Efficient Estimation of Seismic Risk for Distributed Systems

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OpenSRA
https://peer.berkeley.edu/openSRA

Objective

The objective of this task is to speed up the system risk calculations such that the run times are reasonable (< 20 min) on a desktop computer. Using analytical approximations to the risk integral, the calculation time by a factor of 1000 compared to direct numerical integration with a small loss in accuracy.

Introduction

The PEER gas-pipeline risk study computes the seismic risk using the PEER Framing Equation

$$P(DV) = \int_{IM}\int_{EDP}\int_{DM} P(DV|DM) f_{DM}(EDP) f_{EDP}(IM) Rate(IM) dDM\, dEDP\, dIM$$

- Intensity Measure (IM) - Spectral Acc
- Engineering Design Parameter (EDP) - Permanent ground displacement
- Damage Measure (DM) - Pipe Strain
- Decision Variable (DV) - Pipe Break or Leak

Calculation Speed Issues

- Spatially distributed gas pipeline system:
  - For the evaluation of the pipeline system during a single earthquake, realizations of the spatial distribution of the IM are also needed to capture the spatial correlation of the ground motion
- Combining this large set of realizations of the IM with the integrals over EDP and DM for each site leads to long computational times.
  - Including epistemic uncertainty in each model further increases the run times.
- To reduce the run times:
  - Use polynomial chaos (PC) to model the effect of spatial correlation of the IM and epistemic uncertainty in the model inputs (median models)
  - Approximate the EDP, DM, and DV models with linear forms with analytical solutions to the integrals.

Computing the Risk Integral

For a Single Model

(no epistemic uncertainty)

- Common approach
  - Numerical integration
- OpenSRA approach
  - Use approximations to EDP, DM, DV models to allow analytical calculation of the PEER integral
  - Loss of accuracy in total risk is small

For Epistemic Uncertainties in Models

- Ground-motion models
- EDP(IM) model
- DM(EDP) model
- DV(DM) model

Common approach to Epistemic Uncertainty

- Logic trees with 3 branches per node for EDP, DM, DV and 15 branches for GMM (ergodic)
  - 405 total branches

OpenSRA Approach to Epistemic Uncertainty

- Use polynomial chaos to approximate the epistemic uncertainty in the input models
- Epistemic fractiles are more accurate than using sparse logic trees (3 branches)

Example Application

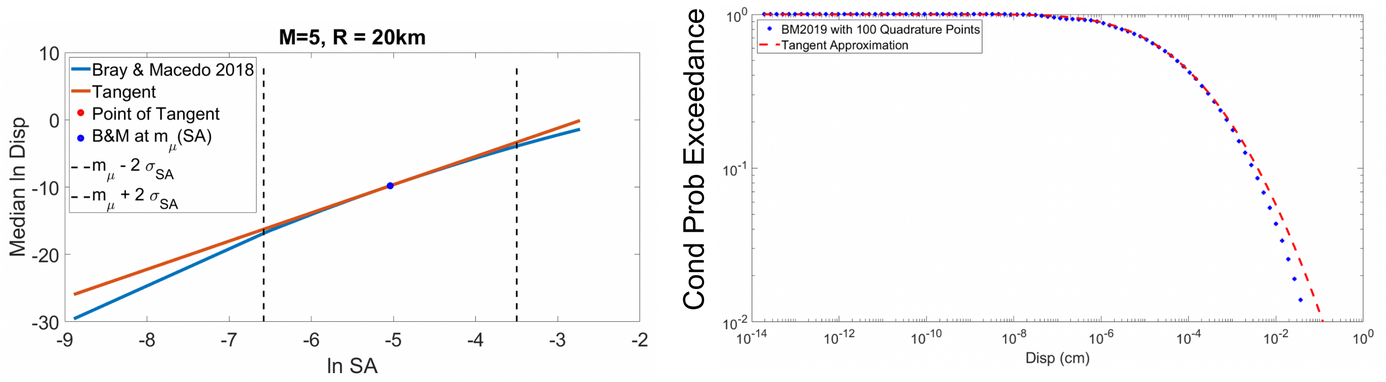

Figure 1. (a) Approximate EDP(IM) median function with a linear model. (b) Accuracy of the approximation

