

User's Guide

GMotion Graphical User Interface

Cristopher Vetter and Alexandros A. Taflanidis
University of Notre Dame
Hazards Hub



Scope: GMotion provides ground motions generated from two popular stochastic ground motion models (one source-based [1] and one record-based [2]) for either a specific seismic event or for an ensemble of events with potentially different seismicity characteristics (described through user-defined distributions).

1 Installation

GMotion needs the MATLAB Compiler Runtime version 8.2 (MATLAB R2013b). Users that do not have MATLAB R2013b can download the compiler from (select appropriate version, that is, version 8.2 and either 32 or 64 bit depending on machine)

<http://www.mathworks.com/products/compiler/mcr/index.html>

Installation of compiler needs to be performed only once (before running GMotion for the first time).

2 Execution

GMotion is executed through the GMotion.exe executable file, which can be placed in any folder on the computer. Files generated by GMotion will be directly saved in this folder. The overall GUI for GMotion is shown in Figure 1.

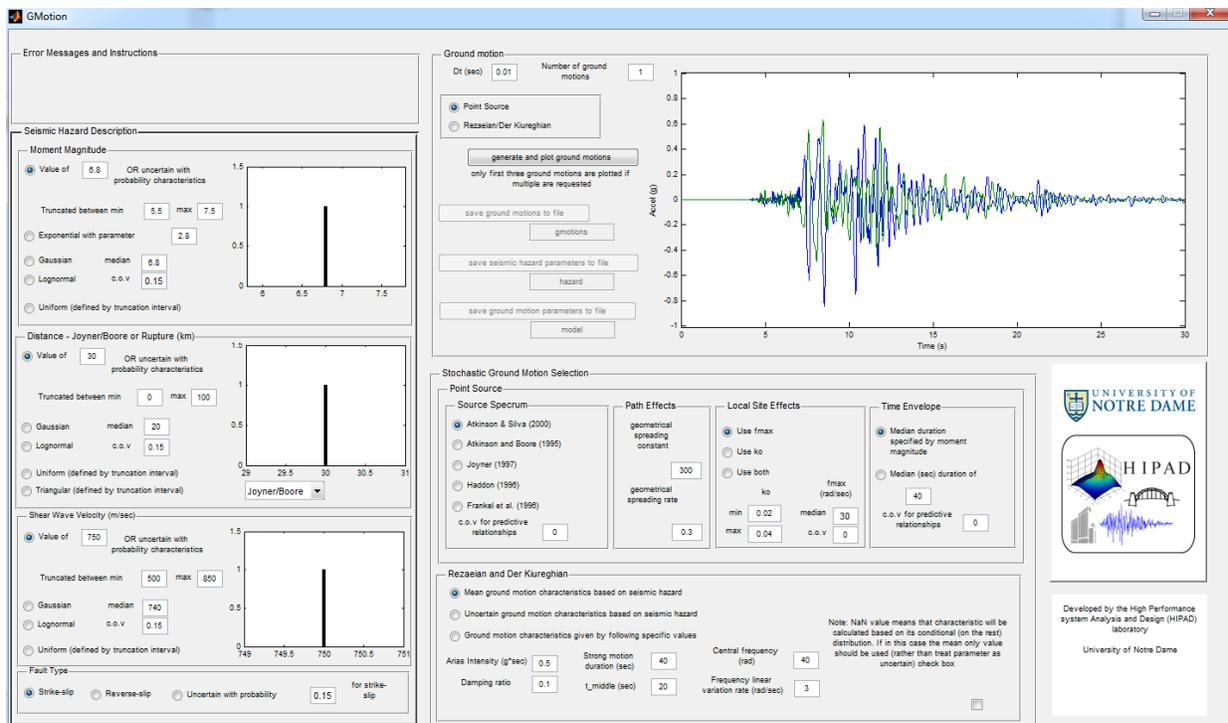


Figure 1: GUI (Graphical User Interface) of GMotion

The GUI has four different panels,

- 1) Error Messages and Instructions Panel, providing instructions and error messages when needed.
- 2) Seismic Hazard Description, used to provide the input information that defines the seismic hazard.

- 3) Ground Motion, used to select stochastic ground motion model and generate, save the outputs.
- 4) Stochastic Ground Motion Selection, used to define the stochastic ground motion model's parameters.

2.1 Error Messages and Instructions Panel

This panel provides various error messages or instructions for the user. Both of these are updated during the execution of GMotion.

