A coupled gradient-based shape and topology optimization method

Citation for published version (APA):

Document status and date:
Published: 23/10/2017

Document Version:
Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:
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Download date: 02. Aug. 2019
Introduction
Shape and topology optimization address different aspects of a structural design problem. **Shape optimization** is concerned with finding the optimal shape of a structure (Fig. 1(c)). The aim of **topology optimization** is to determine the material distribution for a fixed shape (Fig. 1(d)). However, the design with both optimal shape and topology often would be highly desirable.

Therefore, a coupled gradient-based shape and topology optimization method is proposed. It enables the consideration of shape variation in structural topology optimization.

**Coupled optimization model**
Such a coupled optimization model (1) is built to minimize the structural compliance $c$ with given material volume $V$ and geometry constraints.

$$
\begin{align*}
\text{minimize} & \quad c(a, \rho) = f^T u(a, \rho) \\
\text{subject to} & \quad V(a, \rho) = f, \\
& \quad l_m \leq a_s \leq u_m, \quad s = 1, \ldots, S \\
& \quad 0 \leq \rho_{\text{min}} \leq \rho_e \leq 1, \quad e = 1, \ldots, N
\end{align*}
$$

where $l_m$ and $u_m$ are the lower and upper bounds of shape design variable $a_s$; $\rho_e$ is the relative density assigned to each element $e$; $f$ is the given fraction between material volume $V$ and initial design domain volume $V_0$; $f$ and $u$ are the system force and displacement vector, respectively.

**Solution strategy**

![Flowchart of the solution strategy](image)

**Numerical examples**
A cantilever beam design problem, illustrated in Fig. 1(a), is solved by the coupled optimization method with different optimization sequences. The result of the optimization procedure is shown below.

**Conclusion**

The shape of a design domain has a large influence on topology optimization both qualitatively and quantitatively. Additionally, the optimization sequence might affect the convergent speed, however, it does not have a critical influence on the final outcome of the optimization procedure.