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The DMG Quick Reference Manuals

MCSI

Maximum Credible Seismic Input

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Author:	Franco Vaccari, Andrea Magrin

University of Trieste
Department of Mathematic and Geosciences
Group of Seismology
via Weiss, 4
34128 Trieste, Italy

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MCSI for regional seismic hazard

Introduction

MCSI computations require three steps:

1) Generation of the unscaled seismograms, for the grid or for a set of observation points
2) Convolution of the unscaled seismograms with multiple realisations of the source rupturing process, and MCSI generation for multiple scenarios
3) Generation of the statistics and of the MCSI plots

In step 1), to save the unscaled seismograms in a hazard run, cleaning option 11 must be specified in `makehaz.par` file.

⚠➡Please note that multiple realisations of a hazard run at national scale may require huge computational resources, so it is strongly suggested to configure the run so that synthetic seismograms are generated for a small set of sites, to be specified in a .obs file⬅⚠.

The example computations described below are limited to 5 realisations of the source rupturing process and 4 sites where MCSI is computed. In such configuration, all the commands can be executed interactively in the Terminal.

For each step of the computations, the input files required can be found in

```
/XDST/Examples/HazardExamples/Multi
```

You can copy them from the subdirectories:

```
/XDST/Examples/HazardExamples/Multi/01-PrepareUnscaled/Base
/XDST/Examples/HazardExamples/Multi/02-MultipleScaling/Base
/XDST/Examples/HazardExamples/Multi/03a-CombineResultsJointly/Base
/XDST/Examples/HazardExamples/Multi/03b-CombineResultsSeparately/Base
```

Actually, for MCSI computations dedicated to real engineering analyses, MCSI should be obtained using a much larger number of realisations. The source spectra files pointed by the path defined in file `makemultihaz.par` in step 2) allows to use up to 99 realisations of the rupturing process, which should be enough for most applications. If you believe you need more than that, you should generate yourself the source time functions, according to what is described by the Pulsyn manual.

Step 1) Generation of the unscaled seismograms

The directory `/XDST/Examples/HazardExamples/Multi/01-PrepareUnscaled/Base` contains the required files for a hazard run where seismograms are generated at four sites, whose coordinates are defined in `z1de.obs` file.

⚠➡Please note that MCSI computations require that the cutoff frequency of the synthetic seismograms is 10 Hz⬅⚠.

Create a directory `Multi` and inside it the directory `01-PrepareUnscaled`.

```
mkdir -p Multi/01-PrepareUnscaled
```

and copy into it the required input files:

```
cd Multi/01-PrepareUnscaled
cp /XDST/Examples/HazardExamples/Multi/01-PrepareUnscaled/Base/* .
```

Run

```
makehaz.out
hazard
```

The unscaled seismograms will be saved in the `Unscaled` directory.

Step 2) Convolution with multiple realisations of the source process, and MCSI generation for each requested scenario

Create inside `Multi` the directory `02-MultipleScaling` and copy into it the file `makemultihaz.par` file:

```
cd Multi
mkdir 02-MultipleScaling
cd 02-MultipleScaling
cp /XDST/Examples/HazardExamples/Multi/02-MultipleScaling/Base/* .
```

In this example, MCSI is required only for 5% damping of the response spectra. Two scenarios are requested (b090 and b180), and five realisations of the rupturing process will be saved in the `b090` (for bilateral rupturing style with 90° directivity) and `b180` (for bilateral rupturing style with 180° directivity) directories. Inside each of the two directories, a `Results` directory will contain the data and the plots of the MCSI, computed separately for each requested scenario. ⚠➡Please note that the real MCSI at one site is obtained by merging both scenarios, according to what is described in steps 3a) and 3b)⬅⚠.

Below is the content of file `makemultihaz.par`:

```
parameter file for makemultihaz
------------------------------------------------------------------------
common parameters for all tests
------------------------------------------------------------------------
../01-PrepareUnscaled        path of original hazard run (max 100 chars)
0                obs (if 0 use all original run)
1                maxnumrun
1                compute mcsi (irs)      (0=no, 1 = only 5% damping, 2 = all damping)
2                plot mcsi for each point (iplotmcsi) (0=no, 1=yes, 2=yes with table)
1                clean scaled seismograms (0 - save, 1 - remove)
0                clean unscaled seismograms from Base directory (0 - save, 1 - remove)
1                copy input of original run
------------------------------------------------------------------------
b090                  Name of test 1
0                     increase length of scaled seismograms (ipoints)
5                     number of realisations
90                    directivity angle
1                     format of source spectra (1 - like guphas)
/tmpXDST/SeismoWeb/Par/ExtendedSources/G11/Bil/STF                  path of source
spectra (max 100 chars)
0                     structure of source spectra directory (0 - all realisations in
the same folder, 1 - one realisations for each folder)
------------------------------------------------------------------------
b180                  Name of test 2
0                     increase length of scaled seismograms (ipoints)
5                     number of realisations
180                   directivity angle
1                     format of source spectra (1 - like guphas)
/tmpXDST/SeismoWeb/Par/ExtendedSources/G11/Bil/STF                  path of source
spectra (max 100 chars)
0                     structure of source spectra directory (0 - all realisations in
the same folder, 1 - one realisations for each folder)
------------------------------------------------------------------------
```

Maximum number of characters for path of original hazard run and path of source spectra area 100.