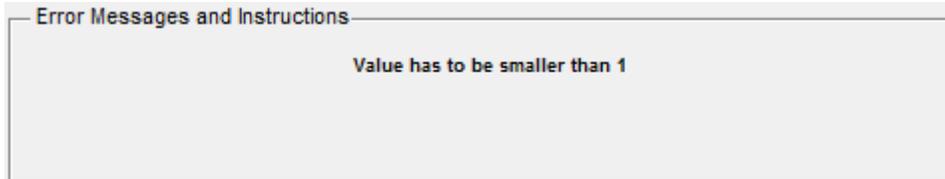


Figure 2: Error Messages and Instructions Panel

2.2 Seismic Hazard Description Panel

The ground motion is described by its seismic hazard description relating to the following information

- 1) Moment Magnitude
- 2) Distance Measure – either Joyner/Boore or Rupture Distance may be selected
- 3) Shear Wave Velocity
- 4) Faulting Type

When selecting the distribution for any of the first 3 descriptions from the radio buttons on the left in each of the sub-panels, the plots of the distribution (either deterministic through defining a value or probabilistic through the selection of a probabilistic density function, PDF) on the right of the sub-panels will update as seen in Figure 3. The description of the available PDFs will be provided in the appendix of this manual. More descriptions of each of these sub-panels and their appropriate values for input will be provided in the following sub-sections.

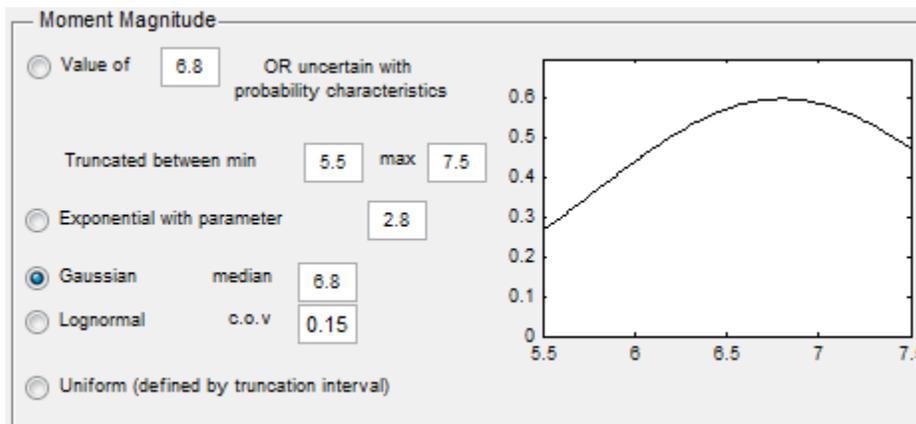


Figure 3: Example of Seismic Hazard Sub-Panel

2.2.1. Moment Magnitude

Here the moment magnitude description of the seismic hazard is input. The first radio button selection allows for a deterministic value for the moment magnitude, M , and must take on a value between 4 and 8. The following four radio button selections allow for a probabilistic distribution of M each with inputs defined in the input boxes outlined (in three colors explained below) in Figure 4.

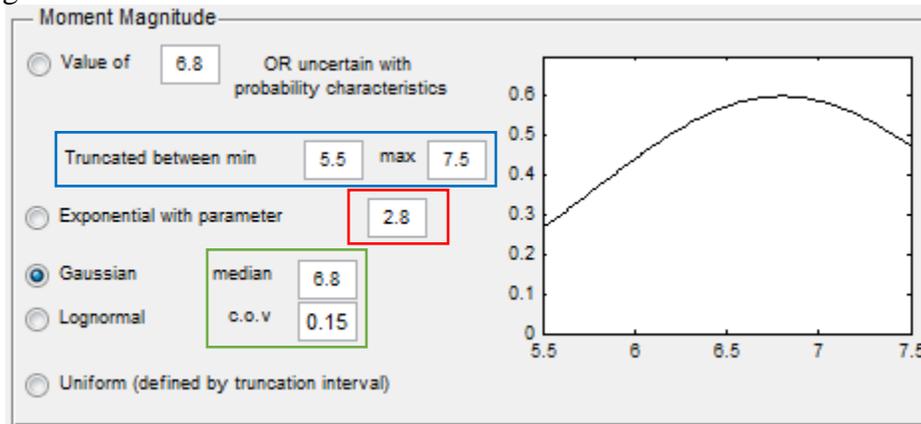


Figure 4: Moment Magnitude Sub-Panel

The first highlighted area (blue) in Figure 4 represents the domain that the PDFs will be allowed to take on. Like the deterministic value, **all four** of the PDFs that can be selected will be allowed to take on a minimum value of 4 and a maximum value of 8; therefore, this truncated domain is used in the characterization of all four PDFs. The following provides a brief description of the inputs to the four possible PDFs that can be selected:

