A Subset of CyberShake Ground Motion Time Series for Engineering Response-History Analysis

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Abstract

This project selected and vetted a subset of 320 CyberShake numerically simulated ground motions (Study 15.12) for use in engineering response history analyses. Ground motions were selected that have seismological properties and response spectra representative of conditions in the Los Angeles area, based on disaggregation of seismic hazard. Ground motions were selected from millions of available time series and were reviewed to confirm their suitability for response history analysis. The process used to select the time series, the characteristics of the resulting data, and the provided documentation, are described here.

Project Approach

Our audience is an engineering consultant looking to utilize ground motions in a project in the Los Angeles area. Rather than focus on a single site, we selected ground motions of engineering relevance throughout the region. Engineers need a relatively small pool of ground motions, which have been screened and vetted to some degree. Steps in our calculations were:

- Specify candidate locations and site conditions of interest.
- Perform hazard disaggregation for cases of interest, to determine earthquake scenarios contributing most to hazard.
- Select a small number of target earthquake scenarios based on disaggregation data and screen the CyberShake database to find simulations from those scenarios.
- Generate target response spectra for each target earthquake scenario and select closely matching recordings from the screened database.
- Review the identified time series.
- Produce documentation.

Candidate Locations and Site Conditions

We considered 52 locations in a Los Angeles region, as shown in Figure 1. These are a subset of the locations previously used by the SCEC Utilization of Ground Motion Simulations (UGMS) committee, selected from the available 336 sites in CyberShake study 15.12. For each location, we considered two near-surface site conditions ($V_{S,30}$ = 365 m/s and 760 m/s).

