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DIRECT NUMERICAL SIMULATION FROM 3D IMAGING

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In the last decade, the finite element method has shown to be a powerful and accurate computational tool to deal with material behavior and fluid-structure interaction simulations, with the increase on the computational power through the use of grids or cloud computing. On the other hand, numerical description of the researched objects with the improvement of imaging techniques, like X-Ray tomography (micro or nano) is very interesting, since it accesses the heterogeneity of the different phases with a definition and quality that may be very important. In the literature, the classical method to generate finite element meshes from images (2D or 3D) is based on a three-step processes: segmentation, for the identification of the different phases in the image; construction of a surface mesh for each phase, representing its boundary; construction of one or several volume meshes on which the specific properties of each phase can be defined.

In this paper, we propose an efficient way to build directly the volume finite element representation of the multiphase domains using an "image immersion" method, by skipping the Marching Cubes' step. Before mapping the image values in the mesh, we apply mathematical morphology treatments to the image, such as segmentation, distance to the interfaces function construction, and etc. Then, the treated image values are mapped in the coarse initial mesh by direct interpolation, providing the distance field distribution on the mesh. An appropriate error estimator built from this distance is used to compute a metrics field that our topological mesher will consider to adapt the mesh [1]. Finally, we have implemented a reinitialization procedure that, coupled to the automatic anisotropic mesh adaptation algorithm, allows the smoothing of the interpolated distance, but also the built-up of a smooth and regularized Heaviside function of this distance, which is actually a phase function. Meshes obtained using these techniques are well adapted for monolithic based methods (one mesh containing all the phases, each represented by an implicit - phase - function, like in classical diffuse interface methods). Furthermore, mesh adaptation provides nodal enrichment near phases "boundaries or interfaces", which will allow results to converge towards a "sharp-interface" solution.

Computations on such meshes will illustrate the relevance of our methodology. Firstly, we will show general cases of multiphase flows on common 2D pictures, all these 2D pictures can be taken from Paint, Camera, and even Smartphone. Secondly, for the 3D cases, the 3D images contain a huge number of fibers. Flows are calculated using a stabilized mixed finite element method, obtained through discretization of the Navier-Stokes equations and by imposing the rigid body motion.

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