ABSTRACT

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Title: Efficient Computation of Accurate Seismic Fragility Functions Through Strategic Statistical Selection.
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A fragility function quantifies the probability that a structural system reaches an undesirable limit state, conditioned on the occurrence of a hazard of prescribed intensity level. Multiple sources of uncertainty are present when estimating fragility functions, e.g., record-to-record variation, uncertain material and geometric properties, model assumptions, adopted methodologies, and scarce data to characterize the hazard. Advances in the last decades have provided considerable research about parameter selection, hazard characteristics and multiple methodology for the computation of these functions. However, there is no clear path on the type of methodologies and data to ensure that accurate fragility functions can be computed in an efficient manner. Fragility functions are influenced by the selection of a methodology and the data to be analyzed. Each selection may lead to different levels of accuracy, due to either increased potential for bias or the rate of convergence of the fragility functions as more data is used. To overcome this difficulty, it is necessary to evaluate the level of agreement between different statistical models and the available data as well as to exploit the information provided by each piece of available data. By doing this, it is possible to accomplish more accurate fragility functions with less uncertainty while enabling faster and widespread analysis. In this dissertation, two methodologies are developed to address the aforementioned challenges. The first methodology provides a way to quantify uncertainty and perform statistical model selection to compute seismic fragility functions. This outcome is achieved by implementing a hierarchical Bayesian inference framework in conjunction with a sequential Monte Carlo technique. Using a finite amount of simulations, the stochastic map between the hazard level and the structural response is constructed using Bayesian inference. The Bayesian approach allows for the quantification of the epistemic uncertainty induced by the limited number of simulations. The most probable model is then selected using Bayesian model selection and validated through multiple metrics such as the Kolmogorov-Smirnov test. The subsequent methodology proposes a sequential selection strategy to choose the earthquake with characteristics that yield the largest reduction in uncertainty. Sequentially, the quantification of uncertainty is exploited to consecutively select the ground motion simulations that expedite learning and provides unbiased fragility functions with fewer simulations. Lastly, some examples of practices during the computation of fragility functions that results in undesirable bias in the results are discussed. The methodologies are implemented on a widely studied twenty-story steel nonlinear benchmark building model and employ a set of realistic synthetic ground motions obtained from earthquake scenarios in California. Further analysis of this case study demonstrates the superior performance when using a lognormal probability distribution compared to other models considered. It is concluded by demonstrating that the methodologies developed in this dissertation can yield lower levels of uncertainty than traditional sampling techniques using the same number of simulations. The methodologies developed in this dissertation enable reliable and efficient structural assessment, by means of fragility functions, for civil infrastructure, especially for time-critical applications such as post-disaster evaluation. Additionally, this research empowers implementation by being scalable and expandable, facilitating such analysis at community level and for other critical infrastructure systems (e.g., transportation, communication, energy, water, security) and their interdependencies.