Seismic Risk Assessment of Lifelines

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Introduction

- Lifelines are large, spatially-distributed systems such as transportation networks that are essential support systems for any society
- We propose a new simulation-based framework to assess the seismic risk of lifelines
- Efficient sampling techniques such as importance sampling and data reduction techniques such as k-means clustering are used to drastically reduce the computational complexity
- The effectiveness of the framework is illustrated by assessing the risk of an aggregated form of the San Francisco bay area transportation network

Difficulties in risk assessment

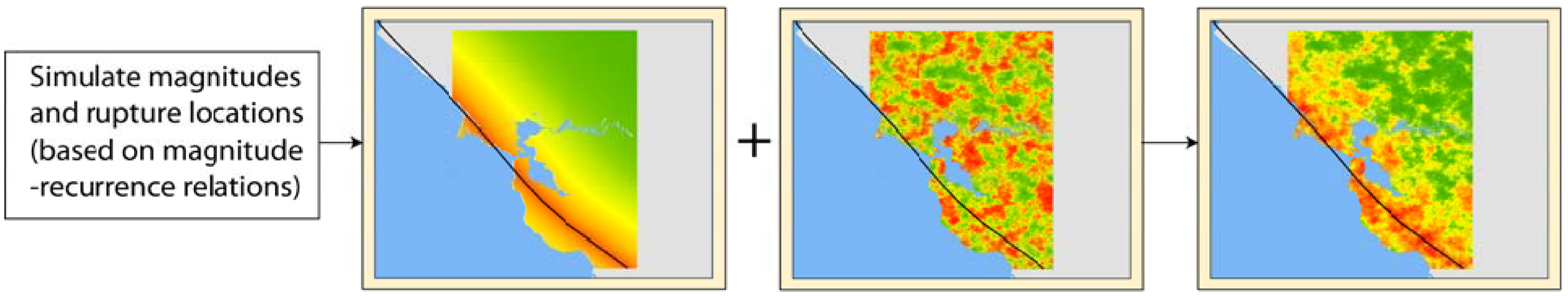
- The risk assessment of lifelines is based on a vector of ground motions (intensities at multiple sites)
- Hazard and loss analyses involving multiple sites need to account for ground-motion spatial correlation
- Lifeline performance measures (e.g., delays in a transportation network) are usually not available in closed form

$$v(DV) = \int\int\int dF(DV|DM)\,dF(DM|EDP)\,dF(EDP|S_a)\,v(S_a)$$

Not in closed form — Now, a correlated vector of intensities

PEER equation for risk assessment

Simulation-based risk assessment framework

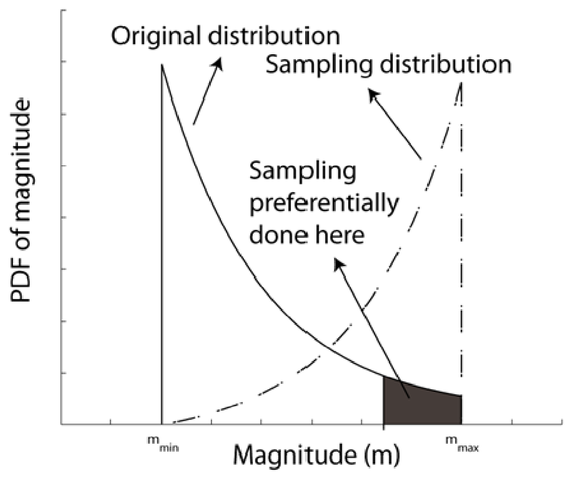


Median ground-motion field | Residuals: Randomness in the ground motion (Gaussian field) | Simulated ground motion field

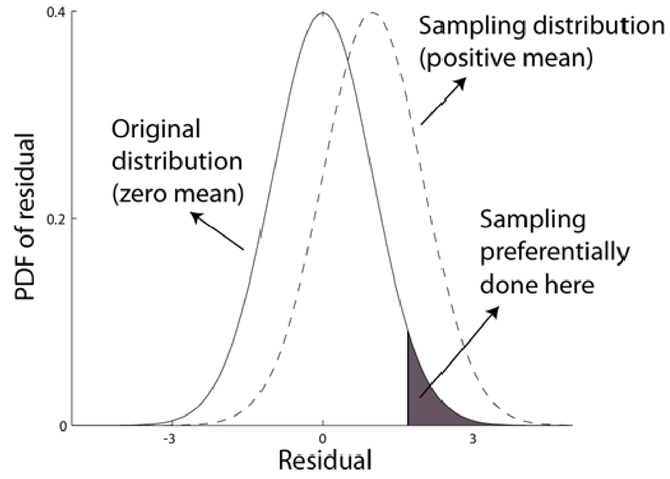
Framework: Simulate ground-motion fields using the above procedure and assess lifeline performance using the simulations