To perform the computations, run program

makemultihaz.out

and, once ended, execute the script

all_multihazard.sh

After this step has been performed, even for different configurations (e.g. random nucleation point, different structural models or focal mechanisms, etc), new statistics can be generated combining the results according to two different strategies, as shown in steps 3a and 3b.

Step 3a) MCSI: combining results as a single scenario

With this first strategy, all the accelerograms obtained from scenarios b090 and b180 are used together to obtain a new MCSI, with the statistics generated considering the ten realisations (five from b090 and five from b180) as part of the same scenario.

To proceed with the computations, create a folder named `03a-CombineResultsJointly at the same level of directory 02-MultipleScaling, cd` into it and prepare file `multifin.par`. It consists of a set of parameters aimed at configuring the execution, and a list of directories from where to take the input files. The part of file with parameters is shown below:

```
Parameter file for multifin.out program written by multihazard.out (v0002)
-----------------------------------------
j              rootname for outfile (rootname)
cou             extension of input files
-----------------------------------------
-----------------------------------------
component
-----------------------------------------
1               consider vertical component (ivert)
1               consider res component (ires)
1               consider max component (imax)
0               consider hor component (iorr)
-----------------------------------------
-----------------------------------------
kind of ground motion parameter
-----------------------------------------
1               consider displacement (idis)
1               consider velocity (ivel)
1               consider acceleration (iacc)
0               consider DGA (idga)
1               consider SA (isa)
1               consider SV (isv)
1               consider SD (isd)
-----------------------------------------
-----------------------------------------
list of run folders (max 100 chars)
-----------------------------------------
```

To add the list of folders at the end of the general parameters a *find* command can be executed:

find ../02-MultipleScaling/b???/R???? -type d >> multifin.par

taking care of the path where step 2) was executed. At this point, file `multifin.par` should look like this:

```
Parameter file for multifin.out program written by multihazard.out (v0002)
-----------------------------------------
j              rootname for outfile (rootname)
cou             extension of input files
-----------------------------------------
-----------------------------------------
component
-----------------------------------------
1               consider vertical component (ivert)
1               consider res component (ires)
1               consider max component (imax)
0               consider hor component (iorr)
-----------------------------------------
-----------------------------------------
kind of ground motion parameter
-----------------------------------------
1               consider displacement (idis)
1               consider velocity (ivel)
1               consider acceleration (iacc)
0               consider DGA (idga)
1               consider SA (isa)
1               consider SV (isv)
1               consider SD (isd)
-----------------------------------------
-----------------------------------------
list of run folders (max 100 chars)
-----------------------------------------
../02-MultipleScaling/b090/R0001
../02-MultipleScaling/b090/R0002
../02-MultipleScaling/b090/R0003
../02-MultipleScaling/b090/R0004
../02-MultipleScaling/b090/R0005
../02-MultipleScaling/b180/R0001
../02-MultipleScaling/b180/R0002
../02-MultipleScaling/b180/R0003
../02-MultipleScaling/b180/R0004
../02-MultipleScaling/b180/R0005
```

Please note the relative path definition: be sure it reflects the actual location of the directories in the file system. Absolute path definitions can also be used. Maximum number of characters for each of these paths is 100.

A file with the coordinates of the sites to be considered for MCSI computations must exist, with name equal to the rootname defined in file `multifin.par`, and extension `.obs`. In this example, it is named `j.obs` and contains the following:

```
    lon       lat     struc  rdep
  13.8000   45.6000 0000    0.000
  13.6000   46.0000 0000    0.000
  13.2000   46.0000 0000    0.000
  12.6000   46.0000 0000    0.000
```

The fields struc and rdep can be left equal to 0.

Now that the two input files are ready, the computations can be started with the sequence of commands

```
multifin.out
multifinmax.out
mcsi.out
plotmcsi.sh -t -b
```

Script *plotmcsi.sh* accepts some options. To see the available options just type

```
plotmcsi.sh -h
```

Of the options used in the example above, `-t` forces the creation of a table with the characteristics of the scenarios that contributed to the MCSI definition, while option -b asks for acceleration axes both in cm/s^2 and g.

The filenames of the pdf files generated follow this scheme:

*rootname*f2*ccc*.05.rsp*X*mf.*nnnnnn*.pdf

where

rootname is the one defined in `multifin.par` file

ccc is the component of motion (max=maximum horizontal; res=horizontal resultant, rzz=vertical)

