME SOLVER

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The project deals with the implementation of memory efficient and convergence acceleration techniques in order to enhance performance of the existing implicit parallel Finite Volume solver in COOLFluiD. COOLFluiD (Computational Object Oriented Library for Fluid Dynamics) is an object oriented software platform for the high performance simulations of Multi-physics phenomena on unstructured grids developed at the VKI.

These improvements have been done on the side of PETSc Linear System Solver module inside COOLFluiD in order to be reusable for all COOLFluiD's solvers (such as FVM, FEM, RDS, ...).

COOLFluiD (Computational Object Oriented Library for Fluid Dynamics) is an object oriented software platform for the high performance simulations of Multi-physics phenomena on unstructured grids developed at the VKI.

The Jacobian-free method has been implemented to lower memory requirements. Several preconditioning algorithms have been developed and implemented to accelerate the convergence of the GMRES linear system solver using the Jacobian-free matrix-vector approach. The implementation allows to use the Jacobian-free method and some preconditioners in all COOLFluiD's solvers, such as FEM, RDS, etc.

The implemented techniques have been tested in the implicit finite volume solver in COOLFluiD on basic 2D first and second order accuracy test-cases. %up to the one of the most challenging 3D test-cases. The first results have shown that the Jacobian-free method is not so efficient in convergence speed, but it really saves a lot of memory. Due to its low convergence speed, it has been decided to try to implement memory saving preconditioner for the standard matrix-storing GMRES method, which has the same performance as commonly used ILU or ASM preconditioners.

A parallel Block LU-SGS preconditioner has been implemented and it has shown the potential to fulfill these conditions. It has been tested on 2D hypersonic cases and also on the complicated 3D Blast ESA reentry capsule (4,363,072 cells, solved using 30 CPUs) and it has gained better results than the same computation with ASM preconditioner (solved using 256 CPUs). The Block LU-SGS has also saved more than 400 MB per CPU in comparison with computation with ASM preconditioner (compared on 30 CPUs).

The future work could be to try to improve the implementation of the Jacobian-free method in order to reduce computational time per GMRES iteration. More sophisticated techniques for choosing the Jacobian-free finite difference approach parameter ε should be investigated. Other families of preconditioners, such as FAS (multigrid preconditioner), or other techniques, such as DPLR (Data Parallel Line Relaxation), should be investigated too.

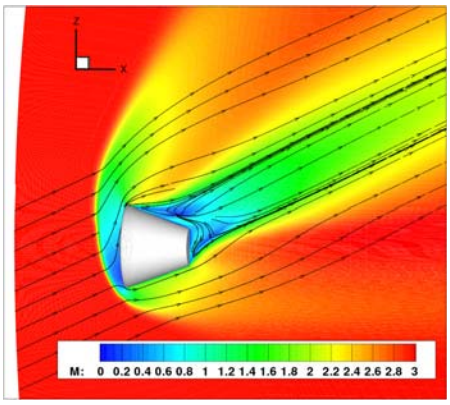

Figure 1: 3D ESA Blast Capsule; Mach number distribution and Stream lines in symmetry plane; r $M\infty$ = 3, α = 25°

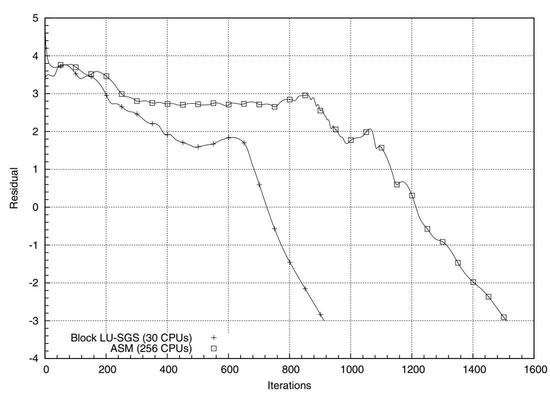

Figure 2: Convergence in iterations (3D ESA Blast Capsule)