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Keio University

Thesis Abstract

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Thesis Title			
Structural Topology Optimization Based on Level Set Method for Multidisciplinary Design			

This dissertation presents a novel concept for allowing the structural optimization process to be influenced by specific designer inputs regarding topological properties and preferences, such as boundary curvature and location of voids. Although such inputs are specified, they are not strictly enforced as the proposed concept is posed as a multidisciplinary problem that finds a balance between engineering and design objectives. Within the scope of this dissertation, engineering objectives are associated with metrics such as compliance and design objectives are associated with topological properties that add aesthetic and/or functional value to the structure. For example, design objectives can also include aspects of architectural design.

There are many challenges to overcome in order to turn this concept into a reality. Multi-objective methods have to be used to solve this multidisciplinary design problem. A technique to express these topological properties and their preferences has to be defined. In addition, the proposed methods and techniques have to be fast.

A deterministic multi-objective method using a real valued function was developed to solve this unique multidisciplinary design problem that involves topological preferences. Before its application to topology optimization, the proposed multi-objective method was first validated by solving various sizing and shape optimization problems, where the solutions make up the Pareto front. Within sizing optimization problems, additional objective functions were introduced to reflect preference towards certain size values. Topology optimization in this dissertation is performed using level set based methods as the above-mentioned designer inputs specifying topological properties can be created very naturally, and with relative ease, within the level set framework. To allow the topology optimization process to be influenced by specified designer inputs, an objective function that measures deviation from those topological properties is proposed. This objective function suggests preference for the specified topological properties; preferences for boundary curvature and/or placement of voids in the structure. The specification for these preferences can be derived from different disciplines. For example, while boundary curvature can be linked to aesthetics, manufacturing constraints might require specific locations for voids.

In multi-objective structural size and shape optimization, sensitivity analyses involving FEM are computationally heavy. For these problems, it was found that the real valued function and the adjoint variable method can be combined for efficient sensitivity analysis, especially when the number of design variables greatly outnumbers the number of objective functions. In order to improve the time efficiency of the level set method used, a high pass strain energy filter and an adaptive scheme for removing elements determined to be of void material by the level set are also proposed to reduce computational cost by as much as 70%.

The numerical examples shown in this dissertation substantiate the innovative use of the methods and techniques described above to solve multidisciplinary structural design involving topological preferences. When aesthetics are considered an objective in structural topology optimization, the interpretation of the multidisciplinary optimization problem becomes one that searches for beauty and performance in topology.