Uncertainty modeling with clouds in autonomous robust design optimization

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Abstract

Traditional modeling of uncertainties faces several problems. The lack of knowledge about distributions of uncertain variables or about correlations between uncertain data, respectively, typically leads to underestimation of error probabilities. Moreover, in higher dimensions the numerical computation of the error probabilities is very expensive, if not impossible, even provided the knowledge of the multivariate probability distributions.

The new concept of clouds for handling uncertainties was introduced by Neumaier in 2004. Clouds combine the concept of a fuzzy set and that of a probability distribution in a computationally attractive way. They capture useful properties of the probabilistic and fuzzy uncertainties, enabling the user to utilize reliably the collected empirical information (even if very limited in amount) and to specify the uncertainty information adaptively. Provided the uncertainty information is given by marginal distributions or only intervals for the uncertain variables, a special class of clouds based on potential functions is constructed.

Clouds are useful to perform worst case analysis in design optimization. The clouds yield a region of relevant scenarios that affects the worst case of a specific design with respect to a certain confidence. Then the task of robust design optimization can be formulated as solving the bi-level problem of finding the design with best worst-case.

The new methods are applied to problems for autonomous optimization in robust spacecraft system design at the European Space Agency.