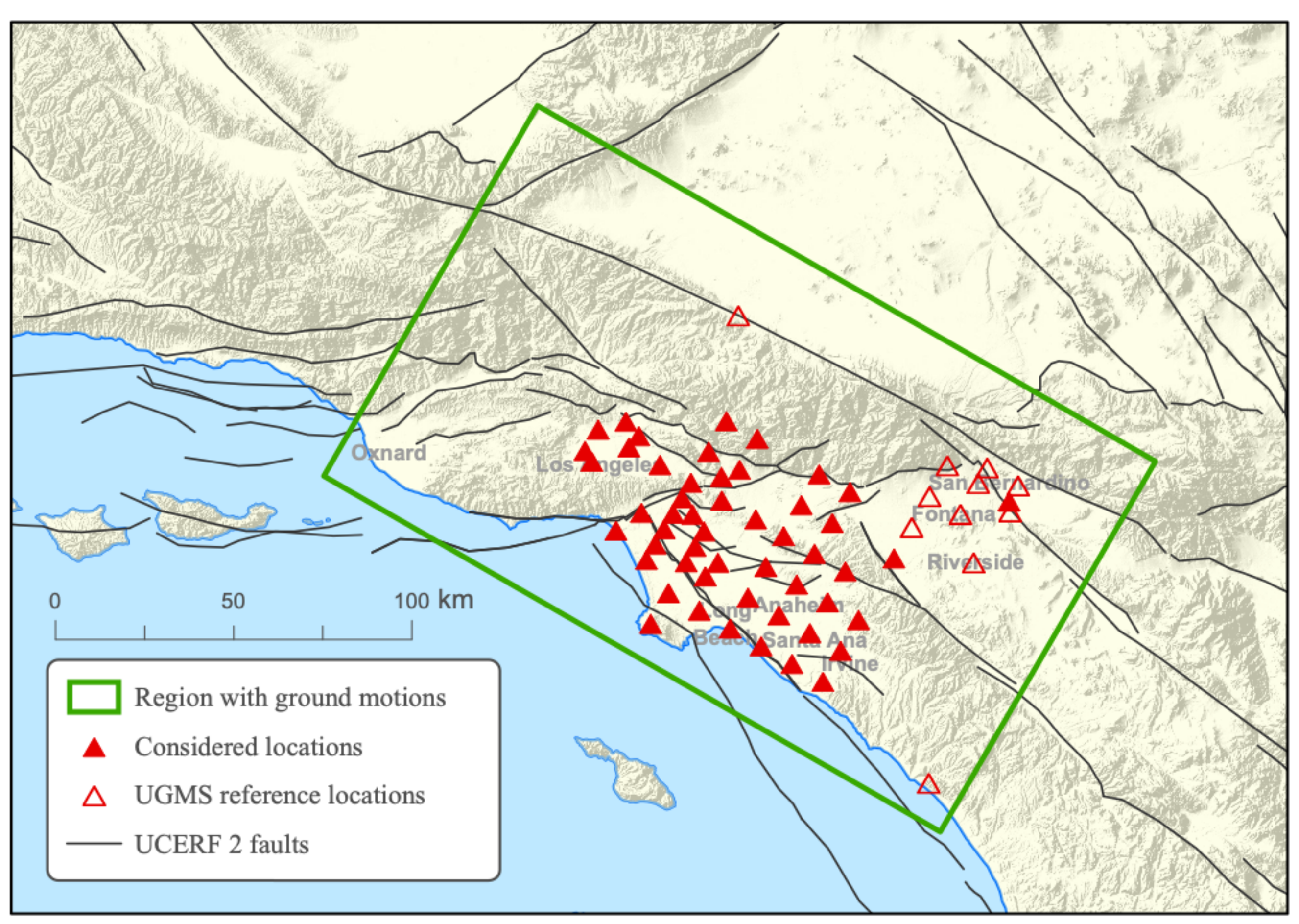

Figure 1: Map of the study area, showing the CyberShake simulation domain, the considered candidate locations and the considered earthquake sources (UCERF2 faults).

Disaggregation

For each of the locations and site conditions, disaggregation was performed to identify the earthquake magnitudes and distances most likely to cause ground motion amplitudes of engineering interest. Hazard and disaggregation calculations from the 2018 USGS National Seismic Hazard Model were used. Disaggregation was initially performed at 22 spectral periods and eight site classes but simplified to the two site classes and four representative spectral periods (0.2, 1, 2, and 5 s). Disaggregation results are shown in Figure 2. As expected, large magnitude ruptures at small distances are dominant, compared to recordings that are mostly from smaller magnitude and larger source-site distances.

The selected ground motions are intended to be relevant for a range of locations, site conditions, and spectral periods, so the disaggregation data were pooled and used to select representative rupture scenarios (M = 6.5, 7.3, 8, R = 5, 8, 40 km). These are scenarios that appear frequently in the disaggregation data, and few recordings are available.

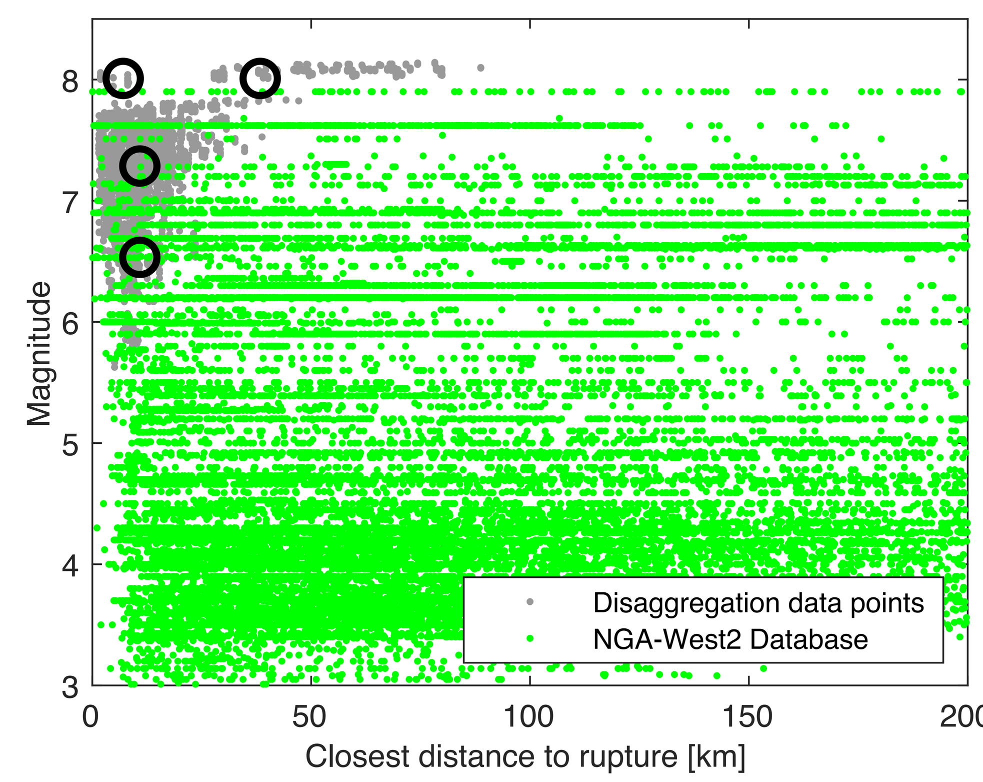

Figure 2: Magnitude and distance values of disaggregation targets from this study, and of ground motions in the NGA-West2 database. The selected scenarios are shown with black circles.

