MascotNum2020 conference - A variance reduction strategy for fragility curve estimation by active learning

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Abstract:

As part of the assessment of the seismic safety of industrial installations, which is an integral part of the probabilistic safety studies conducted on these installations, it is necessary to characterize the fragility of civil engineering structures. This characterization is often expressed in the form of fragility curves, which represent the conditional probability of failure of the quantity of interest as a function of a parameter representative of the intensity of the seismic excitation [3], [4]. These curves must integrate all the uncertainties related to seismic loading (so-called random uncertainties), structural behaviour and design methods (so-called epistemic uncertainties). They can be evaluated by Monte Carlo numerical simulations by propagating random and epistemic uncertainties via a numerical code or, to reduce the number of calculations, by means of parametric models or meta-models. Whatever the method used, the development of a fragility curve requires a good knowledge of the "extreme" behaviour of structures which is, in most cases, a non-linear behaviour. Numerically, the complexity of mechanical models comes from soil-structure interaction, behavioural non-linearities (damage) and structural non-linearities (e. g. contact-friction). In addition, for both tests and numerical computations, it is necessary to have accelerograms that can be real (measured on site) or artificially generated when the number of real seism is limited.

Unfortunately, numerical simulations of mechanical structures are often costly in terms of computation time. In this context, it is crucial to develop experimental design methods to gain the maximum information with the smallest number of numerical code evaluations. We proposed and implement a methodology based on adaptive importance sampling as in [1] and [2], in order to minimize the asymptotic variance of the training loss. We show by asymptotic analysis and numerical simulations that it allows fast convergence of the estimated fragility curve to the true fragility curve.

References

[1] Wei Chu, Martin Zinkevich, Lihong Li, Achint Thomas, and Belle Tseng. Unbiased online active learning in data streams. In *Proceedings of the 17th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, KDD '11, page 195–203, New York, NY, USA, 2011. Association for Computing Machinery.

[2] Bernard Delyon and François Portier. Asymptotic optimality of adaptive importance sampling, 2018.

[3] R.P. Kennedy, C.A. Cornell, R.D. Campbell, S. Kaplan, and H.F. Perla. Probabilistic seismic safety study of an existing nuclear power plant. *Nuclear Engineering and Design*, 59(2):315 – 338, 1980.

[4] Rémi Sainct, Cyril Feau, Jean-Marc Martinez, and Josselin Garnier. Efficient methodology for seismic fragility curves estimation by active learning on support vector machines. *Structural Safety*, 86:101972, 2020.

Short biography – After 3 years in a French engineering school and a Master of Statistics and Machine Learning at Université Paris Sud, I did my end of study internship in EDF R&D Chatou in uncertainty quantification. Because this research topic fits me well, I choose this Ph.D thesis at CEA Saclay. My funding comes from the SEISM Institute, its purpose is to federate several research and academic institutions on the very topic of seismic risk assesment.