Implementation of a generalized conditional intensity measure (GCIM) approach in OpenSHA

Annual report, 2010 SCEC Project #10023

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Introduction

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 [1] into the open-source seismic hazard analysis software OpenSHA [2].

Overview of the GCIM approach

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. $\boldsymbol{IM}|Rup$) has a multivariate lognormal distribution [1]. Characterisation of $\boldsymbol{IM}|Rup$, 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.

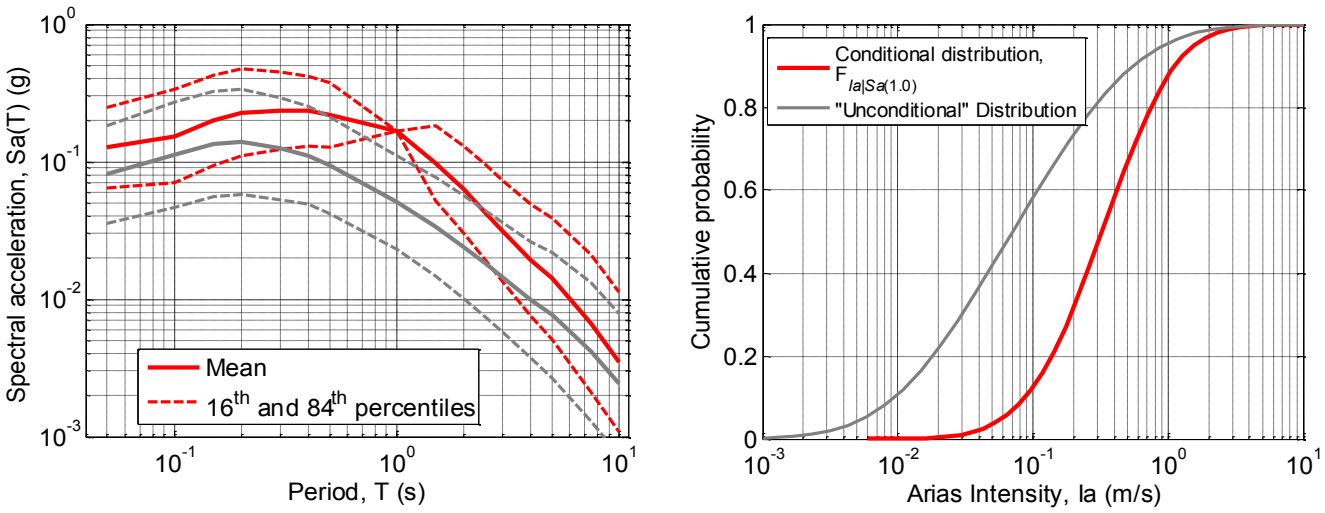

Figure 1: Example conditional distributions for a site in Christchurch, New Zealand

Using the GCIM distributions, Bradley [1] proposed 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

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 [2]. 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 2 illustrates the three key GUI control panels in the GCIM implementation.

Hazard curve calculator

- 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.

GCIM control panel

- Using the GCIM Control Panel 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.

Edit IMi control panel

- Using the Edit IMi Control Panel, firstly the IMi type (e.g. *PGA*, *SA*, *SI*,

IA, 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 2, 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

Implications of the software implementation

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. This should also help facilitate the interaction of engineering seismologists and earthquake engineers.

Anticipated publications

This report is based on a poster presented at the 2010 SCEC annual meeting [3]. The OpenSHA implementation of the GCIM approach is presently being more formally documented for the purposes of a journal publication. The author and other collaborators are using this implementation for various ground motion selection applications which will likely be submitted for publication in the forthcoming year, as well as the 2011 SCEC annual meeting.

Acknowledgments

Assistance from Kevin Milner (USC), Peter Powers (USGS) and Ned Field (USGS) are greatly appreciated.

References

[1] Bradley, BA. A generalized conditional intensity measure approach and holistic ground motion selection. *Earthquake Engineering and Structural Dynamics* 2010; **39**(12): 1321-1342.

[2] Field, EH, Jordan, TH, Cornell, CA. OpenSHA: A developing community-modelling environment for seismic hazard analysis. *Seismological Research Letters* 2003; **74**: 406-419.

