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Final Report

The aim of the stay at the Centre of Autonomous Marine Operations and System (AMOS - NTNU), Dept. of Marine Technology, NTNU, in Trondheim is the further development of the methodology Harmonic Polynomial Cell (HPC)[SF12][SF14] for the solution of the Navier-Stokes equations in the two dimensional incompressible viscous flow. The activity is part of CNR-INSEAN/NTNU collaboration. In 2016, within the CNR Short Term Mobility framework, the activity focused on the development of an efficient and accurate numerical model for potential flow with emphasis on the free surface tracking algorithm in case of large deformation and moving body. The outcomes have been stated in the paper [HBLG]. The success in the generalization of the HPC method, from Laplace to Poisson equation solver [BLA+15], has stimulated to a novel spatial high-order numerical method for the solution of the Navier-Stokes equation by the HPC approach. Under supervision of Proff. Odd M. Faltinsen, Claudio Lugni and Marilena Greco the present activities aimed at the validation of the proposed method. Main focus was on the implementation of the quadtree mesh refinement approach. Indeed, the HPC method, classified as field method with structured grid, requires, for two-dimensional problems, the discretization of the whole computational domain in quadrilateral cells. Quadtree strategy has been identified as the best candidate to fulfill the requirements of accuracy and computational efficiency. In figure 1 (panel A), is shown a generic example

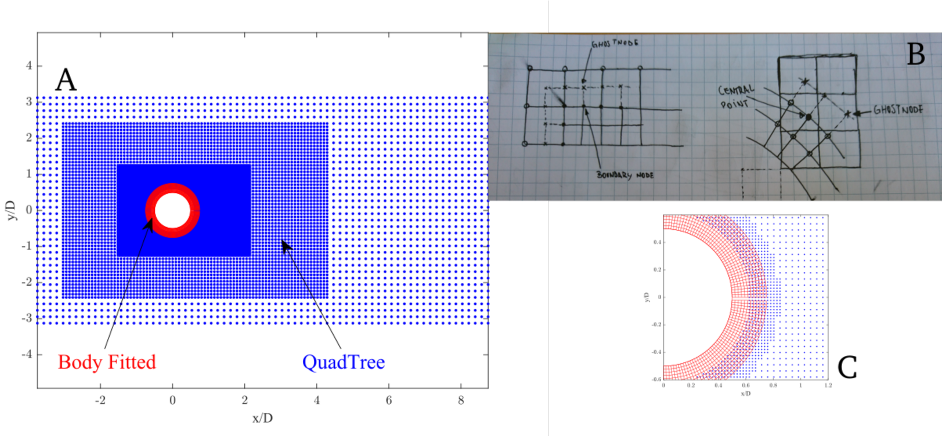

Figure 1: Panel A - mesh refinement applying quadtree method for the two-dimensional problem of a flow around a circular cylinder. Panel B - Hand drawing representing the strategies used in the link between different levels of refinement by using “ghost nodes”. Panel C - Magnification of the grid in the neighbourhood of the cylinder which highlights the intersection of the background (blue) and the body fitted (red) grids.

of mesh refinement for a flow around a cylinder. The blue dots represent the cartesian grid meshing the background field. Red dots identify a body-fitted grid overlapping the background one. It is evident as the cartesian grid is unable to map the curved surface of the cyclinder. Similar issue occurs when an uneven body is present in the field. The strategy of a body fitted grid is an accurate and quite general solution that has been implemented in the solver (figure 1, panel A and C). The body fitted grid allows the treatment of any kind of geometries and ensures a good discretization of the boundary layer, possibly associated with the use of a quadtree refinement or a simple stretching along the normal direction. The main work for the quadtree implementation has been focused on the definition of the links between the different levels of refinement. The boundary nodes of each level (figure 1, panel B) are considered as “ghost” nodes which not belonging to the unknown of the problem; they are only used to interpolate the solution from the upper (coarser) level of refinement. Interpolation is done by using the HPC approach, which preserves the same order of accuracy. A similar approach has been implemented also at the boundary between the body fitted and the background grid. The overlapping area and the ratio between the cell size of the two meshes have been investigated. Several test cases, e.g. two-dimensional Poiseuille flow, lid driven flow problem, flow around a circular cylinder at different Reynolds numbers and impulsive start of a thin flat plate [PP80] have been studied to verify the reliability and the theoretical fourth order of accuracy of the proposed method. The ongoing research activity concerns:

- Dynamic mesh refinement to optimize the computational cost and deal with moving bodies
- Writing a manuscript on the novel proposed method and the obtained results, It will be submitted as soon as possible to a peer review international journal

References

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