- 1) Exponential: This is defined by the rate of the exponential distribution, λ , highlighted in red (in Figure 4).
- 2) Gaussian: This is defined by the median and c.o.v. inputs highlighted in green (in Figure 4). The range allowed for the median are between 2 and 8, while the range allowed for the c.o.v. is between 0 and 1.
- 3) Lognormal: This is described similarly to the Gaussian listed in (2).
- 4) Uniform: This is described entirely by the truncation interval.

Remember all four of the PDFs are defined on a truncated interval.

2.2.2. Distance – Joyner/Boore or Rupture (km)

Here the distance description of the seismic hazard is input. The first radio button selection allows for a deterministic value for the distance, R , and must take on a value between 0 and 100 km. The following four radio button selections allow for a probabilistic distribution of R each with inputs defined in the input boxes outlined (in three colors explained below) in Figure 5.

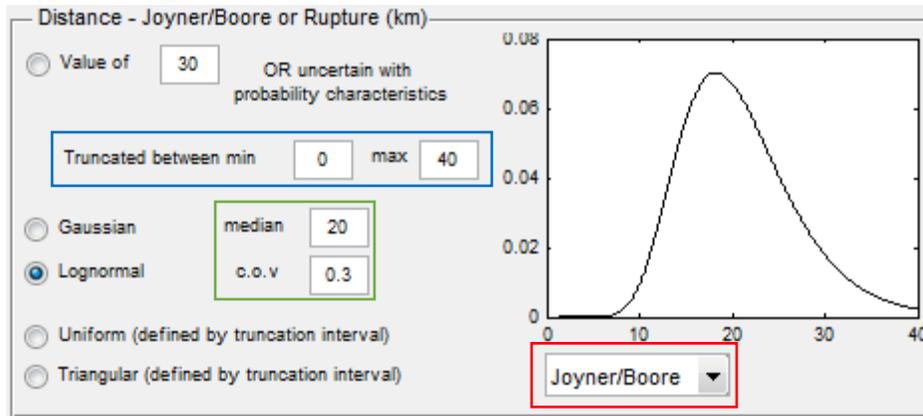


Figure 5: Distance Sub-Panel

The first highlighted area (blue) in Figure 5 represents the domain that the PDFs will be allowed to take on. Like the deterministic value, **all four** of the PDFs that can be selected will be allowed to take on a minimum value of 0 and a maximum value of 100 km; therefore, this truncated domain is used in the characterization of all four PDFs. The following provides a brief description of the inputs to the four possible PDFs that can be selected:

- 1) Gaussian: This is defined by the median and c.o.v. inputs highlighted in green (in Figure 5). The range allowed for the median are between 5 and 100 km, while the range allowed for the c.o.v. is between 0 and 1.
- 2) Lognormal: This is described similarly to the Gaussian listed in (1).
- 3) Uniform: This is described entirely by the truncation interval.
- 4) Triangular: This is described entirely by the truncation interval.

Remember all four of the PDFs are defined on a truncated interval.

As the title of the sub-panel suggests, the selection of two different distance measures is accepted (selection made in dropdown menu highlighted in red). The two different distance measures and their interpretations are illustrated in Figure 6, as presented in [3].