X is the response spectrum type (a=acceleration; d=displacement; v=velocity)

nnnnnn is the site index; order is given by file .obs

```
jf2max.05.rspamf.000001.pdf
jf2max.05.rspamf.000002.pdf
jf2max.05.rspamf.000003.pdf
jf2max.05.rspamf.000004.pdf
jf2max.05.rspdmf.000001.pdf
jf2max.05.rspdmf.000002.pdf
jf2max.05.rspdmf.000003.pdf
jf2max.05.rspdmf.000004.pdf
jf2max.05.rspvmf.000001.pdf
jf2max.05.rspvmf.000002.pdf
jf2max.05.rspvmf.000003.pdf
jf2max.05.rspvmf.000004.pdf
jf2res.05.rspamf.000001.pdf
jf2res.05.rspamf.000002.pdf
jf2res.05.rspamf.000003.pdf
jf2res.05.rspamf.000004.pdf
jf2res.05.rspdmf.000001.pdf
jf2res.05.rspdmf.000002.pdf
jf2res.05.rspdmf.000003.pdf
jf2res.05.rspdmf.000004.pdf
jf2res.05.rspvmf.000001.pdf
jf2res.05.rspvmf.000002.pdf
jf2res.05.rspvmf.000003.pdf
jf2res.05.rspvmf.000004.pdf
jf2rzz.05.rspamf.000001.pdf
jf2rzz.05.rspamf.000002.pdf
jf2rzz.05.rspamf.000003.pdf
jf2rzz.05.rspamf.000004.pdf
jf2rzz.05.rspdmf.000001.pdf
jf2rzz.05.rspdmf.000002.pdf
jf2rzz.05.rspdmf.000003.pdf
jf2rzz.05.rspdmf.000004.pdf
jf2rzz.05.rspvmf.000001.pdf
jf2rzz.05.rspvmf.000002.pdf
jf2rzz.05.rspvmf.000003.pdf
jf2rzz.05.rspvmf.000004.pdf
```

Step 3b) MCSI: combining results as separate scenarios

With this second strategy, scenarios b090 and b180 are different scenarios that can affect the site of interest. Statistics are therefore generated separately for each scenario (5 realisations each), and MCSI is obtained selecting at each period of the spectrum the scenario with the highest median, and its associated percentiles.

To proceed with the computations, create a folder named `03b-CombineResultsSeparately at the same level of directory 02-MultipleScaling, cd` into it and prepare file `plr2rsp.par` as follows:

```
parameter file for plr2rsp (v0002)
------------------------------------------------------------------------
s       root name of output file
1        use vertical component (0 no, 1 yes)
1        use res component (0 no, 1 yes)
1        use max component (0 no, 1 yes)
1        SD (0 no, 1 yes)
1        SV (0 no, 1 yes)
1        SA (0 no, 1 yes)
0        obs file (only when all blocks below are in format 2) (0=take from run)
------------------------------------------------------------------------
2     format of input (1 - siteanalysis, 2 - multihazard)
../02-MultipleScaling/b090/Results                  path with scenario (max 150 chars)
1  site selection criterium (0 - take only sites that are in the previous scenarios, 1
- take all sites)
bn source label
------------------------------------------------------------------------
2     format of input (1 - siteanalysis, 2 - multihazard)
../02-MultipleScaling/b180/Results                  path with scenario (max 150 chars)
1  site selection criterium (0 - take only sites that are in the previous scenarios, 1
- take all sites)
bb source label
------------------------------------------------------------------------
```

It consists of a set of parameters aimed at configuring the execution, and then two or more blocks, each associated with an available scenario generated in Step 2). Maximum number of characters for path with scenario is 150.

With this approach, quite different scenarios could be considered for MCSI generation since, for instance, a different structural model could have been used in the scenario referenced in each block.

Once file `plr2rsp.par` is ready, the whole execution is performed by issuing the command

```
   plr2mcsi.sh -t
```

The MCSI plots will be stored in the new directory Mcsi/PlotPdf. The filenames of the pdf files generated follow this scheme:

*rootname*f2*ccc*.05.rsp*X*mf.*nnnnnn*.pdf

where

rootname is the one defined in `plr2rsp.par` file

ccc is the component of motion (max=maximum horizontal; res=horizontal resultant, rzz=vertical)

X is the response spectrum type (a=acceleration; d=displacement; v=velocity)

nnnnnn is the site index; order is given by file .obs

Clarification on MCSI plots obtained in steps 2), 3a), 3b)

For each site considered by the hazard computations, synthetic seismograms are generated along several paths, according to the distribution of sources around the site.

In step 2), for each of the two directivity values taken into account (90° and 180°) the MCSI plot shows at each period the largest median between those obtained separately for each path from the five realisations of the source rupturing process, and its 95th percentile.

In step 3a), the statistics are generated jointly for the two directivities considered. So the MCSI plot shows at each period the largest median obtained separately for each path from the ten realisations (five at 90° and five at 180°). So all the realisations (90° and 180°) are considered when computing the median and the percentile for each path.

In step 3b), a comparison is made, period by period, of the two MCSI obtained in step 2) for 90° and 180°, and the largest median value is retained, with its percentile.

MCSI for sites located along 2D profiles

Introduction

MCSI computations require three steps:

1) Generation of the unscaled seismograms along the profile
2) Convolution of the unscaled seismograms with multiple realisations of the source rupturing process
3) Generation of the statistics and of the MCSI plots

Step 1) Generation of the unscaled seismograms

This is done as described in the manual DMGQuick2Dprofile.pdf, so it is here assumed that this step has been already executed and that the unscaled synthetic seismograms are ready to be convoluted with the source time functions corresponding to multiple realisations of the fault rupturing process.