[3] Bradley, BA. OpenSHA implementation of the GCIM approach for ground motion selection, in *Southern California Earthquake Centre (SCEC) Annual Meeting*: Palm Springs, California, USA. 2010.

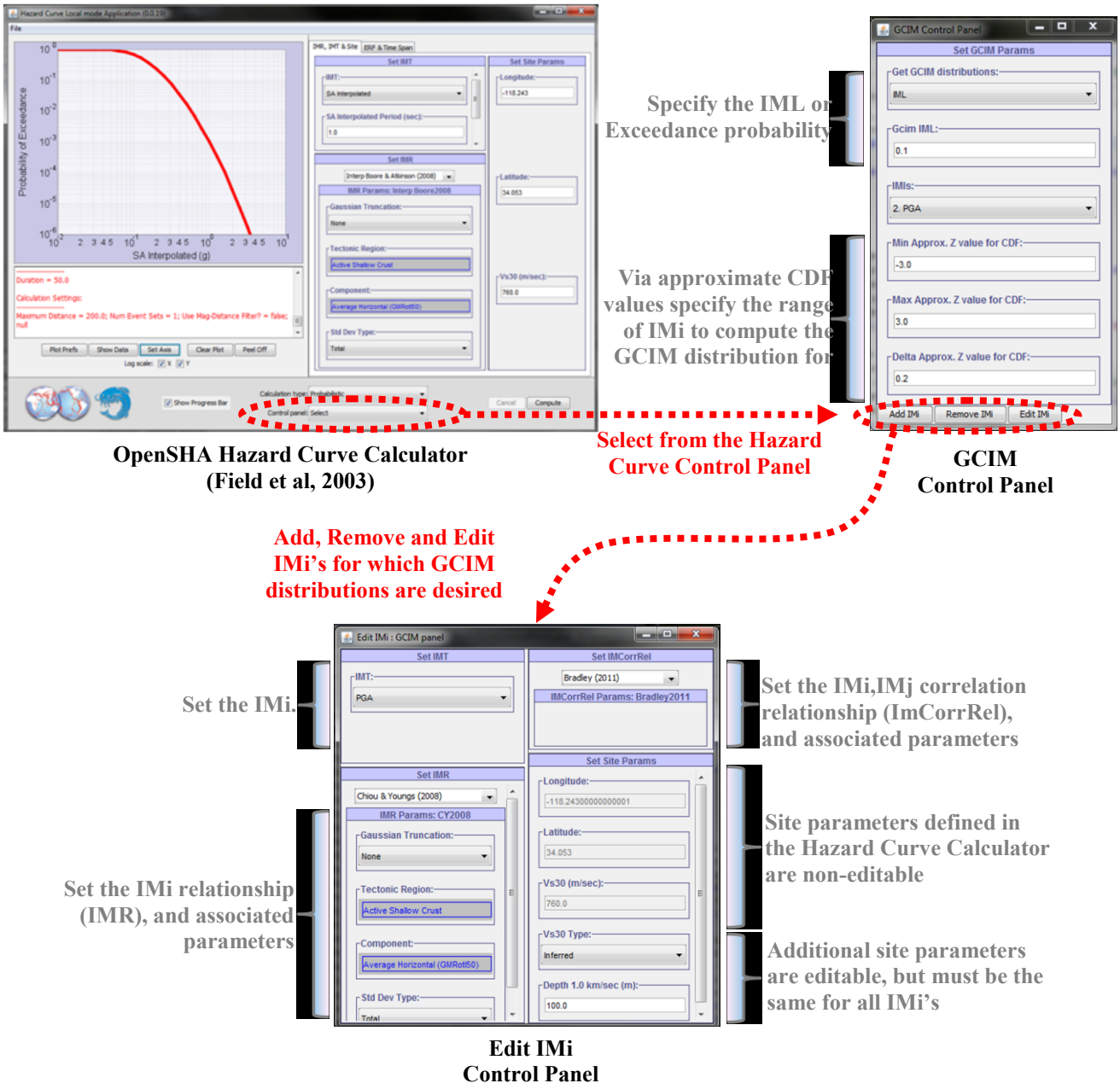

Figure 2: The OpenSHA hazard curve calculator and the GCIM control panels