Development and Evaluation of Level Set Methods for Crashworthiness Topology Optimisation

Name: Mariusz Bujny  
E-Mail: mariusz.bujny@tum.de  
Supervisor: Univ.-Prof. Dr.-Ing. habil. Fabian Duddeck  
Chair of Computational Mechanics  
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Introduction
Although Topology Optimization [1] is widely used in many industrial applications, it is still in the initial phase of development for highly nonlinear, multimodal and noisy problems such as crashworthiness optimization. Since for such problems, gradient-based methods cannot be applied, a search for alternative approaches is inevitable. On the other hand, in the state-of-the-art methods for crashworthiness Topology Optimization [2], very strong assumptions about the properties of the optimization problem are made and heuristic approaches are used to optimize structures. As a result, in each of those methods, the optimality criterion is arguable.

The project aims to improve methods for early phase design of automotive car body structures via novel methods for structural shape and topology optimization. The focus hereby lies on advancing Topology Optimization methods by combining so-called Level Set Methods [3] introduced by the group of Sethian in the late 1980s and methods from the field of computational intelligence like modelling methods and evolutionary computation.

Proposal
A level-set-based crash topology optimization method is proposed. Unlike in the classical density-based approaches, the design parametrization is not done explicitly by defining the densities of the voxels filling the design domain, but implicitly, by the level set function, which indicates the interface between the regions occupied by material and void.
This allows for a clear definition of the material boundary, leading to the desirable properties in terms of manufacturability and accuracy of crash simulations. Furthermore, the number of design variables is reduced significantly via introduction of basis functions [4] allowing for an efficient use of the non-gradient optimization methods, like Evolutionary Algorithms. A method for optimization of solid structures, based on voxel elements, is developed [5], and the further application of the method to a direct optimization of thin-walled structures, based on shell meshes, is considered [6]. Due to the high computational costs of the Evolutionary Algorithms, the potential of applying different methods for cost reduction is evaluated: (i) exploitation of an approximate gradient information in local-search-enhanced hybrid evolutionary methods [7], (ii) application of the meta-modelling techniques for surrogate assisted evolutionary computation [8], (iii) introduction of an adaptive representation [9], with increasing number of basis functions during the optimization process based on data mining and machine learning techniques. The possibility of practical applications of the method is assured via introduction of manufacturing constraints. In the final stage of the project, both the issue of robustness and the multi-objective optimization [10] is addressed.

Fig. 1: Designs obtained with the method for optimization of solid (left) and thin-walled structures (right).

References