Epistemic Uncertainty Workshop

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For some time, various research communities have been dealing with the topic of epistemic uncertainty, i.e., uncertainty due to lack of knowledge. During the last several years, the risk assessment community has begun to make a clear distinction between aleatory uncertainty, i.e., uncertainty due to a random process, and epistemic uncertainty. With this distinction, additional focus is being placed on the question of the appropriateness of using traditional probability theory to represent epistemic uncertainty in reliability engineering and risk analyses. One method of describing epistemic uncertainty in a parameter is to specify an interval value for the parameter.

The Epistemic Uncertainty Project (`http://www.sandia.gov/epistemic`) was formed at Sandia National Laboratories to investigate the applicability and usefulness of some of the modern mathematical theories for the representation of different types of uncertainty. Some of the theories of interest are interval analysis, fuzzy set theory, possibility theory, evidence (Dempster-Shafer) theory, and imprecise probability theory. Most of these theories are in an early stage of development relative to classical probability theory and Bayesian estimation. Although there are still many theoretical and applied research questions about these theories, the purpose of the Epistemic Uncertainty Project is to evaluate, develop and apply the most useful theories to reliability engineering, risk analysis, and system safety assessment.

As part of the project, Sandia National Laboratories brought together leading researchers with differing viewpoints to discuss and exchange ideas on the issue of epistemic uncertainty. These researchers were joined by leading reliability engineering and risk analysts who face the issue of epistemic and aleatory uncertainty in the assessment of high consequence engineered and natural systems.

To focus attention and discussion on the topic of epistemic uncertainty, the organizing committee has constructed a sequence of challenge problems (`www.sandia.gov/epistemic/challenge.htm`). Each of the challenge problems deals with the representation and aggregation of mixtures of epistemic and aleatory uncertainty and the propagation of these mixtures through a simple mathematical model. In each problem some of the input parameters:

- specify uncertainty by an interval of possible values,
- specify uncertainty by a probability distribution (e.g., lognormal) for which we only know intervals of possible values of parameters,
- are given by intervals from conflicting sources.

The goal of the analysis for each problem is to provide guaranteed bounds on the range of possible values of the outputs and on the probabilities of different output values.

The mapping of inputs to outputs for the first set of challenge problems is given by an algebraic equation and the second mapping is given by a linear ordinary differential equation. The problems are intended to serve as a common focus and challenge for experimentation, discussion, and comparison of multiple approaches to the problems.

At the Workshop, 14 invited talks were given by internationally known researchers in the field. Six additional presentations have been chosen from extended abstracts submitted by individuals. Most presentations used interval computations and/or related tools to handle interval uncertainty; several papers proposed and/or described new tools that extend interval techniques to situations in which, in addition to intervals of possible values, we have a partial information about probabilities. Proceedings of the workshop will appear as a special issue of the journal *Reliability Engineering and System Safety.*

Invited talks:

- B. M. Ayyub (University of Maryland), "From Dissecting Ignorance to Solving Algebraic Problems,"
- Y. Ben-Haim (Technion, Israel), "Uncertainty, Probability, and Information-gaps,"
- V. Bier (University of Wisconsin-Madison), "Implications of the Research on Overconfidence for Challenge Problem Solution Strategies,"
- R. M. Cooke (Delft University of Technology, Netherlands), "The Anatomy of the Squizzel: the Role of Operational Definitions in Representing Uncertainty,"
- G. de Cooman and M. C. M. Troffaes (Universiteit Gent, Belgium), "Solving the Sandia Problem Set Using the Theory of Coherent Lower Previsions,"
- S. Ferson and J. Hajagos (Applied Biomathematics and State University of New York at Stony Brook), "Don't Open That Envelope: Solutions to the Sandia Problems Using Probability Boxes,"
- J. Helton (Sandia National Laboratories), "An Exploration of Alternative Approaches to the Representation of Uncertainty in Model Predictions,"
- M. Hyman and Weiye Li (Los Alamos National Laboratory), "Data Structures and Computer Arithmetic for Quantifying Uncertainty,"
- G. Klir (Binghamton University, Binghamton, New York), "Generalized Uncertainty-Based Information Theory: Aims, Results, Open Problems,"

- I. Kozine (RISO National Laboratory, Denmark) and L. Utkin (Munich University, Germany), "An Approach to Combining Unreliable Pieces of Evidence and Their Propagation in a System Response Analysis,"
- V. Kreinovich (University of Texas at El Paso), "Probabilities, Intervals, What Next: Representation, Elicitation, and Aggregation of Uncertainty in Risk Analysis—From Traditional Probabilistic Techniques to More General, More Realistic Approaches,"
- A. O'Hagan (University of Sheffield, United Kingdom), "Probability Is Perfect, but I Can't Elicit It Perfectly,"
- J. R. Red-Horse and A. S. Benjamin (Sandia National Laboratories), "A Probabilistic Approach to UQ Using Approximate Information,"
- R. R. Yager (Iona College, New Rochelle, New York), "Toward a General Framework for Uncertainty Representation."

Additional presentations:

- H. Agarwal, J. Renaud, and D. Padmanabhan (University of Notre Dame), "Uncertainty Quantification in Multidisciplinary Design Optimization,"
- D. Berleant and J. Zhang (Iowa State University) "$(a + b)**a$: Cumulative Credibility, and the Distribution Envelope Determination (DEnv) Algorithm,"
- J. M. Booker and L. A. McNamara (Los Alamos National Laboratory), "Solving the Challenge Problems Using Expert Knowledge Principles and Methods,"
- T. Fetz and M. Oberguggenberger (University of Innsbruck, Austria), "Solution to Challenge Problem 1 in the Framework of Sets of Probability Measures,"
- J. Hall and J. Lawry (University of Bristol, United Kingdom), "Random Set Analysis of System Response Given Uncertain Parameters,"
- E. Nikolaidis and P. Soundappan (University of Toledo), R. T. Haftka (University of Florida), R. Grandhi (Wright State University), and R. Canfield (Air Force Institute of Technology), "Evidence Theory and Bayesian Probability for Characterizing Epistemic Uncertainty,"
- F. Tonon (University of Utah), "Using Random Set Theory to Solve Challenge Problem B."

Members of the Organizing Committee:
William Oberkampf (Chair), Jon Helton, Steve Wojtkiewicz,
Sandia National Laboratories
Cliff Joslyn, Los Alamos National Laboratory
Scott Ferson, Applied Biomathematics