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COUPLING OF FINITE ELEMENT AND FINITE VOLUME METHODS FOR FLUID-STRUCTURE-INTERACTION IN A MONOLITHIC SCHEME

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In this talk we present the coupling of two different discretization methods for Fluid-Structure-Interaction using a monolithic approach. We use the finite element method for the discretization of the structure and the finite volume method for the discretization of the fluid. Both discretizations are coupled within a monolithic scheme, i.e the fluid and structure sub-problems as well as the coupling conditions for velocity and displacements are assembled into one large algebraic system [1] [2], [4].

The interaction of fluids and structures shows up in many fields of engineering and life-science. A particular field of interest is the simulation of blood flow in large arteries, since many diseases in arteries are closely related with blood flow and the interaction of blood and the artery wall.

On the numerical side, it is possible that different discretization methods for fluid and structure have to be coupled. In fact, for many applications in fluid dynamics the finite volume method is the first choice. For the simulation of structural mechanics the finite element method is one of the most, if not the most popular discretization method. [3]

Therefore the coupling of finite element and finite volume methods for Fluid-Structure-Interaction is of substantial interest. The crucial challenge in coupling fluid and structure is the transfer of forces and displacements at the fluid structure interface. This coupling has to be carried out in a stable and efficient way. We combine the two different discretizations in a monolithic formulation, i.e. the transfer of forces and displacements is fulfilled in a common set of equations for fluid and structure, which is solved simultaneously.

We model the fluid by means of the incompressible Navier-Stokes equation in an Arbitrary-

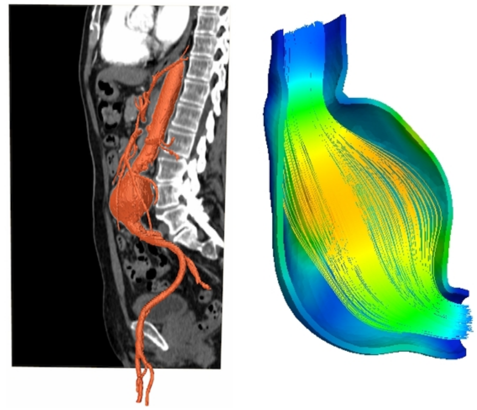

Figure 1: Simulation of the blood flow in an abdominal aortic aneurysm

Eulerian-Lagrangian formulation, while we use a pure Lagrangian formulation for the structure. This leads to an additional quantity to be coupled, a domain velocity for the fluid domain, which we can handle implicitly or explicitly in our simulation framework.

For the discretization in time we use different implicit first and second order time stepping schemes. We illustrate the performance of our approach along patient specific simulations, which are based on geometries derived from clinical data. As a consequence of the complexity of the considered geometries, we end up in algebraic systems with a large number of degrees of freedom, which makes the use of parallel solvers mandatory. Here, a good choice for an efficient preconditioning strategy is important. Our solver bases on the application of Newtons method using iterative solvers within a multi-level method. The multi-level method is constructed on a hierarchy of unstructured nested meshes.

In this talk we discuss both, the coupling approach of the two different discretizations as well as the efficient solution of the arising large nonlinear system.

REFERENCES

[1] Barker A. and Cai X., Scalable parallel methods for monolithic coupling in fluid-structure interaction with application to blood flow modeling. Journal of Computational Physics, 2010

[2] Crosetto, P. and Deparis, S. and Fourestey, G. and Quarteroni, A., Parallel Algorithms for Fluid-Structure Interaction Problems in Haemodynamics. SIAM J. Sci. Comput, 2011

[3] Idelsohn, S. and Oate, E., Finite volumes and finite elements: Two good friends. International Journal for Numerical Methods in Engineering, 1994

[4] Tezduyar T. and Sathe S. and Stein K., Solution techniques for the fully discretized equations in computation of fluid structure interactions with the space time formulations. Computer Methods in Applied Mechanics and Engineering, 2006