Introduction

The objective function in design optimisation represents the “goodness” of a system that we wish to improve i.e. a figure of merit. A typical figure of merit in aerospace design tends to be to minimise gross-takes-off-mass (GTOM), which usually acts as a good approximation to acquisition cost because a smaller aircraft carrying less fuel should cost less to build and operate. However, GTOM as a figure of merit is only valid at a fixed technology level and fixed operational requirements. Changes in, for example engine technology, avionics, materials, mission range, time on station, etc., can lead to a better system solution that can be more profitable or offer better performance capabilities.

The decision support framework developed from this research aims to identify ‘high-impact’ architectural functions that strongly influence the overall system value and cost. The methodology works by defining the architectural decision making process as a network by representing architectural functional elements as nodes and the connecting edges represent the physical and/or functional constraints imposed by the decision maker on the architectural space. The feasible architectures are then assessed to evaluate their impact on stakeholder value and cost. Value metrics act as a common measure of defining the ‘goodness’ of a systems performance. The intended result of the framework is to allow system architects to rationally trade between different architectural solutions and provide a means of numerically capturing the rationale behind the decision-making process. The framework makes use of Multi-Attribute-Utility Theory (MAUT) to capture stakeholder preferences, which allows the system architect to trade between stakeholder value and the cost of implementing and operating the system.

Decision Support Framework

- Construction:
  - Functional-Means Analysis: Captures and represents different architectural solutions in a tabular form.
  - N-squared matrix: Captures the compatibility relationships between different functional elements (i.e. the edges in the architectural network).
  - Logical Constraints: Quantifies the compatibility constraints in a mathematical form such that infeasible solutions are removed during the search phase.

- Search:
  - Uses algorithms from constraint programming, such as backtracking and constraint propagation to remove infeasible system solutions.

- Simulation:
  - The feasible system architectures generated from the search phase are simulated using physics-based/analytical models to capture system value, using MAUT, and life-cycle-cost.

- Representation:
  - The results from the simulation phase are represented in two parts. First as a Pareto-front of value vs. life-cycle cost (i.e. Pareto optimal solutions). Second, quantifying high-impact architectural functions in terms of their impact on value and cost. This is captured by using a variation of the main-effects analysis (from the Design of Experiments (DoE) literature) and using Page-ranking centrality measure (from network analysis literature).

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Case Study: Design of a Small Low-Cost Unmanned Aerial Vehicle (UAV)

The framework is validated by applying it to the design of a small UAV in use for costal monitoring and search and rescue operations. The main role of the UAV is to patrol costal areas for long periods looking out for vessels in distress, pollution, illegal activities, etc.

<table>
<thead>
<tr>
<th>Function</th>
<th>MEANS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize the range of potential architectural solutions</td>
<td>Pareto-optimal solutions</td>
</tr>
<tr>
<td>Minimize the size of the system</td>
<td>Pareto-optimal solutions</td>
</tr>
<tr>
<td>Minimize the weight of the system</td>
<td>Pareto-optimal solutions</td>
</tr>
<tr>
<td>Minimize the cost of the system</td>
<td>Pareto-optimal solutions</td>
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<tr>
<td>Minimize the power of the system</td>
<td>Pareto-optimal solutions</td>
</tr>
<tr>
<td>Minimize the complexity of the system</td>
<td>Pareto-optimal solutions</td>
</tr>
</tbody>
</table>

Figure 1: Representation of an architectural network

Figure 3: Functional decomposition at a platform level

Figure 4: Architectural constraint/compatibility network

The imposed constraints generated 22 feasible system solutions. Future work is focused on simulating all the architectural solutions and identifying high-impact architectural functions based on their impact on system value and cost.

Figure 5: Pareto front of a set of architectural solutions

Table 1: Functional-Means Analysis