Development of Robust Design Optimisation of Space Missions

Type **B** contract	
University of Strathclyde	Inventor
ESTECO SpA	Developer
Surrey Satellite Technology Ltd	Customer

Introduction

The aim of this project was the development of a prototype tool for preliminary robust design optimisation of space systems. The prototype tool can be used to efficiently estimate the propagation of aleatory and epistemic uncertainties in space system models and to enable the design of optimised systems with the goal to minimise the uncertainty impact on system budgets. The target application is the preliminary design of systems, subsystems and components.

The main concepts motivating the prototype development were proven during a previous Type A proposal "Robust Design Optimisation of Space Missions". The previous project showed how Evidence Theory can be used for Robust Design Optimisation in early design stages of space missions where two types of uncertainties have to be faced: aleatory and epistemic uncertainties. The aim of Robust Design Optimisation is to find optimal design points such that the performance indexes of the system remain relatively unchanged when exposed to uncertain conditions.

Evidence Theory provides a consistent formulation for both kinds of uncertainty and can be used as an alternative to the standard margin approach. The margin approach does not give a measure of the robustness of the design. Robustness measures assess how different a system budget can be if the value of the uncertain parameters departs from its initial estimate.

The Innovation

The Evidence Based Robust Optimisation algorithms developed during the Type A project were extended and generalised during this Type B activity. New heuristics were developed for the worst-case scenario optimisation with the Min-Max method to reduce the computational cost and solve convergence rate issues. An efficient strategy for system characterisation based on a subsystem decomposition was developed.

The inclusion of these algorithms in modeFRONTIER enabled the exploitation of all the features already available in modeFRONTIER, such as: i) the automation of the design simulation process, ii) the integration with various CAD/CAE applications, iii) the live analysis of running design optimisation sessions, iv) the data analysis and charting of the optimisation results, v) decision making.

Results of the ITI activity

The outcome of this Type B ITI project is a breadboard prototype for Evidence-Based Robust Optimisation which extends the functionalities of the software platform modeFRONTIER with the inclusion of an EBRO numeric library that enables the solution of a range of optimisation problems affected by epistemic uncertainties. The numeric algorithms were developed and extended by the University of Strathclyde. ESTECO implemented them as add-ons of modeFRONTIER, with a dedicated graphical user interface and documentation.

As a preliminary work the identification and analysis of scenarios relevant to EBRO was performed by ESTECO and the University of Strathclyde. The development of the EBRO modules in modeFRONTIER and the refinement of the numeric algorithms went on in parallel with frequent joint reviews. Constant feedback was exchanged during teleconference meetings between all the project partners.

The algorithms were tested on a series of mathematical benchmark problems. A few real-world examples were provided by the industrial partner SSTL and by ESA. SSTL use case was defined during a set of dedicated meetings. The University of Strathclyde elaborated the models for all the test cases. The test results proved the feasibility of the approach adopted during this project.

On a realistic use case the breadboard was also used to perform a sensitivity analysis to identify the most important uncertainty contributions and further reduce the computational cost of the system characterisation.

Future applications

The target application of the developed breadboard and methods is the preliminary design of systems, subsystems and components during early stage phases of aerospace missions. The tool can assist designers and decision makers in making optimal robust and reliable choices as an alternative to the current margin approach. The methods developed for this project can be applied also to other sectors, like manufacturing, to address epistemic uncertainty in the context of Systems Engineering.

Contacts

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