MONTE-CARLO-TYPE TECHNIQUES FOR PROCESSING INTERVAL UNCERTAINTY AND THEIR ENGINEERING APPLICATIONS

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Typically, in engineering applications, we need to make decisions under uncertainty. In addition to measurement errors, some uncertainty comes from the fact that we do not know how exactly the engineering devices that we produced will be used: e.g., we have limits L_i on the loads l_i in different rooms i, but we do not know how exactly these loads will be distributed – and we want to make sure that our design is safe for all possible $l_i \le L_i$.

Traditionally, in engineering, statistical methods are used, methods assuming that we know the probability distribution of different uncertain parameters. Usually, we can safely linearize the dependence of the desired quantities y (e.g., stress at different structural points) on the uncertain parameters x_i – thus enabling sensitivity analysis.

Often, the number n of uncertain parameters is huge – e.g., in ultrasonic testing, we record (= measure) signal values at thousands moments of time. To use sensitivity analysis, we must call the model n times – and if the model is complex, this leads to a lot of computation time. To speed up the processing, we can use Monte-Carlo simulations. Their main advantage is that for Monte-Carlo techniques, the required number of calls to a model depends only on the desired accuracy ε and not on n – so for large n, these methods are much faster.

In real life, we often do not know the exact probability distribution of measurement errors; we also do not know the distribution of user loads – and if we knew, it would be a disaster to, e.g., design a building that is stable against random loads, but could fall down with a rare (but allowable) combination of loads. In such cases, usually, all we know is the *intervals* of possible values of the corresponding parameters: e.g., we know that the load l_i is in $[0, L_i]$.

In such situations, we can use sensitivity analysis, we can use interval techniques – but for large n, this takes too long. To speed up, we developed a new Monte-Carlo-type technique for processing interval uncertainty [1,2]. We will discuss its applications to environmental and power engineering (safety analysis of complex systems), civil engineering (building safety – work related to R. Muhanna's research), and petroleum and geotechnical engineering (how to estimate the uncertainty of the inverse problem).

References

[1] Kreinovich, V., Ferson, S. A., "A New Cauchy-Based Black-Box Technique for Uncertainty in Risk Analysis", *Reliability Engineering and Systems Safety* (to appear).
[2] Trejo, R., Kreinovich, V., "Error Estimations for Indirect Measurements", In: Rajasekaran, S., et al. (eds.), *Handbook on Randomized Computing*, Kluwer, 2001, pp. 673–729.