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Saddlepoint Approximation for Predicting Rare Failure Probabilities in Engineering

Modern society is less tolerant of engineering failures that may result in loss of value or life. Engineers are always surrounded by uncertainty and beset with risk. It is therefore critical to predict the probability of failure of a product during its design and development stage. But it is challenging to do so because of rare failure events and expensive physical models. For this reason, Monte Carlo simulation is not practical. This presentation focuses on how to use the Saddlepoint Approximation (SPA) to predict the probability of the rare failure event so that high accuracy and efficiency can be maintained. Mathematically, the task is to estimate the probability that a response (output) is falling into a failure region for a given joint probability density of input random variables. The response indicates the state (either safe or failed) and is obtained from a computational model derived from physical principles. Using the cumulant generating function, SPA can accurately approximate the rare probability in the tail areas of a distribution. Engineering examples are given to demonstrate the advantages of SPA over traditional physics-based reliability methods.

Dr. Xiaoping Du is a professor of Mechanical Engineering at Indiana University - Purdue University Indianapolis. As an engineer, researcher, and educator in engineering design, he has been involved in many research projects in statistical/probabilistic methodologies, optimization, reliability-based design, and machine learning. As PI, he received seven grants from the US National Science Foundation and also served as PI and Co-PI for many other research projects. He has published over 100 journal articles, and dozens of conference papers. He served as Associate Editor of ASME Journal of Mechanical Design and is serving as Review Editor of Structural and Multidisciplinary Optimization and Associate Editor of IISE Transactions. He is Fellow of ASME and a recipient of Governor's Award for Excellence in Education in the state of Missouri. Prior to joining IUPUI, he was a professor at the Missouri University of Science and Technology, where he also held the title of Curator's Distinguished Professor, the highest and most prestigious academic rank in the University of Missouri system. Dr. Du received his PhD in Mechanical Engineering from University of Illinois at Chicago in 2002.