IMPLICIT SPACE-TIME METHOD FOR LAMINAR VISCOUS FLOW

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The class of Multidimensional Upwind Residual Distribution (RD) schemes has been developed in the past decades as an attractive alternative to both the Finite Volume (FV) and Finite Element (FE) approaches. Although they have shown superior performances in the simulation of steady two-dimensional and three-dimensional inviscid and viscous flows, their extension to the simulation of unsteady flow fields is still a topic of intense research.

Recently a space-time RD approach has been developed at the VKI which allows to perform second order accurate unsteady inviscid computations. In this approach the space-time domain is discretized and solved as a $(d+1)$ -dimensional problem, where d is the space dimension. Thanks to the upwinding properties of RD, the space-time solution decouples over the successive time slabs, and the solution can be obtained by marching in time. The method is implicit and unconditionally stable for arbitrariy large time steps in physical time.

The first aim of this project was to further develop the space-time approach by extending it to laminar viscous flow computations. A Petrov-Galerkin treatment of the viscous terms consistent with the space-time formulation has been investigated, implemented and tested. Second order accuracy in both space and time was observed for arbitrary triangulation of the spatial domain.

The algebraic system obtained at each physical time step was solved in the past using an explicit pseudo-time iteration, which proved to be very costly in terms of CPU time. The second objective of this work was therefore to implement and test an efficient implicit solver in the VKI space-time code. A damped Newton method has been implemented and tested, and the linear systems were solved by a Krylov method, using the PETSc library.

The method was applied to several unsteady flow problems with speed-ups of more than a factor 100 compared to the explicit method. As an example calculation, the figures show the mesh and entropy isolines of the solution for viscous laminar flow around a NACA0012 airfoil at a Mach number of 0.85 and Reynolds number of 10000.