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ON THE FEASIBILITY OF GOAL-ORIENTED ERROR ESTIMATION FOR SHIP HYDRODYNAMICS

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Abstract. The goal of this paper is to investigate the use of adjoint-based techniques of error estimation for the simulation of the flow around ships. These flows are characterised by turbulence at very high Reynolds numbers as well as complex geometries and flow topologies, which generally involve separation and reattachment zones on the aft part of the ship. For simulation in a finite-volume context, this means that grids with high aspect-ratio cells are used. Also, the flow is strongly nonlinear and is expected to be away from the asymptotic range of grid convergence for realistic grids.

Given this context, we will investigate whether goal-oriented error estimation is possible for such flows. The work is based on the ISIS-CFD unstructured finite-volume Navier-Stokes solver developed by ECN-CNRS, which has been optimised for the simulation of hydrodynamic flows and has a proven record of reliability and accuracy for such simulations [1,2]. The solver has a face-based discretisation of the fluxes and is therefore suitable for arbitrary unstructured grids. Pressure-velocity coupling is achieved through a segregated SIMPLE-like resolution procedure.

The paper indicates first how we see the concept of goal-oriented error estimation in a finite-volume context. Then the continuous adjoint solver developed for ISIS-CFD is described. While this solver reuses as much as possible the discretisation and resolution procedures of the primal solver, the existing flux discretisation cannot be used due to the non-conservative nature of the adjoint convective terms. We show how stability can be achieved through a combination of central and upwind discretisation for these terms. Finally, with minor modifications, the SIMPLE-like pressure-velocity coupling can be maintained.

Adjoint error estimation for finite volumes requires a high-order accurate evaluation of the local residuals. This is obtained by substituting the numerical solution in a finite-volume discretisation which uses least-square fitting of third-order polynomials for the reconstruction of the solution from the cell centres to the face centres and nodes, followed by quadrature integration of the fluxes over the faces. While this procedure is accurate, it is sensitive to the reduced stencils available at the domain boundaries. We demonstrate extrapolation to ghost cells behind the boundary, which reduces this problem.

Finally, the usefulness of the error estimation procedure is investigated for 2D airfoils and 3D ship geometries. It is shown that due to the nonlinearity of the flow and the presence of turbulence, the error estimates are not sufficiently accurate to be used as a correction term for the computed functionals. However, in many cases the estimation gives a good indication of the actual error. It may be possible to improve the estimation further by finding a better reconstruction of the local residuals.

REFERENCES

[1] P. Queutey and M. Visonneau, “An interface capturing method for free-surface hydrodynamic flows”, *Comput. Fluids* **36** (9), pp. 1481−1510, (2007).
[2] J. Wackers, G.B. Deng, P. Queutey, M. Visonneau, E. Guilmineau, and A. Leroyer, “Sliding grids and adaptive grid refinement applied to ship hydrodynamics”, *29th Symposium on Naval Hydrodynamics*, Gothenburg, Sweden (2012).