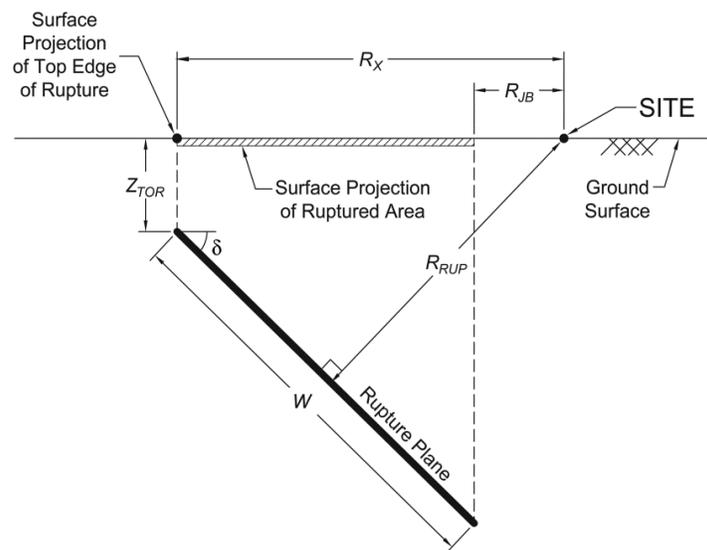


Figure 6: Illustration of Distance Measures

As it is shown in Figure 6, the Joyner/Boore distance is referenced as R_{JB} and the rupture distance is referenced as R_{RUP} . R_{JB} is defined as the closest distance to the surface projection of the ruptured area and R_{RUP} is defined as the closest distance to the rupture plane [3].

2.2.3. Shear Wave Velocity

Here the shear wave velocity (top 30 m of soil) description of the seismic hazard is input; shear wave velocity is defined as the average velocity between 0 and 30 meters. The first radio button selection allows for a deterministic value for the shear wave velocity, V_{S30} , and must take on a value between 200 and 800 m/s . The following four radio button selections allow for a probabilistic distribution of V_{S30} each with inputs defined in the input boxes outlined (in two colors explained below) in Figure 7.

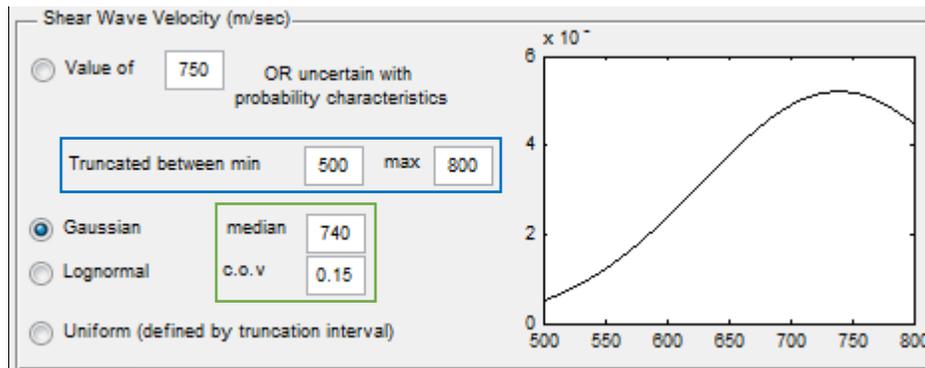


Figure 7: Shear Wave Velocity Sub-Panel

The first highlighted area (blue) in Figure 7 represents the domain that the PDFs will be allowed to take on. Like the deterministic value, **all three** of the PDFs that can be selected will be allowed to take on a minimum value of 200 and a maximum value of 800 m/s ; therefore, this truncated domain is used in the characterization of all three PDFs. The following provides a brief description of the inputs to the four possible PDFs that can be selected:

- 1) Gaussian: This is defined by the median and c.o.v. inputs highlighted in green (in Figure 7). The range allowed for the median are between 600 and 800 m/s , while the range allowed for the c.o.v. is between 0 and 1.
- 2) Lognormal: This is described similarly to the Gaussian listed in (1).
- 3) Uniform: This is described entirely by the truncation interval. Remember all four of the PDFs are defined on a truncated interval; therefore, are truncated PDFs.

Remember all three of the PDFs are defined on a truncated interval.

2.2.4. Fault Type

Here the faulting type is defined for the seismic hazard. Two faulting types are possible: strike-slip or reverse-slip; also, a third scenario is probabilistic nature of the type of faulting defined by a value entered in the block seen in Figure 8. The value here is the probability of the event being strike-slip; as seen 0.15 would mean there is a 15% chance of it being strike-slip. The appropriate values that can be entered are to be between 0 and 1.

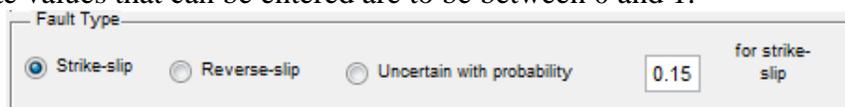


Figure 8: Fault Type Sub-Panel

2.3 Stochastic Ground Motion Selection Panel

This panel allows for the user to define information of the predictive relationships and other constants. These predictive relationships relate seismic hazard description, M , R , V_{S30} , and fault type, defined in the Seismic Hazard Description Panel to the model parameters for the selected stochastic ground motion model [4]. The individual settings for each stochastic ground motion model are discussed below.

