Title: Level-set and ALE based topology optimization using nonlinear programming

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Abstract:

Level-set based topology optimization is nowadays well studied because of its potential in structural optimization; the shape boundaries of the targeting structure is always clear, while the shape and topology of the target structure are changed during optimization. In the level-set method, a scalar function is used to represent the shape and topology of the target structure in Eulerian coordinate system. If the value of the scalar function is positive at an arbitrary point in the design domain, we regard the point is in the material domain. On the other hand, if the value of the scalar function is negative, we regard the point is in the void domain. For the numerical analysis, the design domain is discretized with the Eulerian mesh, and the level-set function is maintained in the Eulerian mesh. Then, numerical techniques are required to compute the state variables because the shape boundaries of the target structure are not coincident with the Eulerian mesh in usual cases. One typical numerical technique is to allow intermediate material property around the shape boundaries. In other words, this technique yields so-called grayscale elements around the shape boundaries. In this manner, the state variables can be computed using the Eulerian mesh, that is, an additional mesh for computing the state variables is not required. However, grayscale elements are not preferred in the engineering view point because it is difficult to interpret their material status. To avoid this problem, we have proposed a level-set based topology optimization method where the arbitrary Lagrangian Eulerian (ALE) method is incorporated. In this method, we provide two types of mesh for level-set based topology optimization; one is the Eulerian mesh that maintains the level-set function, and the other is the ALE mesh for computing the state variables. Since the ALE mesh accurately tracks the shape boundary during optimization on the basis of the ALE method, grayscale elements can be completely eliminated. The proposed method was applied to metallic waveguide design problems and compliant mechanism design problems, and reasonable designs were obtained in our previous studies. In the previous studies, on the basis of the level-set equation, a simple scheme is adopted for updating the level-set function. In this presentation, however, the proposed method is enhanced with nonlinear programming. That is, the level-set function is updated using nonlinear programming. By doing this, we can easily deal with multiple nonlinear constraints, and also speed up the convergence. We will demonstrate the usefulness of the newly proposed method by solving several engineering design problems.