Structural topology optimization with accurate boundary representation using T-splines and Isogeometric Analysis

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Topology optimization is a computational design method that aims to determine the optimal material distribution within a specified design domain for achieving superior performance. This approach has improved significantly by the increasing advancement of computational capabilities in the last decades, while various methods for topology optimization have been developed. So far, the so-called density-based topology optimization is the most popular approach where the optimal material distribution is obtained by determining the existence of material in each point in the domain [1].

The vast majority of studies on topology optimization rely on finite elements analysis (FEA) for solving the structural analysis, while the densities of the finite elements are also used as the design variables in the optimization problem. One of the current challenges in this field is to adopt more accurate numerical analysis approaches that allow an accurate resolution of the boundaries between material phases. Numerous studies have been conducted aiming to achieve this goal, most of them suggesting to enhance the traditional FEA approach, for example using extended FEM (XFEM).

Nowadays, with the increasing progress in the field of Computer Aided Design (CAD), new numerical solution methods have emerged. The key point of these methods is that they adopt the same basis to represent the geometry as well as the solution field for the numerical analysis. This idea was outlined in [2] and is termed Isogeometric Analysis (IGA). One of the key advantages of IGA compared to FEM is that it can provide an accurate representation of the structure's boundaries. In principle, this could make IGA suitable for topology optimization with accurate boundary representation – however there are many challenges, as the geometry constantly evolves during the optimization process.

The main goal of the proposed approach is to allow for accurate boundary representation within topology optimization. So far, studies that utilize IGA for topology optimization rarely accommodate a crisp boundary between material phases (one exception is [3] where trimming is used). In the current work, the geometry is described using T-splines while local refinement and knot insertion techniques are utilized to accurately represent the structure's boundaries. Due to the continuously changing topology along the optimization process, a consistent sensitivity analysis is developed to meet the T-spline geometry representation and the IGA approach. Several challenges arise when aiming to maintain the design freedom as in FEM-based density-based methods, and possible remedies will be discussed in detail in the talk. The proposed approach is applied to structural design problems under static loads. The results are compared to traditional topology optimization approaches, in terms of accuracy and numerical efficiency.

References

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