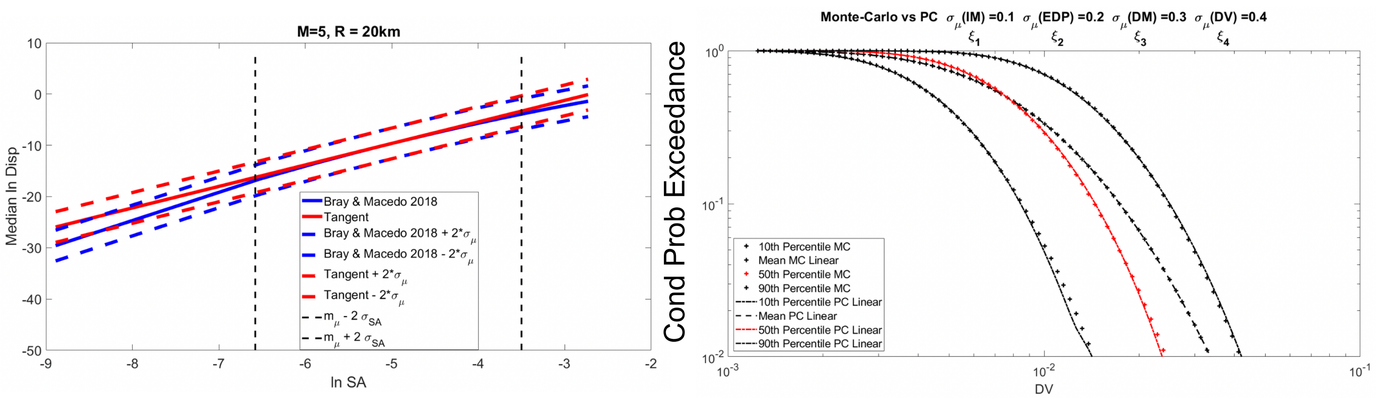

Figure 2. (a) Epistemic uncertainty in median EDP(IM) model. (b) Accuracy of the epistemic fractiles using polynomial chaos

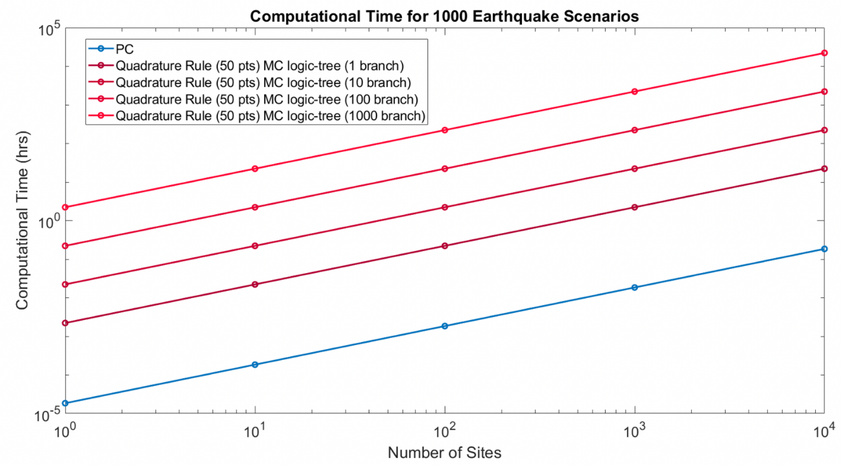

Figure 3. Improved calculation times for system risk including epistemic uncertainties using the linear approximation to the EDP median and polynomial chaos approximation for the epistemic uncertainty

Summary

Significant improvements in computational speed can be made using approximations for the shape of the median EDP(IM), DM(EDP), and DV(DM) that result in analytical solutions to the PEER integral with an acceptable reduction in accuracy

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