Step 2): Scaling for multiple source models (*siteanalysis.sh*)

Once *jobfd* has been executed in step 1), it is possible to use script *siteanalysis.sh* to scale the 2D seismograms in a single run for several source models, taking into account three rupturing styles (unilateral and bilateral rupturing and rupture with random selection of the position of nucleation point), different directivity angles (e.g.: 0-forward, 90-neutral, 180 backward directivity), and properly defined magnitude ranges.

Parameter file `siteanalysis.par` has to be properly prepared before running the command. Also, the source time functions generated by pulsyn06.out program must exist in the directory specified in file `siteanalysis.par` before *siteanalysis.sh* is run.

siteanalysis.sh   applies the scaling to the seismograms

⚠➡A scaling made for a single rupturing style and a single magnitude can be run interactively from the terminal. When activating multiple scalings in `siteanalysis.par` it is strongly suggested to run the program in the background:⬅⚠

```
echo siteanalysis.sh | at now
```

siteanalysis.par

This file contains the information that will be used to properly generate to scale the 2D seismograms in a single run for several source models, taking into account three rupturing styles (unilateral and bilateral rupturing and rupture with random selection of the position of nucleation point), different directivity angles (e.g.: 0-forward, 90-neutral, 180 backward directivity), and properly defined magnitude ranges.

```
Parameter file for script siteanalysis.sh
----------------------------------
range and step of magnitude and directivity angles for different types of source (to be written in fdscale.par)
-------------------------------------------------------------------------------------------------------
0 6.0 6.0 0.1   Scaled point source approx.   (0=no 1=yes,start,stop,step mag)
1 6.0 6.0 0.5 0 90  190  Unilateral source approx. (0=no 1=yes,  start,stop,step mag, start,stop,step dir)
0 6.0 6.0 0.2 0 180 90  Bilateral source approx. (0=no 1=yes,  start,stop,step mag,  start,stop,step dir)
0 6.0 6.0 0.2 0 180 90  Random nuc   source approx. (0=no 1=yes,  start,stop,step mag,  start,stop,step dir)
-------------------------------------------------------------------------------------------------------
10                     number of realizations to be used for unilateral source (#nuni)
0                      number of realizations to be used for bilateral source (#nbil)
0                      number of realizations to be used for source with random nucleation point (#nran)
-------------------------------------------------------------------------------------------------------
./                     directory with 2D run (#base_dir)
/XDST/Par/Gusev/       directory with scaling curves for point source (#point_dir)
/XDST/Examples/2DHybridExamples/SourceUni   directory with scaling curves for unilateral (#uni_dir)
/XDST/Examples/2DHybridExamples/SourceBil   directory with scaling curves for bilateral (#bil_dir)
0                      directory with scaling curves for random nucleation point  (#ran_dir)
-------------------------------------------------------------------------------------------------------
parameters for plot (to be written in plotxyrc.par)
-------------------------------------------------------------------------------------------------------
0      start time for plot       (#t_start)
20     stop time for plot        (#t_stop)
-------------------------------------------------------------------------------------------------------
compute max and res components of spectra
-------------------------------------------------------------------------------------------------------
1      compute res component of response spectra  (#res)
1      compute max component of response spectra  (#max)
```

Order of the first 8 lines is mandatory. The script searches the parameters in the other lines by the string that begins with #.

Example: the directory with point source spectra is read by this line of the script

point_dir="$(grep '#point_dir' $parfile | awk '{ print $1 }')"

Directories created by siteanalysis.sh

Script *siteanalysis.sh* organizes its output in a separate directory, named SiteAnalysis. Inside this folder, it creates as many folders as the number of sites specified in file selplot, where the site results will be stored. Relevant output files are renamed so that from the filename it will be possible to recover the information about the scaling that was applied in the processing.

Inside the folder for each site, these folders are created:

PlotsPS	plot files in PostScript format
Plt	xy files of seismograms (time, amplitude)
Plr	xy files of response spectra (period, spectral acceleration)
Plf	xy files of Fourier spectra (freq., amplitude spectrum)

Inside each folder with xy files, there will be a directory for each considered rupture style, magnitude and directivity angles. For a run made with the siteanalysis.par shown in this manual, where only M=6.0 is considered for the scaling, and unilateral rupture stile is taken into account, the only directory created is:

U000m60   scaled seismograms for unilateral, forward

If ranges of magnitudes are defined in file siteanalysis.par, a directory for each considered magnitude will be created for scaled seismograms (e.g. U000m65, U000m70 etc). Properly renamed .ps, .plt, .plr and .plf files will be placed in the PlotsPs, Plt, Plr and Plf respectively.