2.3.1. Point Source model

One of the two choices of stochastic ground motion model is a point source model which involves modeling the physics of the fault rupture at the source as well as the propagation of the seismic waves through the ground medium till the site. With the point source model, there are model parameters, to be defined by the user, related to the following:

- 1) Source Spectrum
- 2) Path Effects
- 3) Local Site Effects
- 4) Time Envelope, duration of ground motion.

These four sets of parameters provide the description of the stochastic ground motion model with item numbers (1) and (4) being related to the seismic hazard description, M and R . A selection the user cannot define is the relationship the stochastic ground motion model has to the seismic hazard description, V_{S30} ; this directly relates to a set of amplification factors, as made available in [5].

The source spectrum selection allows the selection from five different spectrums summarized in [1]. Some of these selections have one, two, or three model parameters to describe the shape of the source spectrum. More information on the functional forms of the spectra can be found in [1]. As shown in Figure 9, the model parameters related to the shape of the source spectrum can be either deterministic (by setting the c.o.v. to 0) or probabilistic following a lognormal distribution (setting the c.o.v. to a value greater than 0 but not greater than 1).

The screenshot shows the 'Point Source' sub-panel with four main sections:

- Source Spectrum:** Radio buttons for 'Atkinson & Silva (2000)' (selected), 'Atkinson and Boore (1995)', 'Joyner (1997)', 'Haddon (1996)', and 'Frankel et al. (1996)'. Below is a text input for 'c.o.v for predictive relationships' with the value '0'.
- Path Effects:** Text input for 'geometrical spreading constant' with value '300'. Text input for 'geometrical spreading rate' with value '0.3'.
- Local Site Effects:** Radio buttons for 'Use fmax' (selected), 'Use ko', and 'Use both'. Below are text inputs for 'ko' (min: 0.02, max: 0.04), 'fmax (rad/sec)' (median: 30), and 'c.o.v' (0).
- Time Envelope:** Radio buttons for 'Median duration specified by moment magnitude' (selected) and 'Median (sec) duration of'. Below is a text input for 'c.o.v for predictive relationships' with value '0'.

Figure 9: Point Source Sub-Panel

The user may then define the path effects of the stochastic ground motion model by adjusting the deterministic value related to the geometrical spreading constant and the geometrical spreading rate. The geometrical spreading constant is limited to take on a value between 1 and 800 and the rate is unbounded.

The local site effects are defined by two model parameters, f_{max} and κ_o , or a combination of both depending on the selection made by the user. These two model parameters may have a probabilistic or deterministic value depending on the selections made by the user, similar to that of the source spectrum. Here the model parameter f_{max} is a lognormal distributed with the median (limited to be between 10 and 100 rad/sec) and c.o.v. defined by the user. As with the source spectrum setting the c.o.v. to 0 allows for a deterministic value equal to the value defined in the box for the median value; whereas, a value greater than 0 but not greater than 1 would result in a probabilistic description for f_{max} .

The final value, which the user can define, for the point source model is the duration of the strong ground motion. Here the user can define values related to the median duration by either using the predictive relationship—relating it to M —or define the value themselves to be between 10 and 120 sec. The user then, similar to the other blocks in this sub-panel, may input the c.o.v. of this lognormally distributed parameter. Similar to before 0 would have the parameter taking on a deterministic value related to the median selected by the user or defined by the predictive relationships (depending on the radio button selected) and a value greater than 0 but not greater than 1 would result in a probabilistic description for the duration.

2.3.2. *Rezaeian and Der Kiureghian record-based model*

This sub-panel allows for the user to have control over the deterministic or probabilistic description of the model parameters related to the stochastic ground motion model developed by Rezaeian and Der Kiureghian [6]. As seen in Figure 10, the user may select from one of three options:

- 1) mean ground motion characteristics based on the seismic hazard,
- 2) uncertain ground motion characteristics based on the seismic hazard, or
- 3) ground motion characteristics given by specific values.

The items (1) and (2) are straight forward; in both of these the mean values are determined by the predictive relationships developed in [6]. In item (2), there is uncertainty incorporated as also developed in [6]. The final item, (3), is a bit trickier because it allows for three different possibilities.

