**A prototype tool for the robust design optimisation of space missions**

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1. **Abstract**

We present a prototype tool developed to efficiently estimate the propagation of epistemic uncertainties in space system models and to enable the design optimisation with the goal of minimising the uncertainty impact on system budgets. The prototype exploits advanced methods for Evidence-Based Robust Optimisation (EBRO) [1,2,3]. The target application is the preliminary design of systems, subsystems and components, as it is in the initial design phases that epistemic uncertainties (due to a lack of knowledge rather than to a probabilistic description of random phenomena) play a crucial role. Most of this work was done under an ESA-funded Innovation Triangle Initiative (“Demonstration of feasibility and use”) project.

The methods proposed, based on Evidence Theory (ET), are an alternative to the standard margin approach. In ET uncertainty can be quantified with two complementary measures: Belief (Bel) and Plausibility (Pl), which represent the lower and upper probability that an event can occur under the available evidence [4]. These measures can be used for a worst-case scenario optimisation of the overall system and for a rigorous quantification of the design margins, because Bel and Pl indicate the lower and upper probability that the design budgets will be as expected at the end of the design process once the design parameters are known exactly. Bel and Pl are computed using intervals of uncertainty with associated values of belief. Their computation with a straightforward application of ET grows exponentially with the number of epistemic uncertainties and can become soon prohibitive. Thus, efficient methods were implemented to reduce the computational cost [1,2,3]. These methods provide conservative estimates of Bel and Pl.

The prototype is a module of the multi-disciplinary optimisation and integration software modeFRONTIER [5]. The module extends modeFRONTIER numeric libraries with algorithms for min-max optimisation, min-min optimisation, and reconstruction of Bel and Pl curves based on evidence-based network models. The resulting tool provides a dedicated user interface and exploits all the features already available in modeFRONTIER to promote the automation of the design simulation process and facilitate data analysis.

In this article, we show the validation of the tool on a simple but illustrative model: the sizing of a nanosatellite composed of three subsystems (attitude and orbit control system, electrical power system and telemetry and telecommand) [6]. As design budget we chose the total mass. We started from a min-max optimisation to find the worst-case configuration and then we reconstructed the Bel curve with different levels of accuracy. Through a sensitivity analysis we were able to further simplify the model by reducing the number of epistemic variables and obtained consistent results for the reconstruction of the Bel curve.

1. **References**

[1] Ortega C. and Vasile M.: New heuristics for multi-objective worst-case optimization in evidence-based robust design, IEEE Congress on Evolutionary Computation, 2017.

[2] Vasile, M., Filippi, G., Ortega, C. and Riccardi, A.: Fast belief estimation in evidence network models, EUROGEN, 2017.

[3] Filippi, G., Vasile, M., Marchi, M. and Vercesi, P.: Evidence-based robust optimisation of space systems with evidence network models, IEEE Congress on Evolutionary Computation, 2018.

[4] Dempster, A.P.: Upper and lower probabilities induced by a multivalued mapping, The Annals of Statistics, Vol. 28, pp. 325-339, 1967.

[5] <https://www.esteco.com/modefrontier>.

[6] Alicino, S. and Vasile, M.: Evidence-based preliminary design of spacecraft, SECESA, 2014.

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