Graphic files (in PlotPS directory)

PostScript files will be all stored in a common directory named PlotsPS for each site. Files collected in the PlotsPS directory are renamed according to the scheme

nnnrdddmxx.rl.plotType.1.ps

where

`nnn`	index of random realization
`r`	rupturing style (b=bilateral, u=unilateral, p=point, r=random nucleation point)
`ddd`	directivity (e.g.: 000=forward, 090=neutral, 180=backward)
`m`	prefix for magnitude (fixed!)
`xx`	magnitude*10
`rl`	run label (t1 in the example)
`plotType`	plot type (accmed05.rsp = acceleration response spectrum, velmed05.rsp = velocity response spectrum, dismed05.rsp = displacement response spectrum, sis = accelerograms)

Seismogram files in xy format (in Plt directory)

Mainly for importing in other, generic, software (for plotting, reprocessing etc), seismogram files in xy format (time, amplitude in cm, cm/s or cm/s^2) are stored in the `Plt` directory and are renamed according to the scheme

`nnnrdddmxx.rlf0.rty.mty.iiiiii.plt`

where

`nnn`	index of random realization
`r`	rupturing style (b=bilateral, u=unilateral, p=point, r=random nucleation point)
`ddd`	directivity (e.g.: 000=forward, 090=neutral, 180=backward)
`m`	prefix for magnitude (fixed!)
`xx`	magnitude*10
`rl`	run label (t1 in the example)
`f0`	fixed
`rty`	run type (l1d, l2d, r1d, r2d; l=Love, r=Rayleigh, 1d or 2d case)
`mty`	motion type (rac, rdi, rve; tac, tdi, tve; zac, zdi, zve; r=radial, t=transverse, z=vertical; ac=acceleration, di=displacement, ve=velocity)
`iiiiii`	index of seismogram along the profile (usually between 000001 and 000100)
`plt`	fixed

Response spectra files in xy format (in Plr directory)

Mainly for importing in generic plotting software, response spectra files (5% damping) in xy format (period in s, 2 unused columns, spectral acceleration in cm/s^2, 4 unused columns, spectral velocity in cm/s, 4 unused columns, spectral displacement in cm, 4 unused columns, spectral pseudovelocity in cm/s, 2 unused columns) are collected in the `Plr` directory and are renamed according to the scheme `nnnrdddmxx.rlf0.rty.mty.iiiiii.plr`

where

`nnn`	index of random realization
`r`	rupturing style (b=bilateral, u=unilateral, p=point, r=random nucleation point)
`ddd`	directivity (e.g.: 000=forward, 090=neutral, 180=backward)
`m`	prefix for magnitude (fixed!)
`xx`	magnitude*10
`rl`	run label (t1 in the example)
`f0`	fixed
`rty`	run type (l1d, l2d, r1d, r2d; l=Love, r=Rayleigh, 1d or 2d case)
`mty`	motion type (rac, rdi, rve; tac, tdi, tve; zac, zdi, zve; r=radial, t=transverse, z=vertical; ac=acceleration, di=displacement, ve=velocity)
`iiiiii`	index of seismogram along the profile (usually between 000001 and 000100)
`plr`	fixed

Fourier spectra ratio files in xy format (in Plf directory)

Mainly for importing in generic plotting software Fourier spectra are stored in xy format (frequency in Hz, amplitude spectrum, real part of the spectrum, imaginary part of the spectrum) in the `Plf` directory and are renamed according to the scheme

`nnnrdddmxx.rlf0.rty.mty.iiiiii.plf`

where

`nnn`	index of random realization
`r`	rupturing style (b=bilateral, u=unilateral, p=point, r=random nucleation point)
`ddd`	directivity (e.g.: 000=forward, 090=neutral, 180=backward)
`m`	prefix for magnitude (fixed!)
`xx`	magnitude*10
`rl`	run label (t1 in the example)
`f0`	fixed
`rty`	run type (l1d, l2d, r1d, r2d; l=Love, r=Rayleigh, 1d or 2d case)
`mty`	motion type (rac, rdi, rve; tac, tdi, tve; zac, zdi, zve; r=radial, t=transverse, z=vertical; ac=acceleration, di=displacement, ve=velocity)
`iiiiii`	index of seismogram along the profile (usually between 000001 and 000100)
`plf`	fixed

Step 3) Computation of MCSI (*plr2mcsi.sh*)

After *siteanalysis.sh* has been run for several realizations of the source rupturing process, or even for different profiles crossing each other at a site of interest, the Maximum Credible Seismic Input (MCSI) for the site of interest can be obtained by running the script *plr2mcsi.sh*.

Parameter file `plr2rsp.par` has to be properly prepared before running the command.

plr2mcsi.sh	generates the MCSI for the selected site(s)

plr2rsp.par

This file contains the information that will be used to properly generate the MCSI. The first block of parameters defines which components and which response spectra (Displacement, Velocity, Acceleration) should be considered in the computations.

Then as many blocks as the scenarios to be considered for the MCSI generation must be present. Each block is associated with a specific scaling applied to the seismograms obtained at a given site. It consists of the format expected for the input files, followed by the path pointing to the response spectra generated by for the site considered, and the longitude and latitude of the site.

In the given example, two sites are considered (site 32 and site 100), and two source rupturing styles (Unilateral and Bilateral, both with directivity angle 0°) for a M=6.0 event.