The user, when defining the ground motion characteristics themselves, has the choice to either define every value or subsets of values. In order to define a subset of values, the user would put a value of “NaN” in the box corresponding to the model parameters they wish to not define. This means that these model parameters will be determined from the conditional (based on the parameters the user defined) distribution. There is one final selection the user may choose related to the parameters not being defined by them. They may choose to have the parameter be deterministic or probabilistic. In Figure 10, the box highlighted in green can be left unchecked for a probabilistic description of the undefined (by the user) parameters or checked for deterministic description, which would be the mean given by the conditional distribution’s mean.

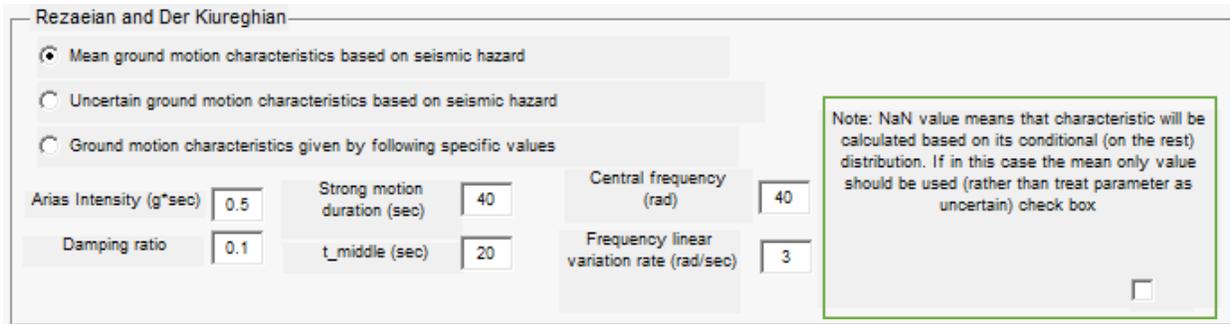


Figure 10: Rezaeian and Der Kiureghian Sub-Panel

2.4 Ground Motion Panel

The ground motion panel is where the user is able to select the time discretization, number of ground motions to generate, and the stochastic ground motion model. These selections can be seen highlighted in red in Figure 11. The user is able to define the time discretization as any value between 0.001 and 0.1 and the number of ground motions to generate. It should be noted to the user that the smaller the time discretization and/or the larger number of ground motions desired the longer the generation will take.

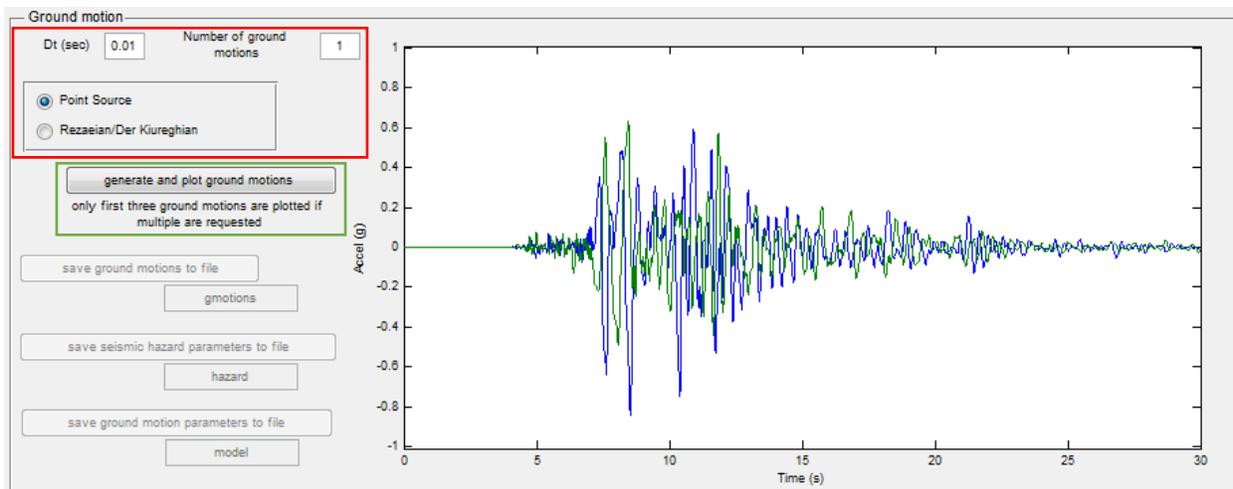


Figure 11: Ground Motion Panel

Once the user has input all the desired values in the Seismic Hazard Description Panel, Stochastic Ground Motion Panel, and has selected the appropriate values in the Ground Motion Panel, they may click the active button highlighted in green in Figure 11 to generate and plot some of the ground motion time histories. Now that the ground motions have been generated, shown in Figure 12, the final three buttons are now active.

