Minisymposium on
Verified and Stochastic Approaches to Modeling and Simulation under Uncertainty in Engineering Applications

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In engineering, it is often impossible to describe a real life system precisely since absolute knowledge regarding the process and its input data is lacking. This and the inherent inexactness in measurements make such general tasks as design of a formal model and definition of relevant parameters and their ranges difficult to complete. At the center of these difficulties is the question of how to deal with the appearing uncertainty. Among different kinds of uncertainty, two general types can be distinguished. Aleatory uncertainty refers to a purely arbitrary variability as occurring, for example, in games of chance. It cannot be reduced by further empirical study. Epistemic (reducible) uncertainty refers to the incertitude due to the lack of knowledge. An example is the absence of information about the probability distribution of a bounded parameter. Some researchers argue the existence of at least one more uncertainty type, the periodic one.

One of the important tasks in engineering is uncertainty propagation through the system. To be able to do so, we need to define mathematical or set theoretical operations along with logical expressions on uncertain numbers. Generally, it was suggested to use probability theory based approaches for propagation of purely aleatory uncertainty and interval methods for treating purely epistemic one. For combinations of epistemic and aleatory uncertainty, such methods as probability boxes and Dempster-Shafer belief theory were developed. Intervals and precise probabilities can be considered as special cases of Dempster-Shafer structures or p-boxes. Fuzzy set theory and possibility theory offer another approach to uncertainty modeling, especially if linguistic information needs to be processed.

Interval methods offer a natural and comparatively simple instrument for specifying the overall imprecision in the outcome given the bounds on imprecision in inputs. It is simple because operations on intervals — whether set theoretical or mathematical — can be defined, implemented and interpreted easily. A disadvantage of fast and naive interval approaches is the problem of overestimation, which is especially noticeable for multiple appearance of the same intervals (with large widths) in mathematical expressions. That means that interval methods cannot produce meaningful results for problems with parameters having known outliers of a considerable magnitude. However, there are several application contexts in which the use of intervals or Taylor models proves itself to be profitable from the point of view of both accuracy and efficiency.

The problem of outliers can be solved by combining stochastic (including Dempster-Shafer and p-boxes) and verified methods, whereas a considerable difficulty lies in defining and understanding the meaning of operations between uncertain quantities defined this way. Overall, the choice of the right method to model uncertainty depend on many external factors, but at least the following four should be taken into account: the kind/source of the uncertainty, the type of available input information (e.g. numerical/ interval/ linguistic/ symbolic), the quality of the available numerical data (nominal/ ordered/ metric/ precise/ interval/ absolute), and the required kind of output information (numerical/ interval/ linguistic/ symbolic).

The goal of this minisymposium is to present both theory and applications of the state-of-the-art verified and stochastic methods for uncertainty treatment.