Incorporation of Value-Driven Design in Multidisciplinary Design Optimization

Christina L. Bloebaum, Dennis and Rebecca Muilenburg Professor of Aerospace Engineering
Department of Aerospace Engineering, Iowa State University

Bryan Mesmer, Post-Doctoral Research Associate
Department of Aerospace Engineering, Iowa State University

Hanumanthrao Kannan, Graduate Student
Department of Aerospace Engineering, Iowa State University

The design of modern day large-scale systems is a highly complex task, involving thousands of individuals from multiple disciplines and various locations in vast organizations. Multidisciplinary Design Optimization (MDO) is a collection of frameworks that are used by design organizations to enable efficient determination of optimal designs of large-scale systems. Common usage of MDO frameworks involves establishing an objective function and requirements. The objective function, requirements and other parameters are then disseminated throughout the organization to various subsystem groups through the MDO frameworks. This paper will explore the use of value-driven design to establish requirement-free utility functions and how those utility functions can be successfully incorporated into existing MDO frameworks.

Value-driven design (VDD) provides a mathematically sound methodology for capturing all of the attributes of a design and converting those attributes into a singular value. The values of design alternatives are then compared directly to one another to determine the optimum design. This is dissimilar to objective functions commonly used in MDO which may be formed around product attributes, which do not fully capture the value of the product. Along with a value function, VDD drives to reduce or eliminate requirements. The requirements that are disseminated in MDO restrict the design space, possibly eliminating potential alternatives that have a dramatic objective function increase but are marginally infeasible. Typically requirements are altered during the course of the design process to allow design alternatives that were previously infeasible, showcasing the initial ambiguity of the requirements. VDD captures the ideas that are attempted to be projected from the establishment of requirements and incorporate them into the value function. The use of VDD value statements in MDO enables true optimum design, based on the value of the design, to be found as well as eliminating constraints on the design space, while preserving the MDO framework. Previous papers have discussed possible benefits of incorporating VDD value statements into MDO. This paper will expand upon the discussion by examining VDD incorporation into specific MDO frameworks.

This paper will examine the incorporation of VDD in both single-level and multi-level MDO frameworks. The single level frameworks to be examined include Multidisciplinary Feasible (MDF), Individual Disciplinary Feasible (IDF) and All-at-once (AAO). These methods use a single system level optimizer. Incorporation of VDD for single level frameworks will involve the use of a well-derived value function in place of the objective function and the elimination or significant reduction of requirements.

The multi-level MDO frameworks will include Collaborative Optimization (CO) and Concurrent Subspace Optimization (CSSO). Multi-level frameworks involve both system level optimizers and subsystem optimizers. Incorporation of VDD into multi-level frameworks will involve the process discussed for single-level frameworks as well as a decomposition of the value function for use by the subsystems. Simple examples will be used in the paper to demonstrate the ability to incorporate VDD into MDO frameworks and to display the benefits of such an integration of ideas. Comparisons will be made, using the examples, between VDD-MDO methods and MDO with the traditional objective function and requirements.