Models and Methods for Structural Topology Optimization with Discrete Design Variables - DTU Orbit (06/08/2016)

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Structural topology optimization is a multi-disciplinary research field covering optimal design of load carrying mechanical structures such as bridges, airplanes, wind turbines, cars, etc. Topology optimization is a collection of theory, mathematical models, and numerical methods and is often used in the conceptual design phase to find innovative designs. The strength of topology optimization is the capability of determining both the optimal shape and the topology of the structure. In some cases also the optimal material properties can be determined. Optimal structural design problems are modeled as optimization problems and solved by numerical methods. The objective function in the problem often models the weight or stiffness of the structure. The functions defining the feasible set of the problem limit the structural response under loading. The constraint functions often model displacements, strains or stresses, or fundamental frequencies. The design variables are either continuous or discrete and model dimensions, thicknesses, densities, or material properties.
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This thesis is devoted to the development of mathematical models, theory, and advanced numerical optimization methods for solving structural topology optimization problems with discrete design variables to proven global optimality. The thesis begins with an introduction which is divided into five chapters. The introduction is followed by 14 scientific articles of which 12 are published in international scientific journals and two are submitted. The first chapter in the introduction presents a brief overview of structural topology optimization and motivates and describes the use of discrete design variables. The chapter also contains a statement of the general global optimization problem and the main consequence thereof. In the following chapter the structural topology optimization problems which are considered in the thesis articles are presented. The main emphasis is placed on the classical maximum stiffness problems. The problem statements are followed by a review of the models and deterministic global optimization methods for structural topology design with discrete design variables which have been proposed in the literature. The main contributions of each of the appended articles and manuscripts are presented in the fourth chapter. A concluding chapter summarizes the most important observation from the thesis and suggests topics for future research.
The structural topology optimization problems that are studied in this thesis are all intrinsically non-convex and can, in their natural formulations, normally not be solved to global optimality. Hence, most of the articles in this thesis rely on equivalent problem reformulations with certain desirable properties in combination with developments of advanced special purpose global optimization methods. The methods are often based on the concept of divide-and-conquer.
Despite the proposed theoretical and numerical advances, this thesis clearly indicates that solving large-scale structural topology optimization problems with discrete design variables to proven global optimality is currently not possible. On the positive side, the appended articles provide a large set of solved benchmark problems which can be used to validate new and existing methods and heuristics.
The computational experiments with several of the developed global optimization methods also indicate that they often quickly find good and even global optimal designs. This observation is indeed encouraging and attempts to turn the proposed methods into robust, efficient, and general heuristics are likely to be successful. Modifications of these methods can perhaps in the future compete, both in terms of popularity and in efficiency, with the algorithms that dominate the field today.

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