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Implementing VOF-PLIC Methods into REEF3D::CFD for Detailed Modelling of Breaking Waves

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ABSTRACT

The dynamics of breaking waves are generally of significant interest for marine engineering disciplines, since they result in considerable slamming forces on structures, when interacting with them (Kamath et al., 2016). A key aspect regarding the precision of the wave breakup dynamics simulation is the correct convection of the free surface. The Navier-Stokes based solver REEF3D::CFD uses a signed distance function for representing the free surface on a structured, staggered, cartesian mesh (Bihs et al., 2016). While comparison to experiments proved that the signed distance function implementation in REEF3D::CFD is able to model the macroscopic shape of breaking waves with great precision (Aggarwal et al., 2019), it is not as well suited for capturing details like spray and green water separation. The goal of this project is therefore to implement an alternate free surface representation method into the solver REEF3D::CFD, to enhance the resolution of breaking wave modelling.

The method to be implemented is the Piecewise Linear Interface Capturing Volume of Fluid (PLIC-VOF) method, first described by (Youngs, 1982). This method represents the free surface by combining a VOF field with a geometrical representation of the free surface as linear planes on a sub-grid scale. Key aspects of this method are deriving the planes from the VOF-field and advecting the planes to update the VOF-field to the next time step (Düz et al., 2016). For both aspects multiple approaches are described in literature. For defining the planes, namely the ELVIRA method and the Mixed-Young-Centred are of interest, while for the advection a variety of explicit, implicit and mixed lagrangian schemes exist (Düz et al., 2016). While the precision of these methods is frequently tested, discussed and compared in literature, their suitability for simulating violent wave breakups in the scope of practical applications is less clear. Especially since for practical cases, not only the precision of representing interface convection is of relevance, but the method's stability in combination with other aspects of the solver, as the Runge-Kutte time advection or the density field is crucial. This project thus takes on the challenge of implementing and combining named methods to build a functioning model for violent breaking waves as a part of the solver REEF3D::CFD, that can handle violent impacts on structures and ships, while resolving the complex free surface deformation and breakup.

References

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