Bayesian inference distinguishing variability from uncertainty 2D Monte Carlo simulations, 2D distributions and 2D sensitivity analysis

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Abstract

Subjective probability is a quantitative expression of uncertainty, which combined with Bayesian inference let us integrate evidence in scientific assessments and quantity uncertainty in parameters and conclusions. An assessment model may include probability models describing variability in the system. Uncertainty about the models and the parameters within the models is epistemic (i.e. related to limitations in our knowledge).It matters, if, and in what way, epistemic uncertainty is distinguished from variability (see e.g. Nauta 2000).

Two-dimensional (2D) Monte Carlo simulation distinguish variability from uncertainty, when both variability and uncertainty are simulated.

Uncertainty about a quantity with inherent randomness (a variable quantity) can be thought of as a two-dimensional (2D) probability distribution, from which uncertainty about relevant non-variable quantities or events can be derived (Benford et al., 2018). The marginal distribution of the variable quantity derived from a model is similar to a posterior predictive distribution (but not for data used to inform the model) which represents a mixture of variability and uncertainty. Inference based on predictive distributions and 2D distributions represents two valid approaches for Bayesian inference, but with different ways to treat uncertainty.

We revisit the uncertainty analysis done by Nauta (2000) on a quantitative microbial risk assessment model with the concepts of 2D distributions resulting from 2D MC simulation. To support assessments in food safety, we demonstrate a method for sensitivity analysis distinguishing between variability and uncertainty, considering how parameters are nested in variability.

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