Propagating Epistemic and Aleatory Uncertainty in Nonlinear Dynamic Models

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Engineering analysis and design problems frequently involve uncertain parameters and inputs. Propagating these uncertainties through a complex model to determine their effects on system states and outputs can be a challenging problem, especially for dynamic models. Lin and Stadtherr recently described the implementation of a new validating solver "VSPODE" for parametric ordinary differential equations (ODEs). Using this software, it is possible to obtain a Taylor-model representation (i.e., a Taylor polynomial function and an interval remainder bound) for the state variables and outputs in terms of the uncertain quantities. We give numerical examples to illustrate how these Taylor models can be used to propagate uncertainty about inputs through a system of nonlinear ODEs. We show that the approach can handle cases in which the uncertainty is represented by interval ranges, by probability distributions, or even by a set of possible cumulative probability distribution functions bounded by a pair of monotonically increasing functions (a "p-box"). The last case is useful when only partial information is available about the probability distributions, as is often the case when measurement error is non-negligible or in the early phases of engineering design when system features and properties have not yet be selected.