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ADAPTIVE GRID REFINEMENT FOR FREE-SURFACE HYDRODYNAMIC FLOWS

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Free-surface water flows feature the creation of gravity waves due to the interaction of the surface with immersed bodies, as well as the propagation of these waves and their interaction with other flow phenomena. For Reynolds-Averaged Navier Stokes (RANS) simulation of such flows, grids are needed that are refined in the vicinity of the water surface in order to resolve the surface model (for example, a level set or volume-of-fluid equation). Furthermore, fine grids are needed below the surface for the accurate resolution of the pressure–velocity fields which drive the surface deformation. The goal of the research presented in this paper is to create such refined meshes with automatic adaptive mesh refinement.

The work is based on the ISIS-CFD unstructured finite-volume RANS solver which our group develops. This solver contains a surface-capturing model for the water surface, where the surface is represented as a discontinuity in the volume fraction for the water; the volume fraction is computed with a linear convection equation. The automatic grid refinement method developed for ISIS-CFD [1] performs anisotropic refinement of unstructured hexahedral grids by division of the cells. Like the solver, it is fully parallel.

The first part of the paper concerns the appropriate choice of a refinement criterion, which indicates where the grid should be refined. We propose combined refinement criteria, consisting of refinement around the surface in order to resolve correctly the volume fraction equation, combined with pressure Hessian-based refinement below the surface to capture the pressure and velocity fields associated with the waves. The computation of the Hessian matrix is complicated by the variations in cell size that appear in unstructured hexahedral meshes, which lead to large errors in the computed second derivatives. A double application of Gauss's theorem, followed by smoothing of the obtained first and second derivatives to eliminate the irregularities, is proposed. The difficulty of eliminating numerical errors while preserving the effects of physical pressure peaks is discussed.

From a technical point of view, a powerful algorithm for derefinement (undoing earlier refinement) is needed even for steady computations. Since the mesh is adapted repeatedly to the solution as it develops and converges, cells that were initially refined may no longer be needed in the end. We show that treating this derefinement, like the refinement, in an anisotropic way allowing the undoing of refinement in one direction only, is a necessity for obtaining good-quality meshes.

Finally, the refinement procedure is tested on realistic cases of ship flow, in order to confirm the validity of the combined criterion and to determine guidelines for its use. Accurate simulation of the flow is obtained with significantly less cells (often 50% or more) than without automatic grid refinement.

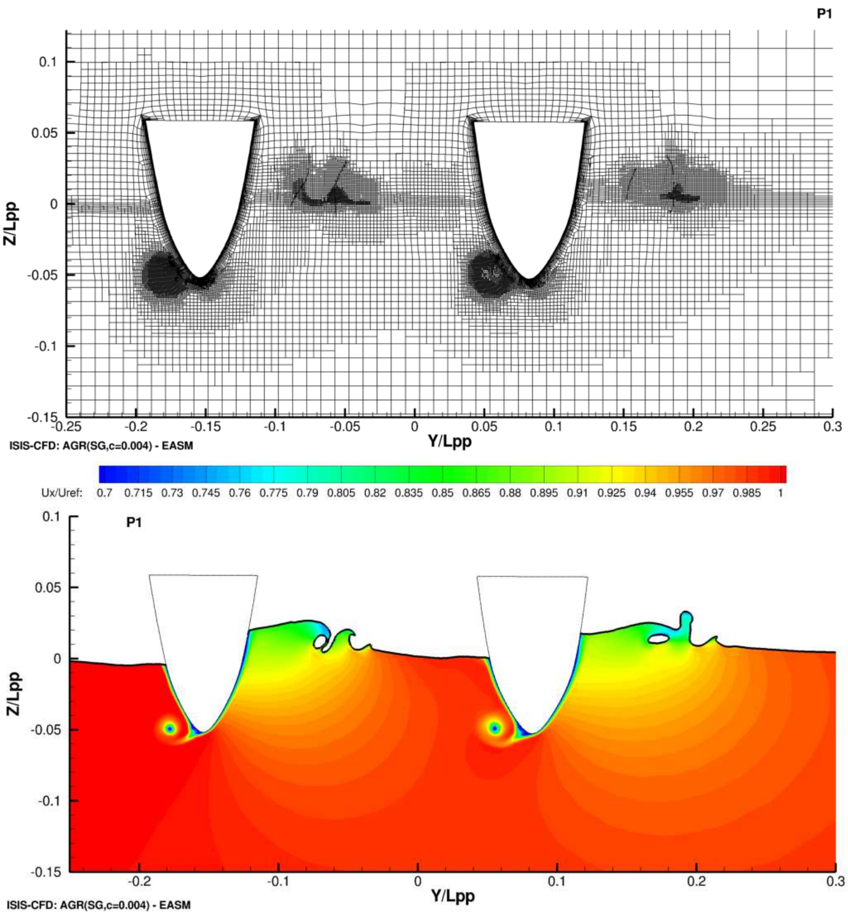

Figure 1: Flow around a catamaran in sideways motion: transverse cuts show the two hulls, the refined mesh (top), the axial velocity with longitudinal vortices and breaking bow waves (bottom).

REFERENCES

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