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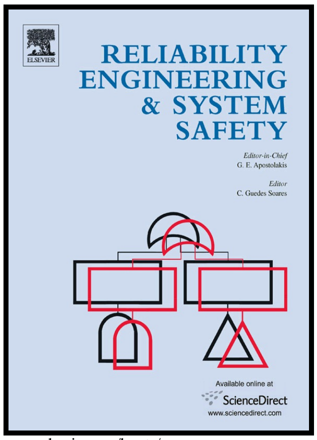

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Simulation-based exploration of high-dimensional system models for identifying unexpected events

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ABSTRACT

Mathematical numerical models are increasingly employed to simulate system behavior and identify sequences of events or configurations of the system's design and operational parameters that can lead the system to extreme conditions (Critical Region, CR). However, when a numerical model is: i) computationally expensive, ii) high-dimensional, and iii) complex, these tasks become challenging.

In this paper, we propose an adaptive framework for efficiently tackling this problem: i) a dimensionality reduction technique is employed for identifying the factors and variables that most affect the system behavior; ii) a meta-model is sequentially trained to replace the computationally expensive model with a computationally cheap one; iii) an adaptive exploration algorithm based on Markov Chain Monte Carlo is introduced for exploring the system state-space using the meta-model; iv) clustering and other techniques for the visualization of high dimensional data (e.g., parallel coordinates plot) are employed to summarize the retrieved information.

The method is employed to explore a power network model involving 20 inputs. The CRs are properly identified with a limited computational cost, compared to another exploration technique of literature (i.e., Latin Hypercube Sampling).

Keywords: Critical Region exploration; Unexpected Event; Polynomial Chaos Expansion; Kriging; Markov Chain Monte Carlo (MCMC); Clustering; Local Outlier Factor; Integrated Deterministic Probabilistic Safety Assessment (IDPSA).

ACRONYMS

AK-MCS : Adaptive Kriging-Monte Carlo Simulation
CR : Critical Region
CRA : Computational Risk Assessment
CSN : Consejo de Seguridad Nuclear (Nuclear Safety Council)
DC : Direct Current
DEX : Deep EXploration