05/5201 The application of clouds for modelling uncertainties in robust space system design domain

Type of activity: Medium Study (4 months, 25 KEUR)

Background

The complexity of space ESA systems increases and requires a more innovative approach to system design & operation development with respect to safety and dependability. The currently mainly deterministic space system design and operation development approach needs to be advanced to a probabilistic approach to better allow for a systematic system optimization. Uncertain system design variables are traditionally modelled either by probability distributions, by range of values (intervals), or by membership-degree functions (fuzzy sets). However, in general, the probability of the failure of a particular design cannot be determined reasonably without knowing the joint distribution of the uncertain variables, or having sufficient amount of data samples from past observations. In the field of robust, verifiable design, the probability model assumptions are replaced by deterministic data, for which rigorous worst-case analysis can be performed by using numerically reliable tools, like verified interval calculations. A promising method to achieve such a goal is based on the concept of clouds. Clouds capture useful properties of the probabilistic and fuzzy uncertainties, and are able to handle multivariate uncertainty problems in algorithmic ways by reducing the necessary calculations to global optimization and constraint satisfaction problems. These techniques allow us to compute bounds for the expected values of multivariate random functions, and also, for probabilities of arbitrary statements involving random variables. Based on the theoretical research on clouds, and its suggested applicability for larger dimensional real problems, the concept is worth to be investigated in practice on small real life design examples.

Study Objectives

- Formulate sample space design applications in the design modelling frame of [4].

- Investigate the possibility of modelling the random (uncertain) design variables by clouds.

- Quantify the kinds of available uncertainty information for the sample applications and study their reliability.

- Verify the robustness of the possible existing solutions of the sample design cases (e.g. by determining a proper failure probability value to the outcome of the design), and propose “safe” designs (for given failure probabilities) as substitution solutions, by using global optimization and constraint satisfaction techniques.

References

[1] D. McCormick and J. Olds, "A Distributed Framework for Probabilistic Analysis," AIAA 2002-5587, 2002 AIAA/ISSMO Symposium on Multidisciplinary Analysis and Design Optimization, Atlanta, Georgia, September 4-6, 2002.
http://www.ssdl.gatech.edu/main/ssdl_paper_archive/aiaa_2002-5587.pdf

[2] Multidisciplinary Optimisation in Mission Analysis and Design Process. ESA GSP contract. Prime Contractor: Alenia Spazio, Consultant: Politecnico di Torino.
http://www.esa.int/gsp/ACT/doc/GSP-RPT-03N16-AleniaSpazioMDO_FinalReport.pdf

[3] A. Neumaier, On the structure of clouds. Manuscript.
http://www.mat.univie.ac.at/~neum/ms/struc.pdf

[4] A. Neumaier, Clouds, fuzzy sets and probability intervals, Reliable Computing 10 (2004), 249-272.

[5] A. Neumaier, Uncertainty modeling for robust verifiable design.
http://www.mat.univie.ac.at/~neum/ms/uncslides.pdf