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Title:

Accurate and Automated Handling of Moving Boundaries in Fluid Flow Simulation

Abstract:

Moving-boundary flow simulations are an important design and analysis tool in production engineering. Interface-capturing offers flexibility for complex free-surface motion, while interface-tracking is very attractive due to its mass conservation properties at low resolution. We focus on these alternatives in the context of flow simulations based on stabilized finite element discretizations of Navier-Stokes equations, and explore space-time formulations that allow extra flexibility concerning grid design at the interface.

Space-time approaches offer some not-yet-fully-exploited advantages; among them, the potential to allow unstructured space-time meshing. New methods for generating simplex space-time meshes have been developed, e.g., allowing arbitrary temporal refinement in selected portions of space-time slabs. The resulting tetrahedral and pentatope meshes are being used in the context of cavity-filling flow simulations, such as those necessary to design injection molding processes [1]. A related approach allows for robust and accurate handling of topology changes, as often encountered in free-surface flows and in fluid-structure interaction with dynamic contact [2].

Many of those novel numerical methods involve multiple discretization points in the time direction, at least in selected spatial areas. And in some cases, the entire space-time domain is solved for at once. This opens a whole range of questions concerning efficient use high-performance computing platforms, from the choice of proper domain decomposition, to the parallelization and preconditioning strategy. Examples of the fully-coupled space-time problems will be presented, including flows past valves involving topology changes, and fluid-structure interaction.

This is joint work with Norbert Hosters, Moritz Billen, Blanca Ferrer-Fabón, Jegor Kravchenko, and Gereon Kornmaier.

References

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[2] M. von Danwitz, P. Antony, F. Key, N. Hosters, and M. Behr, Four-Dimensional Elastically De- formed Simplex Space-Time Meshes for Domains with Time Variant Topology, International Journal for Numerical Methods in Fluids 93 3490–3506, 2021.