Massively parallel adaptive reconstruction methods for real data based numerical simulations

Luisa Silva*, **Thierry Coupez*** and **Hugues Digonnet***

* Ecole Centrale de Nantes
High Performance Computing Institute
1 rue de la Noë, 44321 Nantes Cedex 3, France
e-mail: luisa.rocha-da-silva@ec-nantes.fr, web page: https://ici.ec-nantes.fr/

ABSTRACT

In recent years, imaging techniques have well improved in many sectors, providing accurate numerical descriptions from 2D or 3D images, with applications in different fields, from medical research to material science. In this paper, a methodology to build a numerical description under the mesh format has been implemented and is used for massively parallel finite element numerical simulations, directly based on the image information to obtain an accurate 3D representation [1, 2].
Firstly, mathematical morphology techniques process the image data, providing the specific features of interest for the simulations. Then, the immersed image method interpolates the image information on an initial mesh. Then, an iterative anisotropic mesh adaptation operator has been developed to construct the optimal mesh, based on the estimated error concerning the image interpolation. To perform simulations, one needs to build regularized phase functions, corresponding to the objects we wish to distinguish in the images. Two main advantages of having such functions are: the gradient of the regularized function performs better for mesh adaptation; the regularized function may be directly used in the finite element solver for defining the material properties distribution. To obtain them, a modified convective level-set approach, through the resolution of an hyperbolic equation of the Eikonal type, has been implemented. Finally, flow is determined by solving the multiphase Navier-Stokes equations with a Variational MultiScale method [3], fully coupled to advection, image immersion, anisotropic remeshing and redistancing. All these developments have been extended in a massively parallel context [4] and have shown good performance up to around 200,000 processing cores, meaning 14 billion nodes in 3D cases.
Two types of applications are studied in this work: flow simulations on random fibrous structures issued from in-situ 3D X-Ray tomography imaging; flows in urban environments, where 3D reconstructions comme from different GIS (Geographic Information Systems) supports.

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