Accepted Manuscript

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PII: S0045-7825(18)30329-3
DOI: https://doi.org/10.1016/j.cma.2018.06.032
Reference: CMA 11970

To appear in: *Comput. Methods Appl. Mech. Engrg.*

Received date : 24 January 2018
Revised date : 22 June 2018
Accepted date : 22 June 2018

Please cite this article as: J. Zhang, M. Xiao, L. Gao, J. Fu, A novel projection outline based active learning method and its combination with Kriging metamodel for hybrid reliability analysis with random and interval variables, *Comput. Methods Appl. Mech. Engrg.* (2018), https://doi.org/10.1016/j.cma.2018.06.032

A novel projection outline based active learning method and its combination with Kriging metamodel for hybrid reliability analysis with random and interval variables

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Abstract:

This paper focuses on the hybrid reliability analysis with both random and interval variables (HRA-RI). It is determined that a metamodel only accurately approximating the projection outlines on the limit-state surface can precisely estimate the lower and upper bounds of failure probability in HRA-RI. According to this idea, a novel projection outline based active learning (POAL) method is proposed to sequentially update design of experiments (DoE). Then, a HRA-RI method combining POAL and Kriging metamodel (POAL-Kriging) is developed. In this method, Kriging metamodel is refined based on the update samples, which are sequentially chosen using POAL from the vicinity of the projection outlines on the limit-state surface. In the end, the lower and upper bounds of failure probability in HRA-RI are precisely estimated. Compared to the approximation of the whole limit-state surface, the proposed method only approximates the projection outlines on the limit-state surface, and therefore few DoE are needed to build a high quality metamodel. The accuracy, efficiency and robustness of the proposed method for HRA-RI are illustrated by four examples.

Keywords: Hybrid reliability analysis; Random and interval variables; Projection outlines; Active learning; Kriging metamodel

1 Introduction

Reliability analysis is a significant task in structural safety analysis under uncertainty. Generally, uncertainty can be categorized into two distinct types: aleatory and epistemic [1, 2]. Aleatory uncertainty is objective and irreducible, which stems from the inherent variations of a physical system. The classical probability theory is usually employed to quantify aleatory uncertainty. Epistemic uncertainty is subjective and reducible, which arises from insufficient data, incomplete information and lack of knowledge. It is inappropriate to simply represent epistemic uncertainty by assumed probability distributions [3]. Up to now, some different approaches have been used to quantify epistemic uncertainty, such as possibility theory [4], fuzzy sets [5], evidence theory [6, 7], convex model [8] and interval model [9-12].