On constrained distribution-free p-boxes and their propagation

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Abstract

Propagating uncertainties through computational models is a key ingredient in uncertainty quantification in engineering. In general, uncertainty can be characterized as aleatoric, caused by variability, and epistemic, caused by lack of knowledge. Imprecise probability theory offers a natural framework to deal with both through, through sets of probability distributions. Among the latter, probability-boxes (p-boxes), which specify upper and lower bounds on admissible cumulative distribution functions (CDFs), are well established in the literature. We hereby introduce a novel class of p-boxes, *constrained distribution-free p-boxes*, that is based on imposing constraints on the admissible distributions (e.g. bound moments, symmetry, derivatives, etc.) on otherwise distribution-free p-boxes. We demonstrate that this class maintains most of the flexibility of classical distribution-free p-boxes, while avoiding most of the non-physical configurations it can be associated with. We also show how constrained distribution-free p-boxes can influence uncertainty bounds in the model predictions, thus improving the quality of the resulting uncertainty estimation.