

Integrating Reliability Analysis into Comprehensive Risk Assessment Frameworks

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Abstract: Accurate and efficient risk assessment is paramount to the safety, operational integrity, and longevity of engineering systems. This presentation introduces an advanced risk assessment framework that synthesizes cutting-edge reliability analysis methodologies, including importance sampling, surrogate modeling techniques, and Bayesian Weibull analysis. Importance sampling enhances the efficiency of reliability estimations, particularly in low-probability event scenarios, thereby offering a more nuanced understanding of risk. Bayesian Weibull analysis serves as a robust statistical tool for modeling and analyzing system lifecycle data, especially when failure data is sparse. Notably, the surrogate approach is distinguished by its capacity to compute reliability with high efficiency, rendering it indispensable for practical engineering applications. This approach facilitates precise risk assessments while mitigating the computational demands, thereby preserving the integrity and complexity of the original models. The proposed integrated framework has broad applicability across various engineering domains. In dam water supply gate systems, it ensures uninterrupted water delivery by preventing system failures through rigorous reliability analysis. In wind farm management, it aids in optimizing maintenance strategies, reducing downtime, and maximizing energy output. Additionally, it supports nature-based solutions by balancing engineering reliability with environmental sustainability, considering the interaction between natural systems and engineered structures. Building on prior research, this framework significantly elevates the precision of risk assessments while markedly reducing computational overhead, thereby enhancing its practicality for real-world engineering applications. By underpinning the development of more resilient engineering systems, this framework serves as a strategic tool for decision-makers, facilitating more effective risk management. Ultimately, this research advances the overall safety and reliability of critical infrastructure, ensuring these systems are equipped to withstand a spectrum of operational challenges. The integration of advanced reliability analysis into a holistic risk assessment framework represents a pivotal advancement in engineering risk management, establishing a foundational platform for future innovations in the field.

Keywords: Importance Sampling, Surrogate Modeling, Bayesian Weibull Analysis, Risk Assessment, Engineering Practices