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EFFICIENT ROBUST OPTIMISATION FOR SPACE MISSION DESIGN IN THE FRAME OF EVIDENCE THEORY

Abstract

In the early phase of the design of a space mission an insufficient consideration for uncertain design parameters would lead to a wrong decision on the mission feasibility. Traditionally, a system margin approach is used to take into account the inherent uncertainty related to the computation of the system budgets. Although this is a consolidated approach, it does not give a measure of the robustness of the design. The term robustness is intended as the measure of the sensitivity of the system budgets (e.g. mass and power) to the uncertainties in the design parameters, i.e. how different a system budget can be if the value of the uncertain parameters departs from the initially estimated one.

This paper describes a way to model uncertainty and introduce it explicitly in the design process. The overall system design is then optimised, minimising the impact of uncertain parameters on the optimal value of the system budgets (or performance indexes). This process is generally known as robust optimisation or optimisation under uncertainty (OUU).

Most of the approaches of robust optimisation are based on gradient methods for multi-objective optimisation and on the treatment of uncertainty with probability theory. More recently, other approaches based on have been proposed, with a solution of the associated OUU with evolutionary computation techniques. is attractive for space mission design as it enables to model adequately both epistemic and aleatory uncertainties. This is questionable to the least for probability theory.

Although introducing epistemic and aleatory uncertainties in the design process would greatly improve the quality of the design (and would give a measure of the reliability of the result), it increases significantly the computational cost of any multidisciplinary optimisation.

In this paper, we present two approaches to tackle the OUU associated to the robust design of a space system: a direct solution through a multi-objective evolutionary optimisation algorithm and an indirect solution through a clustering algorithm. In the direct approach, the authors will focus on the techniques used to decrease the computational time by making the most of the information available during the optimisation process. The indirect approach is proposed to mitigate the computational cost related to the introduction of uncertainty in the design process. It will be shown on two different realistic test cases that the clustering method becomes clearly attractive as the number of uncertain parameters and the complexity of the modelling increases.