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# Multi-Objective Topology Optimization of Multi-Component Continuum Structures via an Explicit Level-Set Approach

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## Abstract

This paper presents a framework for multi-objective topology optimization of multi-component sheet metal structures such as those often found in automotive body structures. In multi-component structures *base topology* refers to the equivalent monolithic (one piece) structure, while *joint topology* refers to the decomposition of base topology into multiple components. In practice, the primary reason for decomposition into multiple components is manufacturability concerns, and as such, the optimization model considers indicators of manufacturability and assembleability as objectives and/or constraints alongside the structural performance indicators such as weight and compliance. In general, base and joint topology optimization problems can be strongly coupled, and it can be difficult to derive gradients for manufacturability and assembleability indicators. As such, many popular topology optimization approaches that rely on gradients information are unsuited for this optimization task. On the other hand, non-gradient based optimization algorithms often perform poorly in problems that have a large number of design variables, as is the typical case in continuum structures. Limiting the scope in a previous study[1] to planar structures, a multi-objective genetic algorithm (GA) was tested for the generation of a four-dimensional Pareto-surface. However, even in a coarse-mesh design domain, the number of design variables exceeds five hundred, which caused the performance of GA to be poor. A two-stage approach that sequentially optimizes base topology then joint topology was also explored. While it was established (via full enumeration of a simple example) that not all Pareto solutions can be discovered via the two-stage approach, it was observed to be better in any realistically sized mesh, primarily due to the poor scalability of the single-stage GA.

The approaches adopted in this paper employ an explicit level-set (ELS) formulation of the design variables. Level-set approaches perform classification of a domain based on the value of a scalar function defined within the domain relative to some threshold. In conventional level-set approaches, definition of the scalar function involves many degrees of freedom, which in turn, requires derivation of gradients in order to carry out the optimization. In ELS however, the design variables are defined as the explicit values of the scalar function at a number of *knot points*, and a Kriging model is used to interpolate its value within the rest of the domain. By adopting the ELS formulation, the number of design variables becomes independent from the mesh size, and is reduced from several hundreds to a much more manageable range that allows approaches such as GA to work effectively. A study on a short cantilever structure is solved for twice as fine the mesh as in the previous study with only fifteen and fifty five design variables for the two and single-stage approaches respectively. Results show both the single and two stage approaches with the ELS formulation being successful and having different merits.

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[1] Zhou Z, Hamza K, Saitou K (2011) Multi-Objective Topology Optimization of Spot-Welded Planar Multi-Component Continuum Structures, *9th World Congress on Structural and Multidisciplinary Optimization*, Shizuoka, Japan