AN IMPROVED ALGORITHM FOR GROUND MOTION SELECTION

PEER Transportation Systems Research Program

Stanford | ENGINEERING
Civil & Environmental Engineering

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Introduction

To perform dynamic analyses in earthquake engineering, ground motion time histories must be selected as inputs.

Ground motions are often selected to match a target response spectrum mean and variance, which is a computationally expensive process because there are many combinations of ground motions to choose from.

The ground motion selection method discussed here matches ground motions to a target response spectrum by first matching individual ground motions to simulated response spectra that theoretically match the target spectrum.

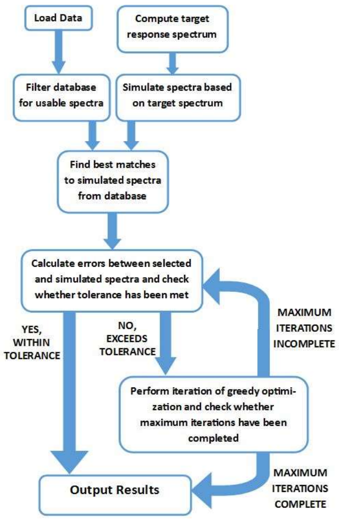
The user can next choose one of two optimization methods to optimize the initially selected ground motions.

The algorithm can conduct conditional or unconditional selection for single- or two-component ground motions.

This algorithm is improved from the code developed by Jayaram et al. (2011), and the software package is available at: https://github.com/bakerjw/CS_Selection

Selection Procedure

The flow chart below shows key steps in the algorithm



Response Spectra Simulation

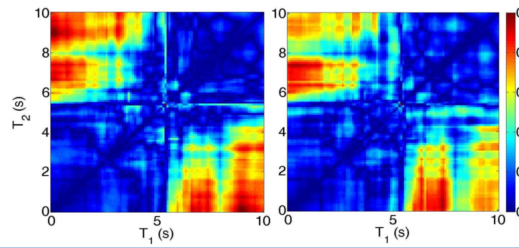
Initial matches to the target spectrum are calculated by minimizing the sum of squared errors between the selected and simulated spectra across all periods.

$$error_{gm} = \sum_{j=1}^{p} \left[\left(\ln(gm_j * SF) - \ln(sim_j) \right)^2 \right]$$

Where gm denotes a selected spectra, SF denotes the scale factor, and sim denotes a simulated spectra.

The algorithm uses Latin Hypercube Sampling (LHS), a combination of importance and random sampling to generate simulated response spectra based on the target spectrum means and variances.

The figures below show the improvement from using LHS (Right: random sampling; Left: LHS) by comparing the differences between 100 initially selected spectra correlation and analytical correlation structures.



$$error_{\rho(i,j)} = \left| \rho(i,j)_{selected} - \rho(i,j)_{target} \right|$$

where $\rho(i,j)$ represents the correlation between periods T_i and T_j

Searchable Databases

The publicly available flatfiles of NGA-W1 and NGA-W2 ground motion spectra and relevant data are included with the software.

For selecting two-component ground motions, orientation independent response spectra are used (RotD50 and RotD100).

The algorithm outputs PEER record numbers that can then be used to retrieve time series (at http://ngawest2.berkeley.edu for NGA-W2 data)

Several databases of simulated ground motions are also included.

Optimization Function

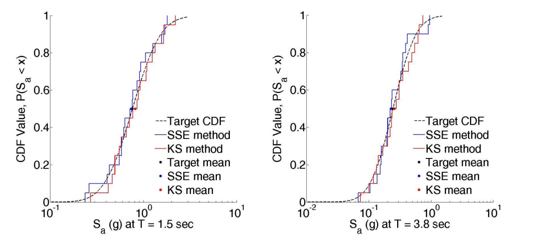
Two methods to select a final set of ground motions are offered :

1. Minimize the sum of squared errors (SSE) between the means and standard deviations of spectral accelerations of the selected spectra

$$SSE = \sum_{j=1}^{p} \left[\left(m_{\ln S_a(T_j)} - \mu_{\ln S_a(T_j)} \right)^2 + w \left(s_{\ln S_a(T_j)} - \sigma_{\ln S_a(T_j)} \right)^2 \right]$$

2. Minimize the sum of Kolmogorov-Smirnov test (KS-test) statistics across all periods of the response spectrum

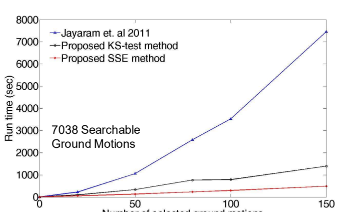
$$KS = \sum_{j=1}^{p} \max\left(\left| normC_j - ECDF_j \right| \right)$$



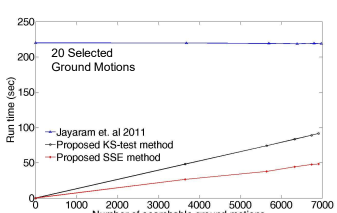
The figures above show the cumulative distribution functions (CDF) at two periods of the target response spectrum of the selected spectra from each method compared to the target CDF. Both methods provide reasonable matches to the distribution, even though minimizing the KS-test statistic does not specifically match the means and variances of the target spectrum.

Efficiency Improvements

Changes to the code's organization and structure made significant improvements to the run time.

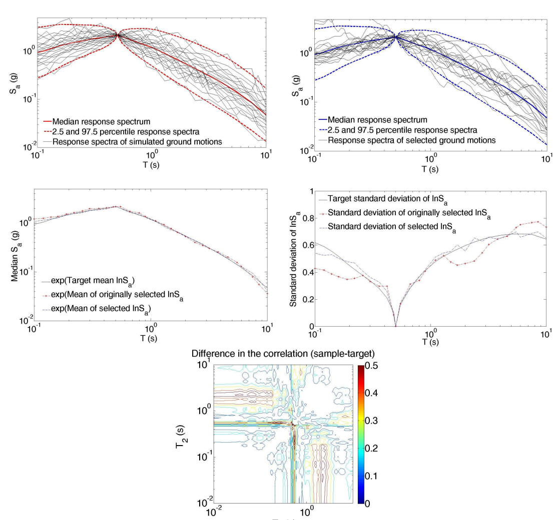


To further reduce software's run time, the algorithm offers options to skip the optimization stage if initially selected records are suitable, and allows the database search to be restricted to ground motions with user-defined ranges for magnitudes, distances and site conditions.



Example Results

The following are typical outputs from a single-component, conditional selection of the NGA-W2 database, using a conditioning period of 0.5 seconds. The target spectrum information comes from considering earthquake hazards on the San Andreas fault for a structure located at Stanford University.



Conclusions and Impacts

An improved ground motion selection algorithm has been developed that is efficient in selecting large numbers of ground motions.

Simulated response spectra are generated with Latin Hypercube Sampling, which ensures that the simulated response spectra are more representative of the full range of spectral accelerations at each response spectrum period than random sampling.

An optimization procedure is then performed to improve the set of selected motions. The user can choose between SSE and KS-test metrics to use in optimization, and can explore the effects of each on the resulting response history analyses.

The code can search any suitably formatted database, and is readily applicable to new databases (e.g. it could be used with the new NGA-East database).

References

Jayaram, N., Lin, T., & Baker, J. W. (2011). A Computationally efficient ground-motion selection algorithm for matching a target response spectrum mean and variance. *Earthquake Spectra*, *27*(3), 797–815.

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