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Image-Based Computational Homogenization using Level Sets and X-FEM

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The emergence of devices allowing an accurate characterization of material microstructures led to the need of computational methods which have the capability to handle this amount of geometrical information. Many approaches have been proposed for the computation of highly heterogeneous materials: (1) statistical and (2) approaches using directly the digital image. This last class of approaches classically uses the finite element method: Voxel-based mesh leads to expensive models with a jagged geometry. Otherwise geometrical informations can be captured from the image then meshed, which can be tedious for 3D complex microstructures. This work presents the advantages of coupling the level set method with the extended finite element method (X-FEM) in order to solve homogenization problems. One of the key features of this approach is the separation between the geometrical data, which are processed by the level set method, and the mesh which does not need to conform to the microstructure geometry thanks to the X-FEM method [1]. This method is based on the partition of unity framework and makes possible the representation of material interfaces or holes inside the elements by means of proper enrichment functions. Therefore, finite elements are freed from their need to conform to the geometry. In addition, level-set are also used to segment the digital images, which leads to a fully integrated approach. We also propose the use of quadtree-based meshes, in order to work on structured mesh which are well fitted to both image structure and mechanical needs. This numerical framework is applied on several examples in order to obtain the overall elastic properties of heterogeneous materials, by solving the homogenization problem posed on their microstructure.

References

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