

OpenSHA Implementation of the GCIM Approach for Ground Motion Selection

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1. Background and Objective

Ground motion selection is known to be an important step in seismic hazard and risk assessment. There have been numerous procedures proposed for selecting ground motions ranging from somewhat ad-hoc guidelines specified in seismic design codes to more rigorous approaches which have found favour in the research-community, but are not yet applied routinely in earthquake engineering practice.

The most common method (often specified in seismic design codes) for selecting ground motion records for use in seismic response analysis is based on their 'fit' to a Uniform Hazard Spectrum (UHS). This is despite the fact that many studies have highlighted the differences between the UHS and individual earthquake scenarios, and therefore its inappropriateness for use in ground motion selection. The reluctance of the earthquake engineering profession to depart from UHS-based selection of ground motions is arguably because of its simplicity to implement relative to methodologies with sounder theoretical bases.

To this end, the aim of the present work was to implement a recently developed Generalised Conditional Intensity Measure (GCIM) approach for ground motion selection (Bradley, 2010) into the open-source seismic hazard analysis software OpenSHA (Field et al. 2003).

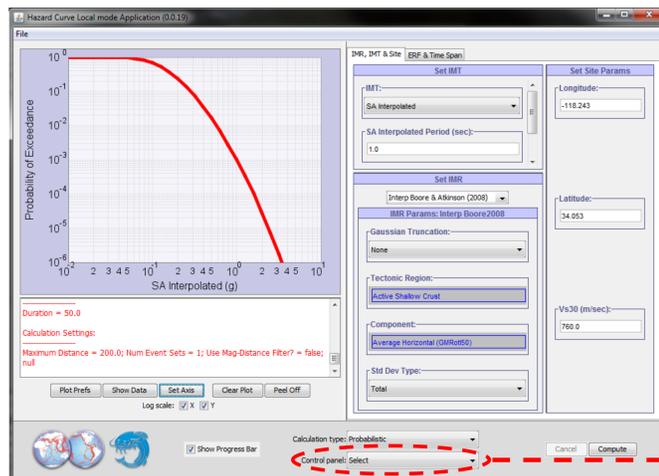


Figure 1: OpenSHA Hazard Curve Calculator (Field et al, 2003)

Specify the IML or Exceedance probability

Via approximate CDF values specify the range of IMi to compute the GCIM distribution for

Select from the Hazard Curve Control Panel

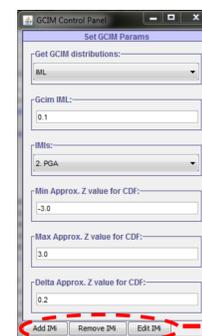


Figure 2: GCIM Control Panel

Add, Remove and Edit IMi's for which GCIM distributions are desired

Set the IMi.

Set the IMi relationship (IMR), and associated parameters

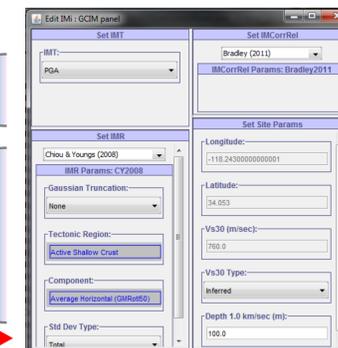


Figure 3: Edit IMi Control Panel

Set the IMi, IMj correlation relationship (ImCorrRel), and associated parameters

Site parameters defined in the Hazard Curve Calculator are non-editable

Additional parameters are editable, but must be the same for all IMi's

2. Overview of the GCIM Method for Ground Motion Selection

The fundamental basis of the GCIM approach is that for a given earthquake scenario (Rup) the joint distribution of a vector of intensity measures (i.e. $IM|Rup$) has a multivariate lognormal distribution (Bradley, 2010). Characterisation of $IM|Rup$, therefore requires the marginal distributions, $IM_i|Rup$ and correlations between IM_i and IM_j for which several prediction equations already exist. The total probability theorem can then be used to construct the conditional distribution of any intensity measure given the occurrence of a specific value of another intensity measure. The figure below illustrates the conditional spectral acceleration and Arias Intensity distributions given $Sa(1.0)$ with an annual exceedance probability of 1/475.

Using the GCIM distributions, Bradley (2010) developed a holistic ground motion selection procedure which can be used to select ground motions for any form of seismic response analysis. The procedure is holistic in that: (i) any level of complexity in ground motion selection for any seismic response analysis can be exercised; (ii) users explicitly understand the simplifications made in the selected suite of ground motions; and (iii) an approximate estimate of any bias associated with such simplifications is obtained.

