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Numerical simulation of shallow-water and floating object nonlinear interactions

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In this work, a novel numerical algorithm is introduced for the study of nonlinear interactions between free-surface shallow-water flows and a partly immersed floating object. The object's motion may be either prescribed, or computed as a response to the hydrodynamic forcing. Away from the object, the nonlinear hyperbolic shallow-water equations are used, while the description of the flow beneath the floating object reduces to a nonlinear algebraic equation for the free-surface, together with a nonlinear ordinary differential equation for the computation of the discharge. In both domains, the model accounts for the possible topography variations. When a free-motion is allowed (with heaving, surging and pitching in the horizontal one-dimensional case), this set of equations has to be supplemented with the Newton's second law for the object's motion, involving the force and torque applied over the object by the surrounding fluid, and a part of this external forcing is regarded as an added-mass effect, in order to benefit from its stabilizing influence. At the discrete level, we introduce a discontinuous Galerkin (DG) approximation relying on some arbitrary-order polynomials. This DG method is stabilized with a recent \textit{a posteriori} Local Subcell Correction method through Finite-Volume, in the vicinity of the solution's singularities. The motion of the water-object contact-points is described with the help of an Arbitrary-Lagrangian-Eulerian description. We show that the discontinuous nature of the chosen DG approximation leads to a very natural coupling between the exterior and interior flows, resulting in a global method which ensures the preservation of the water-height positivity at the sub-cell level, preserves the class of motionless steady-states (well-balancing) and preserves the Geometric Conservation Law. Several numerical computations, involving well-balancing, prescribed motions and their impact on the surrounding fluid, or the nonlinear interactions between the object and surface waves, are investigated and highlight that our numerical model effectively allows to model the wave-floating body interactions, with a robust computation of the air-water-body contact-points evolution, as well as of the possible strong flow singularities, and retains the highly accurate sub-cell resolution of DG schemes.

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