EVOLUTIONARY SHAPE OPTIMIZATION OF CRASHWORTHY STRUCTURES

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The design of automotive structures to improve crashworthiness and safety remains a challenging problem. The nature of these problems is dynamic and highly nonlinear, with many uncertainties in the loading conditions, boundary constraints and material properties. Further, the number of possible design variables can be very large, and the relationships among these variables are complex. Given this level of complexity, an engineer's intuition is often insufficient to identify a high quality design that simultaneously satisfies the targets for safety, cost, mass, and manufacturability.

Advancements in high-performance computing and in nonlinear dynamic structural simulation software have made it possible to virtually test potential designs prior to building and testing expensive prototypes. But these tools alone still require an engineer to develop a design based on intuition and numerous time-consuming iterations. The next level of advancement is software to automate the process of iterating over a large number of design scenarios and intelligently seek optimal values for those parameters that strongly affect product performance and cost. In the design of complex systems, this automated optimization procedure can significantly reduce development time, while substantially increasing quality.

Crashworthiness problems do not lend themselves well to classical optimization techniques because of their very multi-modal, non-convex design space. However, advanced evolutionary-based design approaches that employ a form of guided stochastic search algorithm have been successfully applied to these problems. The power of evolutionary algorithms can be increased by combining them with classical local optimization methods and/or by embedding them within adaptive agents — methods that communicate but work semi-independently on a common problem. The authors have developed and demonstrated such a hybrid approach to optimization, combining advanced evolutionary algorithms with local optimization. Within this approach, autonomous agents decompose a problem hierarchically, using divide-and-conquer rules. These agents simultaneously search a design space at various levels of resolution and may use different performance measures (combinations of objectives and constraints) and local search methods. The agents exchange information about the solution space with each other, helping them jointly to satisfy multiple constraints and objectives. The result is that improved solutions are found much more efficiently and effectively, even for design problems involving *hundreds* of variables. In addition, designs are made more robust by accounting for uncertainties *during* the design process.

This technology has been implemented into a software product called HEEDS (Hierarchical Evolutionary Engineering Design System). Using ABAQUS and LS-DYNA as the finite element solvers within the HEEDS optimization environment, this process has been applied to numerous automotive, aerospace and manufacturing problems. For example, its application to several automotive lower compartment rails has resulted in significant gains in performance (energy absorbed) along with up to 20% reductions in mass compared to baseline rails designed by experienced engineers.