Ground Motion Selection

Simply constraining the rupture and site characteristics for ground motion selection leaves millions of available candidate time series from the CyberShake database. To further reduce the selected set of motions, a spectral-target-based selection approach was utilized. This reduces the large dataset and eliminates time series that diverge significantly from a typical spectral shape. Figure 3 illustrates the process.

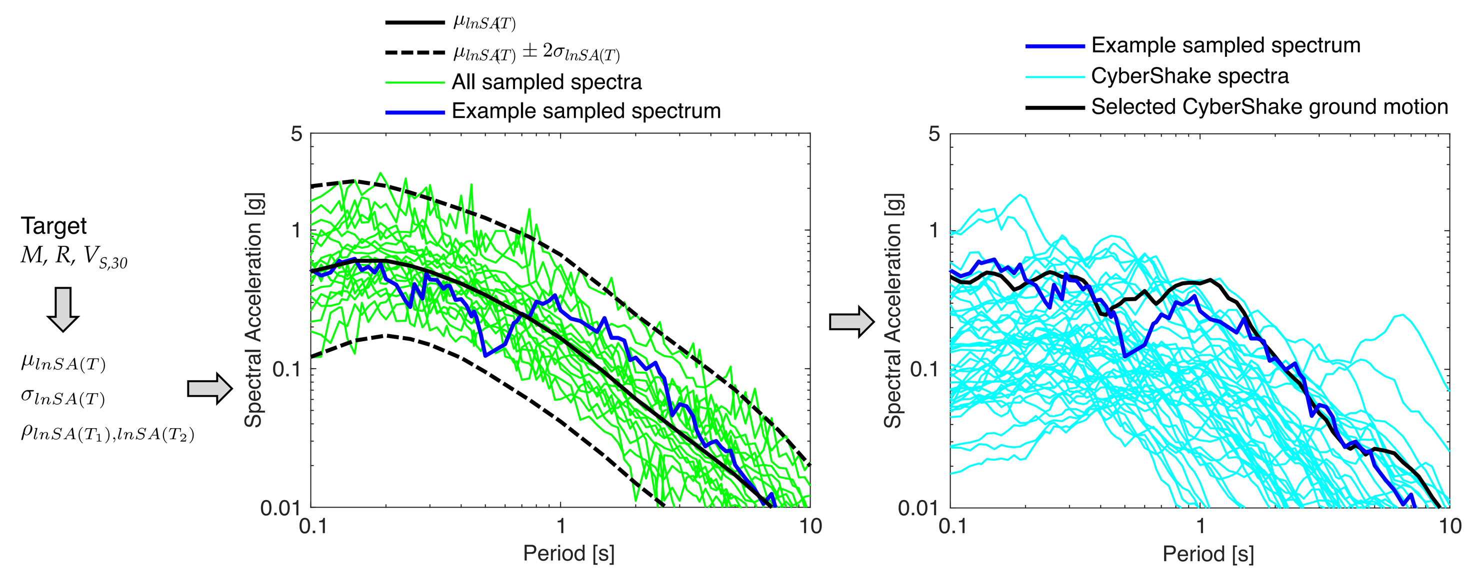

Figure 3: Schematic illustration of the ground motion selection process. We first specify a target scenario and compute the means, standard deviations and correlations of ln*SA* (left); we then Monte Carlo sample response spectra from the resulting distribution (middle); finally, we compare each sampled response spectrum to the CyberShake spectra and select the closest match (right).

Time Series Review

The process and results described above were subject to several stages of review during the project. The locations, disaggregations, and target earthquake scenarios were presented to the SCEC Ground Motion Simulation Validation (GMSV) group. The ground motion selection process and selected ground motions were presented to the GMSV group and some members of the SCEC UGMS committee, for further comment.

Documentation

The data are archived at *doi.org/10.5281/zenodo.3875541* and loaded into a ground motion selection tool at *github.com/bakerjw/CS_Selection*. A report provides plots of response spectra and time series for each ground motion component (e.g., Figure 4). A flatfile provides several dozen data fields for each ground motion.