The coordinates written into each block identify the site, rather than the site index which appears in the path. This is required since in the case of two profiles crossing each other at the site of interest, site index will be different for the two profiles, while the coordinates uniquely identify the site and therefore can be used for the site-specific response spectra selection needed for the MCSI computation.

```
parameter file for plr2rsp (v0002)
------------------------------------------------------------------------
test    root name of output file
1        use vertical component (0 no, 1 yes)
1        use res component (0 no, 1 yes)
1        use max component (0 no, 1 yes)
1        SD (0 no, 1 yes)
1        SV (0 no, 1 yes)
1        SA (0 no, 1 yes)
0        obs file (only when all blocks below are in format 2) (0=take from run)
------------------------------------------------------------------------
1     format of input (informat) (1 - equal to Siteanalysis results)
SiteAnalysis/032/Plr/B000m60  path with scenario
13   lon of obs point
45   lat of obs point
------------------------------------------------------------------------
1     format of input (1 - equal to Siteanalysis results)
SiteAnalysis/100/Plr/B000m60  path with scenario
13.1   lon of obs point
45.1   lat of obs point
------------------------------------------------------------------------
1     format of input (informat) (1 - equal to Siteanalysis results)
SiteAnalysis/032/Plr/U000m60  path with scenario
13   lon of obs point
45   lat of obs point
------------------------------------------------------------------------
1     format of input (1 - equal to Siteanalysis results)
SiteAnalysis/100/Plr/U000m60  path with scenario
13.1   lon of obs point
45.1   lat of obs point
------------------------------------------------------------------------
```

⚠➡The names of files and directories previously generated by *`sitenalysis.sh`* must not be changed, or *`plr2mcsi.sh`* will fail.⬅⚠

Directories and files created by plr2mcsi.sh

Script `plr2mcsi.sh` organizes its output in a separate directory, named `Mcsi`. Inside this folder, it creates a `Results` folder and a `PlotPs` folder with the PostScript files of the MCSI at each site, for each of the requested components and type of response spectra requested in `plr2rsp.par`.

The naming of the postScript files looks like

```
testf2max.05.rspamf.1.ps
```

where the relevant parts are:

`test` is the label chosen by the user in file plr2rsp.par
`max` identify the component (could be max, res, rzz for maximum, resultant and vertical, respectively)
`05` is the damping used in the response spectra computations (05=5%, can’t be anything else at the moment)
`amf` type of response (could be amf, vmf or dmf for acceleration, velocity or displacement, respectively).
`1` the site index, corresponding to the coordinates listed in the `.obs` file found in the `Results` folder

The `Results` folder inside `Mcsi` contains:

`.par` the parameter files used to generate the MCSI
`.obs` the file with extension .obs with the coordinates of the considered sites.
`.rsp[avd]m` the files with statistical information (mean, standard deviation, median, ...) for each scenario for maximum (max), resultant (res) and vertical (rzz) components; there is one record for each scenario. The header record describes each column’s content.
`.rsp[avd]mf` the files with MCSI for maximum (max), resultant (res) and vertical (rzz) components; there is one record for each site and each period of the spectrum.

MCSI for extended source models

Introduction

In order to generate the MCSI spectrum at selected sites for an extended source model, it is first required to generate the unscaled synthetic seismograms running *makescenario.out* and *scenario.sh* as described in the manual “Ground Motion Scenario for an Extended Source Model”.

Therefore the steps to follow are:

1) Generation of the unscaled seismograms, for the selected sites
2) Convolution of the unscaled seismograms with multiple realisations of the source rupturing process, and MCSI generation for multiple rupturing scenarios
3) Generation of the statistics and of the MCSI plots for parametric tests executed on the fault geometry and mechanism(e.g. fault size, strike, dip and rake variations)

The example computations described below are executed with 10 realisations of the source rupturing process and 4 sites where MCSI is computed (the same sites considered in MakescenarioExample directory). In such configuration, all the commands can be executed interactively in the Terminal.

Actually, for MCSI computations dedicated to real engineering analyses, MCSI should be obtained using a much larger number of realisations (a hundred or more).

Before starting the computations, create a directory tree with this suggested naming scheme:

```
mkdir -p ExtendedSourceScenario/Multi/A/01-PrepareUnscaled
mkdir -p ExtendedSourceScenario/Multi/A/02-MultipleScaling
```

Step 1) Generation of the unscaled seismograms

This step is described with more detail in the manual “Ground Motion Scenario for an Extended Source Model” in the Pulsyn section of Manuals.

For this example, the required input files can be found in

```
/XDST/Examples/ExtSourceScenarioExamples/Multi/A/01-PrepareUnscaled/Base
```

So navigate to the working directory and copy there the required files:

```
cd ExtendedSourceScenario/Multi/A/01-PrepareUnscaled
cp /XDST/Examples/ExtSourceScenarioExamples/Multi/A/01-PrepareUnscaled/Base/* .
```

Then run

```
makesrc.out
makescenario.out
scenario.sh
```

The unscaled seismograms will be saved in the `UnScaled` directory.

⚠➡Remember to select the proper method to generate the unscaled seismograms: Modal Summation when the far field condition is satisfied, and DWN in the near field!⬅⚠.