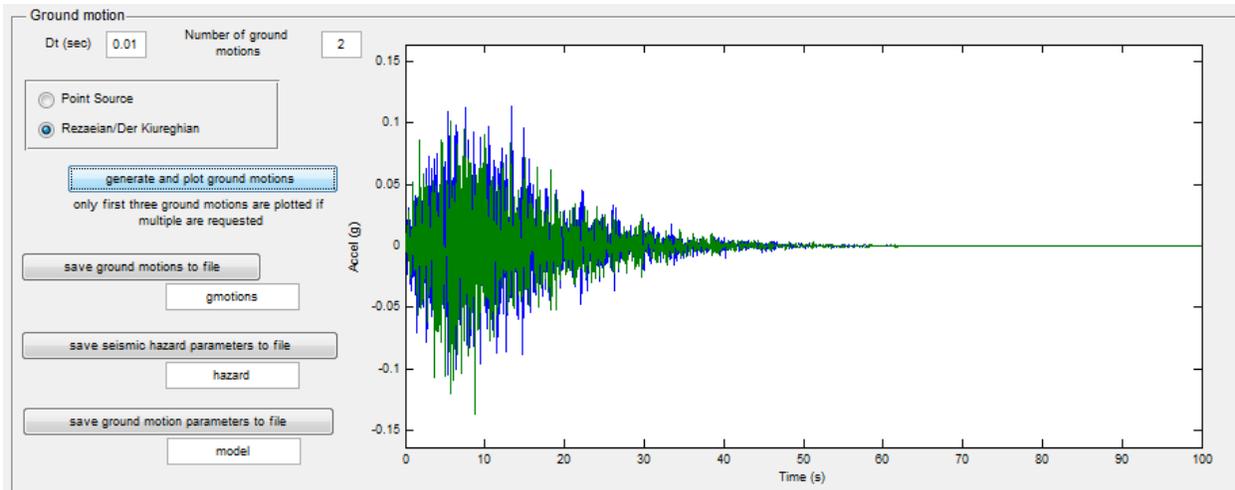


Figure 12: Generated Ground Motions

The first button opens a dialogue window that asks the user where to save a space delimited text file with the first column being the time vector of the ground motion and the subsequent columns corresponding to the ground motions themselves.

The second button opens a dialogue window that asks the user where to save a space delimited text file that saves the Seismic Hazard Descriptions for each ground motion generated. The rows here correspond to the first being Moment Magnitude, second Distance, third Shear Wave Velocity, and finally the Fault Type (0 being strike-slip and 1 being reverse-slip). The columns correspond to those values for each ground motion generated.

The third button opens a dialogue window that asks the user where to save a space delimited text file that saves the Stochastic Ground Motion Model Parameters for each ground motion generated. Here the structure is different depending on the model chosen. If the point source model is chosen the rows correspond to $[\kappa_o, f_{max}, f_a, f_b, e, \lambda_t, \eta_t, t_{dur}]$ and the columns correspond to each ground motion generated. More information regarding the above parameters (except $f_a, f_b,$ and e) can be obtained from [4]. The values of $f_a, f_b,$ and e depend on the source spectrum that is selected (as discussed in Section 2.3.1) so more information on these values can be found in [1]. If the any of the values aren't used they will be held with a place holder of 0. If the Rezaeian/Der Kiureghian model is chose the rows correspond to $[I_a, D_{5-95}, t_{mid}, f_{mid}, f', \zeta]$ and the columns correspond to each ground motion generated.

References

- [1]. Boore, D.M., Simulation of ground motion using the stochastic method. *Pure and Applied Geophysics*, 2003. **160**: p. 635-676.
- [2]. Rezaeian, S. and A. Der Kiureghian, Simulation of synthetic ground motions for specified earthquake and site characteristics. *Earthquake Engineering and Structural Dynamics*, 2010. **39**(10): p. 1155-1180.
- [3]. Kaklamanos, J., L.G. Baise, and D.M. Boore, Estimating Unknown Input Parameters when Implementing the NGA Ground-Motion Prediction Equations in Engineering Practice. *Earthquake Spectra*, 2011. **27**(4): p. 1219-1235.
- [4]. Vetter, C. and A.A. Taflanidis, Comparison of alternative stochastic ground motion models for seismic risk characterization. *Soil Dynamics and Earthquake Engineering*, 2014. **58**(0): p. 48-65.
- [5]. Boore, D.M. and W.B. Joyner, Site amplifications for generic rock sites. *Bulletin of the Seismological Society of America*, 1997. **87**: p. 327-341.
- [6]. Rezaeian, S. and A. Der Kiureghian, Simulation of synthetic ground motions for specified earthquake and site characteristics. *Earthquake Engineering & Structural Dynamics*, 2010. **39**(10): p. 1155-1180.

