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3D TOPOLOGY OPTIMIZATION WITH H-ADAPTIVE REFINEMENT BASED ON THE CARTESIAN GRIDS FINITE ELEMENT METHOD (CGFEM)

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Abstract: Regarding optimization of structural components, topology optimization has become one of the most popular methods to achieve significant reductions in mass and volume. The topology optimization algorithm considered in this paper, the SIMP method, is described in Bendsøe 1989 [1]. Topology optimization is an iterative process, which requires the Finite Element Method (FEM) to obtain the objective function and gradients. A better performance of FEM can be achieved if all the elements have a uniform shape. This is usually impossible with standard FEM where elements must fit the boundary of the working space. In this work, we propose the use of the Cartesian grid FEM (cgFEM) [2], instead of the standard FEM. The main features of this method are the use of Cartesian FE grids independent of geometry and an efficient hierarchical data structure. The SIMP method has been adequately adapted to the cgFEM framework, where elements can be cut by the boundary. In addition, we propose the use of h-adaptative mesh refinement in the optimization loop as a way to improve the accuracy in the definition of the contour of the component provided by optimization. The iterative process begins with a mesh of uniform element size. SIMP convergence requirements are relaxed to avoid a large number of iterations. Once this process reaches the prescribed convergence level, the elements with intermediate density levels are refined, halving their element sizes, and a new SIMP loop will then start. This process will be repeated until a minimum prescribed element size is reached. The use of h-adaptative refinement leads to solutions that, being topologically similar to those obtained with the initial coarse uniform mesh, have a high contour definition. This high quality definition of the contour, where intermediate values of density are practically nonexistent, noticeably simplifies the manufacturing of the topology-optimized geometries. [1] M. P. Bendsøe, 1989. Optimal shape design as a material distribution problem. Structural Optimization 1, 193-202. [2] E. Nadal, 2014. Cartesian grid FEM (cgFEM): High performance h-adaptive FE analysis with efficient error control: application to structural shape optimization. Ph.D. Thesis, Universitat Politècnica de València.