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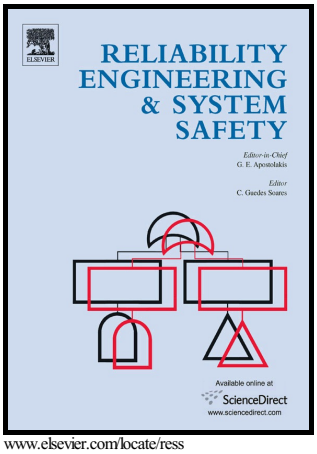

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Multilevel Monte Carlo for Reliability Theory

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Abstract

As the size of engineered systems grows, problems in reliability theory can become computationally challenging, often due to the combinatorial growth in the number of cut sets. In this paper we demonstrate how Multilevel Monte Carlo (MLMC) — a simulation approach which is typically used for stochastic differential equation models — can be applied in reliability problems by carefully controlling the bias-variance tradeoff in approximating large system behaviour. In this first exposition of MLMC methods in reliability problems we address the canonical problem of estimating the expectation of a functional of system lifetime for non-repairable and repairable components, demonstrating the computational advantages compared to classical Monte Carlo methods. The difference in computational complexity can be orders of magnitude for very large or complicated system structures, or where the desired precision is lower.

Keywords: reliability theory, multilevel Monte Carlo, cut sets, system lifetime estimation

1. Introduction

It can prove to be computationally intractable to perform classical reliability analysis of very large engineered systems when the number of cut (path) sets grows combinatorially. It is well understood that working instead with subsets of the cut (path) sets or bounding structural designs can provide probability bounds in many reliability problems [4], but such bounds can be crude or may not be well characterised at all.

Evaluation of the reliability of engineered systems is a crucial part of system design and often scenario planning may involve repeated evaluation of the reliability for changing system configurations or component types meaning rapid simulation is highly desirable. For simplicity of exposition we herein

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