Step 2) Convolution with multiple realisations of the source process, and MCSI generation for the scenario

The input file required is

`/XDST/Examples/ExtSourceScenarioExamples/Multi/A/02-MultipleScaling/Base/makemultiscenario.par`

and must be copied where you want to perform the multiple scaling. In this example:

```
cd ExtendedSourceScenario/Multi/A/02-MultipleScaling
cp /XDST/Examples/ExtSourceScenarioExamples/Multi/A/02-MultipleScaling/Base/* .
```

In this example, MCSI is required only for 5% damping of the response spectra. Ten realisations of the rupturing process will be saved in the `test` directory.

The `test/Results` directory will contain the data and the plots of the MCSI, computed separately for each requested scenario. ⚠➡Please note that the real MCSI at one site is obtained by merging several scenarios, according to what is described in step 3), where a small parametric test on rake influence is done⬅⚠.

Below is the content of file `makemultiscenario.par`:

```
parameter file for multiple realizations of the rupturing process
-------------------------------------------------------------------------
common parameters for all tests
-------------------------------------------------------------------------
../01-PrepareUnscaled                           path to UnScaled direcory of makescenario run
0                   obs (if 0 use all original run)
5                   max number of parallel jobs (1-5)
1                   compute mcsi (irs)      (0=no; 1 = only 5% damping; 2 = all damping)
2                   plot mcsi for each point (iplotmcsi) (0=no; 1=yes; 2=yes with table)
1                   clean scaled seismograms (0 - save; 1 - remove)
1                   clean unscaled seismograms from Base directory (0 - save; 1 - remove)
0                   copy input of original run
-------------------------------------------------------------------------
test                    Name of the test 1
10              number of realisations
0      mode_seedscommon (0 - individual value for each seed; 1 - identical values for all seeds)
0      common_nstate common "nstate" value;
11     nstatet;     Mosub(t) seed     (-1|0|n) (-1=fixed; 0=random, can't be reproduced; n=value)
11     nstatex;     slip(x,y) seed    (-1|0|n)
11     nstatev;     velocity(r) seed  (-1|0|n)
-1     nstatem;     Mach value seed   (-1|0|n)
11     nstaten;     nucl point seed   (-1|0|n)
-1     nstates;     stress drop seed  (-1|0|n)
-1     nstateh;     HF stress drop seed (-1|0|n)
-------------------------------------------------------------------------
```

To perform the computations, run program

```
makemultiscenario.out
```

and, once ended, execute the script

```
all_multiscenario.sh
```

Main output directories and files

After Step 2) has been performed, in the `test` directory the most important directories created are:

```
R0001      R0003     R0005     R0007     R0009     Results
R0002      R0004     R0006     R0008     R0010
```

R000x directories

Each `R00xy` directory contains the results of the xy-*th* realisation of the rupturing process. Inside each `R00xy` directory, the plot of the source rupturing can be visualised with the command:

```
gs *slip*ps
```

Results directory

The `Results` directory contains the MCSI plots obtained from the requested realisations, for the four sites considered in the example:

```
testf2res.05.rspamf.000001.pdf     testf2res.05.rspdmf.000003.pdf
testf2res.05.rspamf.000002.pdf     testf2res.05.rspdmf.000004.pdf
testf2res.05.rspamf.000003.pdf     testf2res.05.rspvmf.000001.pdf
testf2res.05.rspamf.000004.pdf     testf2res.05.rspvmf.000002.pdf
testf2res.05.rspdmf.000001.pdf     testf2res.05.rspvmf.000003.pdf
testf2res.05.rspdmf.000002.pdf     testf2res.05.rspvmf.000004.pdf
```

The characterising elements of the filenames are

`rspamf`	Response Spectra in Acceleration
`rspdmf`	Response Spectra in Displacement
`rspvmf`	Response Spectra in Velocity

and

`0001`	Site n.1
`0002`	Site n.2
`0003`	Site n.3
`0004`	Site n.4

Step 3) MCSI: combining results for parametric tests

Suppose you performed a second run of Step 1) and Step 2) in a directory named `B`, modifying some fault parameter. For instance defining a different rake value for the fault mechanism.

You may have done this for instance creating the directories:

```
mkdir -p ExtendedSourceScenario/Multi/B/01-PrepareUnscaled
mkdir -p ExtendedSourceScenario/Multi/B/02-MultipleScaling
```

and copying the required input files:

```
cd ExtendedSourceScenario/Multi/B/01-PrepareUnscaled
cp /XDST/Examples/ExtSourceScenarioExamples/Multi/B/01-PrepareUnscaled/Base/* .
cd ../ExtendedSourceScenario/Multi/B/02-MultipleScaling
cp /XDST/Examples/ExtSourceScenarioExamples/Multi/B/02-MultipleScaling/Base/* .
```

The only difference with the run previously made in `A/01-Unscaled` is in file `makesrc.par`. In `B/01-Unscaled` rake is:

```
80            rake
```

instead of

```
119           rake
```

As before, you produce the multiple realisations of the B scenarios with commands

```
cd ../01-PrepareUnscaled
makesrc.out
makescenario.out
scenario.sh
cd ../02-MultipleScaling
makemultiscenario.out
all_multiscenario.sh
```

You can then combine the results of `A` and `B` using the same philosophy and the same commands of case 3b) described above in the Section about MCSI for Regional Seismic Hazard.

