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Corresponding author: SONNEVELD, Jente
e-mail of corresponding author: j.s.sonneveld@tudelft.nl
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Title

Dynamic workflow generation applied to aircraft moveable architecture optimization

Authors

Jente S. SONNEVELD [1], Anne-Liza M.R.M. Bruggeman [2], Gianfranco La Rocca [3]. Tobie van den Berg [4], Bas van Manen[5]*

** Corresponding author*
[1] TU Delft, DELFT, 2629 HS, The Netherlands, j.s.sonneveld@tudelft.nl
[2] TU Delft, DELFT, 2629 HS, The Netherlands, a.m.r.m.bruggeman@tudelft.nl
[3] TU Delft, DELFT, 2629 HS, The Netherlands, g.larocca@tudelft.nl
[4] GKN Fokker, PAPENDRECHT, 3351LB, The Netherlands, tobie.vandenberg@fokker.com
[5] GKN Fokker, PAPENDRECHT, 3351LB, The Netherlands, bas.vanmanen@fokker.com

Abstract

Consolidated strategies and optimization algorithms can be used to perform multidisciplinary and multi-objective optimization of engineering products, as far as the architecture of the system to be optimized is fixed. Accounting for the complete system architecture design space in an optimization process is very challenging because of the presence of integer and categorical design variables (architecture variables) which lead to a combinatorial explosion of designs to be evaluated, and because of the hierarchical relationships, which may exist between some design variables. I.e., the number or existence of certain design variables may depend on the value assumed by other design variables, which makes the design vector dynamic and unknown a priori.

A practical approach to handle such challenging problems is to split them into smaller more tractable sub-problems, hence focusing on (the optimization of) certain preselected architectures. However, this approach prevents a true exploration of the entire design space and suffers from the initial architecture selection biases. Alternatively, a fixed length design vector can be constructed out of all possible design variables and a so-called imputation strategy [1] can be implemented to inform the optimizer to deactivate, at each iteration, the design variables that become irrelevant because of the value assigned to other variables, higher in the hierarchy. This approach is not trivial and may result in poor computational efficiency.

This paper discusses an alternative approach for architecture design space optimization, investigated in the DEFAINE [2] project for the design of an aircraft movable. Here categorical, integer and continuous variables are present, namely: type of material, number of spars and ribs and thicknesses of the various skin material zones. The number of skin material zones depends on the number of spars and ribs and their relative position. Thus, the exact number of design variables is known only once the movable model is generated and the intersection of the skin panels with spars and ribs is performed. When the material design variable is set to metal, the thicknesses of the various skin material zones are continuous variables. For composite they become discrete variables based on predefined laminate stacks. A nested optimization strategy is implemented to deal with the dynamic nature of the design vector, with an outer loop to handle the architecture variables (material and number of spars and ribs) and an inner loop to evaluate the number and type of design variables (skin material zones). Here, structural optimization is performed to minimize the movable mass, subjected to failure criteria constraints. The GKN Fokker's Multi-Disciplinary Modeler (MDM) [3,4] tool is used to automatically generate and analyze various moveable architectures. The TU Delft workflow formulation software KADMOS [5,6] is used to define the outer and the internal loop, which are then integrated and executed using the DLR's open source MDO workflow management system RCE [7].

The internal loop for structural optimization is dynamically formulated on the basis of the number and type of design variables derived from the execution of the outer loop.
The initial implementation proved effective in handling the hierarchal mixed integer nature of the design variables, with some limitations. At the moment of writing, a Design of Experiments is possible in the outer loop, and a full architecture design optimization is not possible yet. A strategy is currently being devised to automate the dynamic formulation and execution of the nested optimization problem, whose results are expected to be included in the final paper.

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