COMBINING PROBABILITY AND POSSIBILITY TO RESPECT THE REAL STATE OF KNOWLEDGE ON UNCERTAINTIES IN THE EVALUATION OF SAFETY MARGINS

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Taking uncertainties into account has become of prime importance in many industrial applications. It is particularly crucial in safety studies where misleading representations of uncertainties can lead to incautious and therefore potentially dangerous decisions. The Uncertainty analysis of a model (such as a computer code used for accident management procedures in nuclear industry) is usually performed in four steps:

Identification of uncertain parameters
All important factors affecting the model results must be identified. These factors are generally referred to as the "uncertainty sources" or as the "uncertain parameters".
Quantification of the knowledge about uncertain parameters
The available information about uncertain parameters is formalized. The uncertainty of each uncertain parameter is quantified. If dependencies are known between uncertain parameters and judged to be potentially important, they also need to be specified.
Propagation of uncertainties through the computer code
The propagation requires, except for very simple computer codes, a coupling between the code and a statistical software.
Treatment and interpretation of the code responses
The code responses are used to get quantitative insights regarding the output variable.
For example, in risk studies, the main concern is to estimate the likelihood of the code response to be above a critical value.

When performing practical studies, the two following requirements have to be respected in order to guarantee a relevant uncertainty evaluation:

- The method has to respect the state of knowledge in the quantification of the information about uncertain parameters.
- The method has to lead to a tractable algorithm for uncertainty evaluation i.e. with a reasonable computational cost.

A large majority of uncertainty analysts uses uncertainty methodologies based on a probabilistic modelling combined with Monte-Carlo simulations to propagate the uncertainties through their computer code or metamodel. However, the two following limitations can reduce the efficiency of such an approach and deteriorate the relevance of the decision-making process:

- These methods require a lot of knowledge to determine the probability law associated to each uncertain parameter and all the possible dependencies between the uncertain parameters. In practice, such information is rarely fully available.
- Working within the probability theory framework implicitly assumes that all uncertainties are aleatory (i.e. due to the natural variability of an observed phenomenon). In practice,

uncertainties can arise from imprecision (a variable has a fixed value which is badly known due to the lack of data, knowledge or experiment).

Therefore, recent works combining probability and possibility ([1]) have focused on new methods able to avoid the subjectivity which may exist in the choice of a single probability distribution in presence of incomplete knowledge or when uncertainties are due to imprecision. Unless a metamodel is used, existing methods are often computationally costly since they require several computer runs. They are thus applicable to relatively simple models, which limits the efficiency of such approaches in fields (such as nuclear safety) where models can be very complex and where computation costs have to be taken into account.
We propose in this work a new numerical treatment of such methods based on Monte-Carlo sampling techniques which reduces the computational cost and can be applied to complex models. Moreover, by using notions of order statistics, our method proposes a way to estimate the numerical accuracy of the results. The key point of our work mainly consists in setting some decision step before the uncertainty propagation, whereas usual methods postpone this step after the propagation.
We start by recalling the principle of the probabilistic modelling. Then, we describe our new method, called the **RaFU** method, allowing to work within an unified framework ([2]) to properly represent the real state of knowledge on uncertainties while ensuring a minimal computation cost. Finally, an application of the RaFU method to a large break loss-of-coolant accident ([3]) is given and a comparison with probability-based methods is provided as well. It appears that that this new approach leads to robust uncertainty margins related to the assumptions about probability density functions (pdf) that are required within the classical probabilistic modelling. These results are less precise (i.e an interval instead of a value) but are more reliable for safety studies. The effect of pdf choices can be evaluated. Moreover, thanks to its numerical strategy, it is well fitted to uncertainty analysis of complex computer codes where computer cost has to be taken into account.

REFERENCES:

[1] D. Dubois, H.T. Nguyen and H. Prade, Possibility Theory, Probability and Fuzzy Sets: Misunderstandings, Bridges and Gaps, pages 343-438, Fundamentals of Fuzzy Sets, Kluwer Academic Publishers, Boston (2000).

[2] G. Shafer, A Mathematical Theory of Evidence, University Press, Princeton (1976).

[3] A. Petruzzi, F. D'Auria, J-C. Micaeli, A. De Crecy and J. Royen, "The BEMUSE programme (Best-Estimate Methods – Uncertainty and Sensitivity Evaluation ", Proc. of the Int. Meet. On Best-Estimate Methods in Nuclear Installation Safety Analysis (BE-2004), IX, volume 1, page 225-235 (2004).