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Uncertainty Quantification: Theory, Implementation, and Applications. By *Ralph C. Smith*. SIAM, Philadelphia, 2014. \$74.00. xviii+382 pp., hardcover, ISBN 978-1-611973-21-1.

Aerospace engineering undergraduate majors in my department often want to know why they are required to take a class in statistics and probability, when it seems disconnected from the (highly deterministic!) remainder of their engineering curriculum. We explain just how important it is to account for uncertainty when making critical decisions in engineering—whether we are analyzing measurements from a wind tunnel experiment or analyzing the outputs of a computational fluid dynamics simulation, our data are laden with uncertainties that must be accounted for as we issue predictions on the performance of an aircraft or as we make crucial decisions on the design of a wing shape. Yet historically, as the students rightly perceive, there has been a large gap between the theory/methods of statistics and their rigorous application across engineering and science. This is especially true when it comes to the use of computational simulations.

In recent years, a vibrant intellectual community has grown to fill that gap. The field of uncertainty quantification (UQ) involves the quantitative characterization and management of uncertainty in a broad range of applications. UQ draws upon many foundational ideas and techniques in applied mathematics and statistics, but focuses these techniques on complex models that are primarily accessible through computational simulation. SIAM has been at the forefront of the growth of this interdisciplinary community, establishing a SIAG/UQ in 2011, a SIAM conference on UQ in 2012, and the *SIAM/ASA Journal on Uncertainty Quantification* in 2013.

Ralph Smith's *Uncertainty Quantification: Theory, Implementation, and Applications* is a timely addition to the UQ literature. It provides an excellent foundation in elements of UQ theory and methodology that have become well established, while at the same time providing a valuable snapshot

of the state of the art in several areas. The book covers an impressively broad range of UQ topics, motivated by contemporary examples from across science and engineering, and woven together with illustrative examples based on a set of prototypical models.

What do I like about this book? First, I like its breadth. The book treats a large number of UQ topics related to modeling, uncertainty propagation, sensitivity analysis, and parameter estimation. It pays particular attention to structure-exploiting methods that enable efficient computations for large-scale applications: stochastic spectral methods, sparse grid quadrature and interpolation techniques, and surrogate models. In my view, the book helps to establish the identity of the relatively young UQ field—the integrated presentation of the broad range of topics, together with a focus on scalability and structure-exploiting methods, helps to define “what is UQ?” and what distinguishes UQ from classical statistics.

Second, the topics are presented in an accessible manner, with references to the literature providing a further level of detail. In many cases, the book provides insightful discussion contrasting competing methods, such as the discussion on the attributes of the Galerkin, collocation, and discrete projection methods in Chapter 10. I expect that this book would be particularly useful for the graduate student looking for a strong foundation in UQ, especially those students with a background in engineering, science, or computation, but with less training in statistics. It would also be an excellent resource for those seeking to become educated users of UQ approaches.

Third, a strength of the book is its examples. The motivating applications in Chapter 2 give context, laying out the challenges and the need for UQ. I particularly like the simple but representative “prototypical models” presented in Chapter 3, and the use of these examples throughout the book. These models might provide some useful test cases for graduate students looking for simple examples on which to develop their UQ methods. The webpage http://www4.ncsu.edu/~rsmith/UQ_TIA/

links to MATLAB codes and data for several of the examples.

In choosing to cover a breadth of UQ topics, the book has necessarily traded-off a reduction in its depth in some areas. Those seeking an in-depth treatment in the more advanced topics (e.g., Monte Carlo methods, statistical inverse problems, approximation theory) would be better directed toward one of the books focused on these particular areas. In addition, there are aspects of UQ not covered in the book, particularly those that move beyond predictive estimation to deal with decision-making aspects of UQ (e.g., optimization under un-

certainty and experimental design).

Overall, I find that Smith's text recognizes that UQ is a young and evolving field with many open research questions, but he does an excellent job in providing the foundations. I keep an extra copy of the book on my shelf to give as an introduction to my new graduate students, and I pull it out whenever my undergrads ask me "we're here to design aircraft and launch things into space—why should we care about Bayes theorem?"

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