Efficient sampling

- Risk assessment using Monte Carlo simulation (MCS) of ground-motion fields is computationally inefficient
  - If conventional MCS is used, over a million fields will be required for a robust lifeline risk assessment
  - Performance assessment using a million fields is impossible
- Importance sampling (IS)
  - Sample ground-motion fields that are important for lifeline risk assessment (e.g., large magnitude events, above-average ground motions)
  - *1/100th* the number of MCS simulations will suffice for a robust risk assessment (i.e. , ~10,000 simulations)



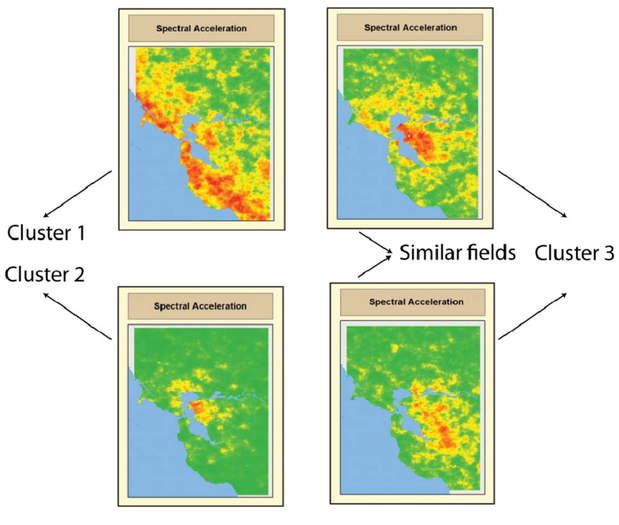
Importance sampling of magnitude



Importance sampling of residuals

Data reduction using K-Means clustering

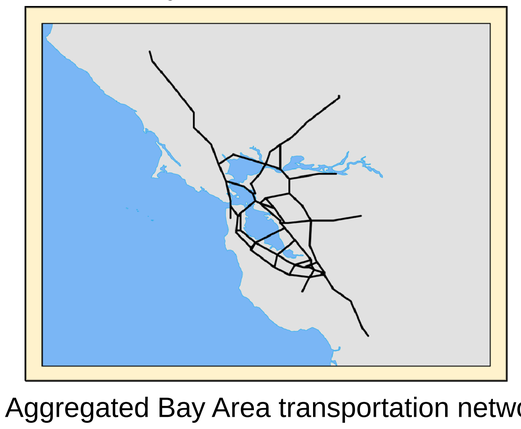
- Fields obtained after sampling are not necessarily distinct
- Proposal
  - Use K-means clustering to identify and combine similar ground-motion fields into clusters, and perform risk assessment using 1 field / cluster
  - This allows a drastic reduction in the number of network performance assessments that need to be done



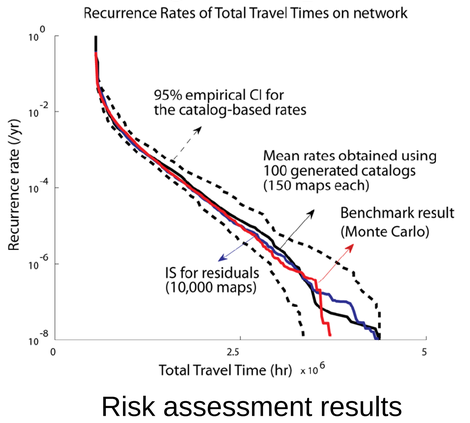
Notion of clustering

Results

- Using IS and K-means clustering enables risk assessment using a *catalog of only 150 ground-motion fields*
- Accuracy of the results were verified using a sample network



Aggregated Bay Area transportation network



Risk assessment results

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