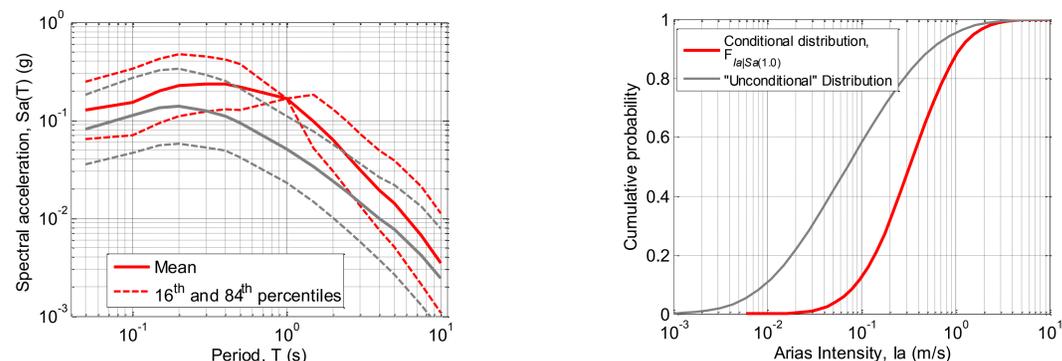


Figure 4: Example conditional distributions for a site in Christchurch, New Zealand.

3. OpenSHA implementation

In order to improve the ease at which the GCIM approach can be utilised, therefore increasing its potential for uptake in earthquake engineering practice, the method was implemented in the open-source software OpenSHA (Field et al, 2003). OpenSHA is an object-oriented, web- and GUI-enabled and freely available software developed as a joint venture between SCEC and USGS (www.opensha.org/). Figure 1 – Figure 3 illustrate the three key objects in the GCIM implementation.

3.1. Hazard Curve Calculator

- Figure 1 illustrates the Hazard Curve Calculator, which is used to obtain seismic hazard curves for the site of interest. Using the Control Panel button the "GCIM distributions" Control Panel can be selected.

3.2. GCIM Control Panel

- Using the GCIM Control Panel in Figure 2, the analyst can first select the Intensity Measure Level (IML) or Probability of exceedance (from the seismic hazard curve), for which the GCIM distributions are desired.
- By using the "Add IMi", "Edit IMi", and "Remove IMi" buttons the analyst can then begin to specify the details of the various IMi's for which GCIM distributions are desired.
- The analyst can also specify additional details, such as the approximate CDF values to compute the GCIM distributions for.

3.3. Edit IMi Control Panel

- Using the Edit IMi Control Panel in Figure 3, firstly the IMi type (e.g. PGA, Sa, SI, I_a , etc.) can be defined. Only those IMi's for which correlation and ground motion prediction equations are available can be selected.
- Next, the ground motion prediction equation (IMR) which is used to predict the marginal distribution of the IMi, and also the IMi,IMj correlation relationship (ImCorrRel) can be defined, as well as their associated parameters. It is not shown in Figure 3, but separate IMR's and ImCorrRel's can be provided for different tectonic regions (e.g. Active Shallow Crustal, Subduction Interface etc.).
- The site parameters required by the IMR and ImCorrRel for the particular IMi are also shown in the Edit IMi Control Panel.
- Those site parameters which are specified in the Hazard Curve Calculator are shown, but cannot be edited. On the other hand, additional parameters which are required can be edited, and are stored for all of the different IMi's considered

4. Implications

The ability to be able to generate GCIM distributions using the open-source software OpenSHA provides a means for users to apply, with the same effort as current UHS-based procedures, a more rigorous ground motion selection methodology.

5. Acknowledgements

Assistance from Kevin Milner (USC), Peter Powers (USGS) and Ned Field (USGS), as well as funding under SCEC award #10023 are greatly appreciated.

6. References

- Bradley, B.A. (2010) A Generalised Conditional Intensity Measure Approach and Holistic Ground Motion Selection. *Earthquake Engineering and Structural Dynamics* (in press – available online or from the author via email)
- Field, E. H., Jordan, T. H. and Cornell, C. A. (2003) OpenSHA: A Developing Community-Modelling Environment for Seismic Hazard Analysis. *Seismological Research Letters*, 74: 406-419.