Topology optimization using the p-version of finite element method

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Abstract:

The traditional element-based topology optimization method, one density represents for a finite element [1], employs the same mesh for the analysis and design optimization that the low order finite element method is often used for the analysis. The high order finite element method or the p-version FEM [2] has been well developed and adopted by some front-end design tools such as MSC/PROBE and pro/ENGINEER. However, the p-version FEM has not been widely used in traditional topology optimization due to the high computational cost in comparison to using low order finite elements for systems with the same resolution. This study proposes a multiresolution topology optimization (MTOP) approach using the p-version FEM. Different from traditional element-based optimization approach, the proposed multiresolution approach employs three different meshes for the finite elements, the density elements, and the design variables [3]. In this study, the finite element mesh is coarser than the density and design variable meshes; therefore, each finite element consists of a number of density elements that can represent material variation within one finite element. The p-version FEM uses higher polynomial degrees for the shape functions which can thus provide more accurate approximation solution than the h-version FEM for a similar computational cost [4]. Numerical examples demonstrate that the proposed multiresolution topology optimization approach using the p-version FEM provides high resolution results with reasonable computational cost.

References

1. Bendsøe, M.P. and N. Kikuchi, *Generating optimal topologies in structural design using a homogenization method.* Computer Methods in Applied Mechanics and Engineering, 1988. **71**(2): p. 197-224.
2. Szabo, B.A. and I. Babuska, *Finite element analysis*1991: Wiley New York.
3. Nguyen, T.H., G.H. Paulino, J. Song, and C.H. Le, *A computational paradigm for multiresolution topology optimization (MTOP).* Structural and Multidisciplinary Optimization, 2010. **41**(4): p. 525-539.
4. Szabó, B., A. Düster, and E. Rank, *The p-Version of the Finite Element Method.* Encyclopedia of computational mechanics, 2004.