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MULTI-FIDELITY APPROACHES FOR CRASHWORTHINESS OPTIMIZATION

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Abstract: Structural optimization for crashworthiness is today an important topic for the automotive industry. Different optimization types (layout, topology, material, shape, size, robustness, reliability, etc.) and algorithms (gradient-based / gradient-free, physical / mathematical surrogates, evolutionary / genetic algorithms, etc.) have been introduced. Methods should be adapted to distinguish between optimization for high energy absorption or for low intrusions (safety cage), and between early and late development phases including the transition between both phases. For late phases, high-fidelity FEM models are normally used while for the concept phase low-fidelity models are more appropriate due to the lack of knowledge of detailed design aspects. For both, a high number of different vehicles, load cases, and disciplines have to be considered simultaneously. This means that the complexity of the optimization problem can only be handled by hybrid and hierarchical approaches establishing a multi-fidelity and partially decoupled methodology. Instead of using a numerical model with the best compromise between accuracy and efficiency, a high-fidelity model (FEM) with high accuracy is combined with often several low-fidelity models (mathematical and physical) with high efficiency. Here, recent results from the author's research groups are presented focusing on a new methodology, called Solution Space approach, for concept development using a sequential multi-fidelity approach. This is based on (i) decoupling a multi-vehicle and multi-disciplinary problem via low-fidelity physical models (e.g. lumped masses) including optimization of the component requirements and (ii) single discipline/vehicle/component optimizations with, as the first step, high-fidelity models. It is then proposed to realize the component optimization with a second multi-fidelity approach where a mathematical surrogate (Kriging, efficient global optimization, EGO) using high-fidelity FE models is enriched by gradients from a second low-fidelity physical surrogate (e.g. equivalent static load method, ESL). Examples for front and side impact cases will be shown. As outlook, these approaches will be embedded into a general overview on possible multi-fidelity optimization schemes for vehicular crashworthiness to motivate future developments and academic and industrial applications. Additional options for low-fidelity crash models will be given.