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Advances in high order sharp immersed methods on adaptive grids

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ABSTRACT

Immersed methods offer powerful advantages over traditional body-fitted techniques for solving differential equations in complex, moving domains in ocean engineering applications. By eliminating the need to create and maintain body-conforming grids, these methods are especially suited for multiphysics problems with moving boundaries. However, most existing immersed methods are only first- or second-order accurate, which leads to prohibitive resolution requirements for high-fidelity 3D simulations of vortical flows. In this talk, I will present our work on a high-order finite-difference-based immersed boundary and interface discretization, along with our error and stability analyses for stationary and moving boundaries (Gabbard and van Rees, 2023). I will show applications to linear and nonlinear elasticity (Gabbard and van Rees, 2025). and the incompressible Navier–Stokes equations (Ji, et. al, 2025). I will also describe our 3D multiresolution grid adaptation approach, based on high-order interpolating wavelet transforms within a scalable parallel framework, achieving predictable convergence across different wavelet orders (Gillis and van Rees, 2021, Gabbard et al., 2025). Finally, I will demonstrate how combining high-order immersed methods with adaptive grids enables robust, accurate simulation of 3D incompressible flows with moving immersed boundaries.

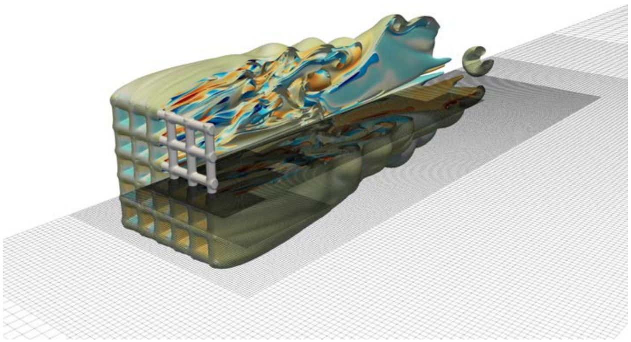

Figure 1: Vorticity field of the 3D flow past a porous screen, simulated using a high order immersed method on a wavelet-based adapted grid

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