Operator-split reduced order models for problems with moving interfaces.

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I will discuss fast solvers, reduced order models, and optimization methods for fluid-structure interaction problems in the zero Reynolds number regime. Our goal is to design a deterministic lateral displacement (DLD) device to sort same-size biological cells by their deformability, in particular to sort red blood cells (RBCs) by their viscosity contrast between the fluid in the interior and the exterior of the cells. A DLD device optimized for efficient cell sorting enables rapid medical diagnoses of several diseases such as malaria since infected cells are stiffer than their healthy counterparts. In this context, I will first describe an integral equation formulation that delivers optimal complexity solvers for this type of problems. Despite its excellent theoretical properties, our integral equation solver remains prohibitively expensive for optimization and uncertainty quantification. I will then summarize our efforts to reduce the computational costs, starting from low-resolution discretization, domain truncation, and model reduction. Model reduction is used to accelerate the action of specific and very expensive nonlinear operators. The final scheme blends ultra low-resolution solvers (who on their own cannot resolve the flow), several regression neural networks, and an operator time-stepping scheme, which we introduced to specifically enable the use of surrogate models. We have used our methodology successfully for flows that are completely different from the flows in the training dataset. I will present results that demonstrate the capabilities of the methodology.

This is joint work with Gokberk Kabacaoglu.