Appendix: Probability Density Functions

This section is to provide the functional forms and how they are derived for the truncated probability density functions that are discussed in Section 2.2. As it will be shown the exponential, Gaussian, and lognormal truncated distributions are based on a normalization of the parent distributions. The uniform and triangular distributions are readily available in literature as they are already truncated distributions, but will be presented here.

Truncated Exponential

The parent (with standard bounds) exponential distribution is given by

$$f(x; \lambda) = \begin{cases} \lambda e^{-\lambda x} & x \geq 0 \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

where λ is the rate of the exponential distribution provided by the user. The truncated exponential distribution is given by

$$f_T(x; \lambda) = \frac{1}{\beta} \begin{cases} \lambda e^{-\lambda x} & a \leq x \leq b \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

where a is the lower bound defined by the user, b is the upper bound defined by the user, and β is a normalization constant needed in order to satisfy the condition that its integral over the entire space is equal to 1. β is a result of performing the following calculation

$$\beta = \int_a^b f(x, \lambda) \quad (3)$$

where $f(x, \lambda)$ is the parent distribution in (1). It should be noted that the truncated domain needs to be a subset of the total domain for the parent distribution.

Truncated Gaussian

The parent (with standard bounds) Gaussian distribution is given by

$$f(x, \mu, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \quad (4)$$

where μ is the median/mean/mode of the distribution provided by the user and σ is the standard deviation equal to $\sigma = \mu c_v$, where c_v is the c.o.v. defined by the user. The truncated Gaussian distribution is given by

$$f(x, \mu, \sigma) = \frac{1}{\beta} \begin{cases} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} & a \leq x \leq b \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

where a is the lower bound defined by the user, b is the upper bound defined by the user, and β is a normalization constant needed in order to satisfy the condition that its integral over the entire space is equal to 1. β is a result of performing the following calculation

$$\beta = \int_a^b f(x, \mu, \sigma) \quad (6)$$

where $f(x, \mu, \sigma)$ is the parent distribution in (4). It should be noted that the truncated domain needs to be a subset of the total domain for the parent distribution.

Truncated Lognormal

The parent (with standard bounds) Gaussian distribution is given by

$$f(x, \mu, \sigma) = \begin{cases} \frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{(\ln x - \mu)^2}{2\sigma^2}} & x \geq 0 \\ 0 & \text{otherwise} \end{cases} \quad (7)$$

where e^μ is the median of the distribution provided by the user and σ is the standard deviation equal to $\sigma = \sqrt{\ln(c_v^2 + 1)}$, where c_v is the c.o.v. defined by the user. The truncated lognormal distribution is given by

$$f(x, \mu, \sigma) = \frac{1}{\beta} \begin{cases} \frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{(\ln x - \mu)^2}{2\sigma^2}} & a \leq x \leq b \\ 0 & \text{otherwise} \end{cases} \quad (8)$$

where a is the lower bound defined by the user, b is the upper bound defined by the user, and β is a normalization constant needed in order to satisfy the condition that its integral over the entire space is equal to 1. β is a result of performing the following calculation

$$\beta = \int_a^b f(x, \mu, \sigma) \quad (9)$$

where $f(x, \mu, \sigma)$ is the parent distribution in (7). It should be noted that the truncated domain needs to be a subset of the total domain for the parent distribution.

Uniform

The uniform distribution is given by

$$f(x) = \begin{cases} \frac{1}{b-a} & a \leq x \leq b \\ 0 & \text{otherwise} \end{cases} \quad (10)$$

where a is the lower bound defined by the user and b is the upper bound defined by the user.

Triangular

The triangular distribution is given by

$$f(x, a, b, c) = \begin{cases} 0 & x < a \\ \frac{2(x-a)}{(b-a)(c-a)} & a \leq x \leq c \\ \frac{2(b-x)}{(b-a)(b-c)} & c < x \leq b \\ 0 & x > b \end{cases} \quad (11)$$

where a is the lower bound defined by the user, b is the upper bound defined by the user, and c is the mode, which is equal to b in this case.