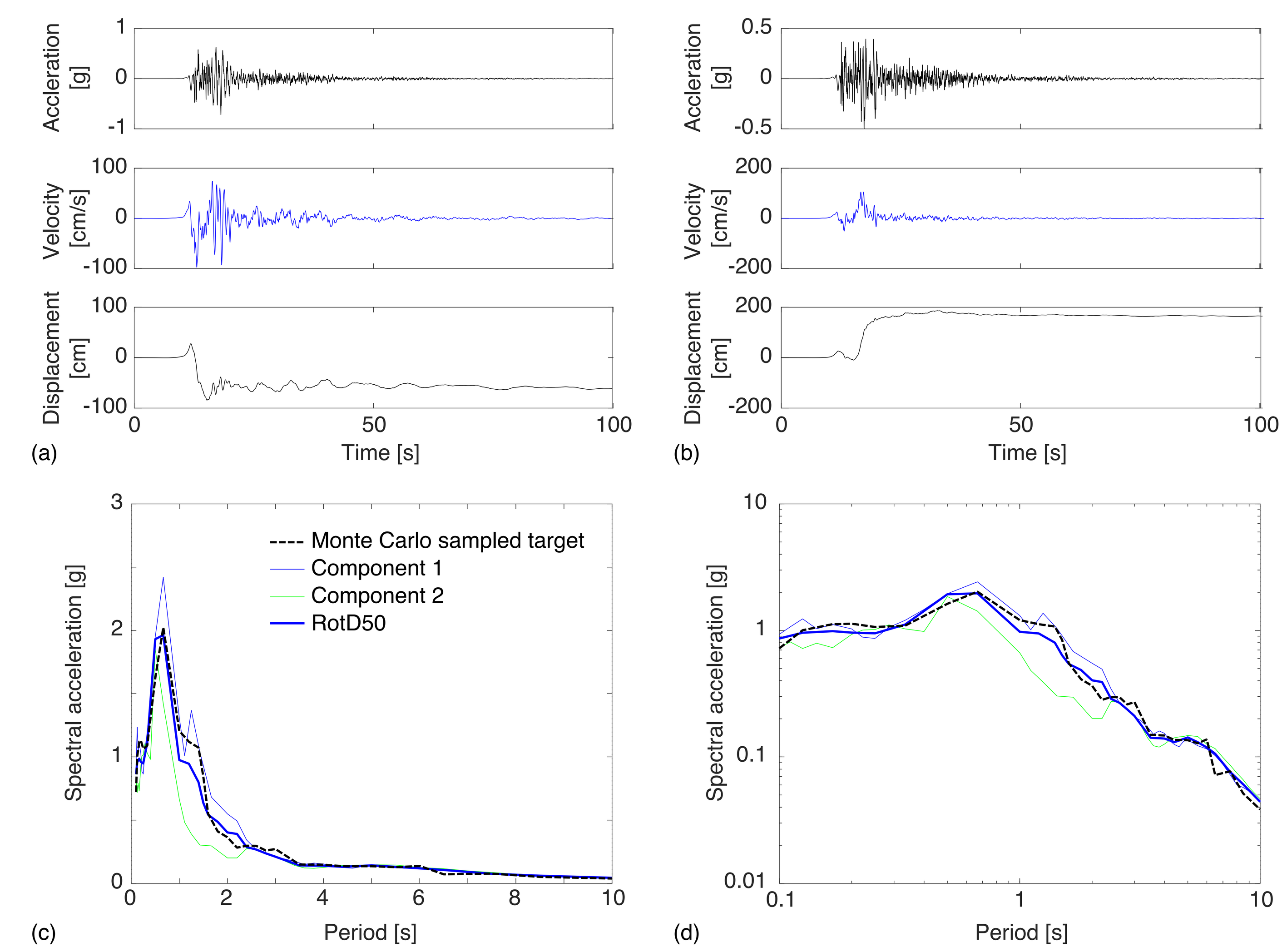

Figure 4: Example time series and spectra plots for a selected ground motion (a M=7.85 San Andreas rupture recorded at a distance of 0.3km with $V_{S,30}$=748 m/s). (a) Component 1 acceleration, velocity and displacement. (b) Component 2 acceleration, velocity and displacement. (c) Response spectra in linear scale. (d) Response spectra in log scale.

Conclusion

The CyberShake database provides a rich source of ground motions, from important conditions such as from large-magnitude ruptures and in sedimentary basins. To utilize these data for engineering purposes, we developed a procedure to screen and select a small number of relevant ground motions. We believe that the resulting set of ground motions are appropriate for use in response history analysis of structures and that the pre-screening and review make the dataset more practical for engineers than the complete original database. The process can also be replicated with future databases.

Acknowledgements

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