To combine the results of A and B, create a folder named `Join` at the same level of directories `A` and `B`, *cd* into it and copy files `plr2rsp.par fvg.obs` from the Examples directory, as described below:

```
mkdir Join
cd Join
cp /XDST/Examples/ExtSourceScenarioExamples/Multi/Join/Base/* .
```

The parameter file looks like this:

```
parameter file for plr2rsp (v0002)
--------------------------------------------------------------------------------
s       root name of output file
0        use vertical component (0 no, 1 yes)
1        use res component (0 no, 1 yes)
0        use max component (0 no, 1 yes)
0        SD (0 no, 1 yes)
0        SV (0 no, 1 yes)
1        SA (0 no, 1 yes)
fvg.obs  obs file (only when all blocks below are in format 2) (0=take from run)
--------------------------------------------------------------------------------
2     format of input (1 - siteanalysis, 2 - multihazard)
../A/02-MultipleScaling/test/Results                                  path with scenario
1  site selection criterium (0 - take only sites that are in the previous scenarios, 1 - take all sites)
A  source label
--------------------------------------------------------------------------------
2     format of input (1 - siteanalysis, 2 - multihazard)
../B/02-MultipleScaling/test/Results                                  path with scenario
1  site selection criterium (0 - take only sites that are in the previous scenarios, 1 - take all sites)
B  source label
--------------------------------------------------------------------------------
```

It consists of a set of parameters aimed at configuring the execution, and then two or more blocks, each associated with an available scenario generated in Step 2). In the blocks you may wish to change the source labels (1 or 2 chars) that will appear in the plots, for an easy identification of the spectra that contributed to MCSI.

Once file `plr2rsp.par` is ready, the whole execution is performed by issuing the command

```
plr2mcsi.sh -t
```

The MCSI plots will be stored in the new directory `Mcsi/PlotPdf`. The filenames of the pdf files generated follow this scheme:

rootname`f2`*ccc*`.05.rsp`*X*`mf.`*nnnnnn*`.pdf`

where

rootname is the one defined in `plr2rsp.par` file (*s* in the example)

ccc is the component of motion (max=maximum horizontal; res=horizontal resultant, rzz=vertical)

X is the response spectrum type (a=acceleration; d=displacement; v=velocity)

nnnnnn is the site index; order is given by file .obs

Reconfiguring MCSI plots

Introduction

MCSI plots are automatically generated by script *plotmcsi.sh* in Step 2) and Step 3) for all the cases described in this manual (regional seismic hazard, 2D profiles, extended sources).

It is then possible to repeat the plotting with additional options that allow for some customisation. The data required for plotting MCSI are stored in files

*.rspamf	Acceleration response spectra
*.rspdmf	Displacement response spectra
*.rspvmf	Velocity response spectra

that can be found in the Results directory, where parameter file plotmcsi.par is also saved.

The plotting script *plotmcsi.sh*

This script requires the presence of a file named plotmcsi.par,

```
parameter file for plotmcsi.sh script
-----------------------------------------
s.obs            file with coordinates to plot (#fileobs)
1                plot sa that contribute to mcsi (#iscenarios)
-----------------------------------------
sf2res.05.rspamf
```

where the name of .obs file with coordinates of site is given, and the name of the .rspamf file with spectral data to be plotted.

The simplest call to *plotmcsi.sh* is

plotmcsi.sh

where, with the above parameter file, sf2res.05.rspamf is the file containing acceleration response spectra, 5% damping, for the resultant horizontal component of motion.

plotmcsi.sh options

The command

plotmcsi.sh -h

lists all the available options that can be used to modify the plot characteristics. Its output says:

```
The correct syntax is:
plotmcsi.sh [-options] [name_of_var=value_of_var] [reference spectrum files]

List of options
-aNNN  plot reference spectrum files scaled by NNN value
-a<ag_file>  plot reference spectrum files scaled by value contained in ag_file (lon
lat ag)
-b  use g and cm/s2 for SA
-g  use g instead of cm/s2 for SA
-h  print help
-f  use frequency instead of period
-t  produce a table with parameters of scenarios that contribute to MCSI
-l[xy]  use logscale for x and/or y axis

Max and min values of y and x axis can be set by this variables:
Fmin  Fmax:  frequency
```

```
Tmin  Tmax:  period
Amin  Amax:  SA in cm/s2
Agmin Agmax: SA in g
Vmin  Vmax:  SV
Dmin  Dmax:  SD
```

Adding a table legend

⚠➡It is warmly suggested to always use at least option -t, so that a table will be placed below the MCSI spectrum, describing the properties of the sources that contributed to the MCSI itself⬅⚠:

```
  plotmcsi.sh -t
```

Usage examples

Plot acceleration MCSI with table, with y-axes units in *cm/s^2* and *g*:

```
  plotmcsi.sh -t -b
```

Plot acceleration MCSI with table, with x-axes in frequency, and range between 0 and 5 Hz:

```
  plotmcsi.sh -t -f Fmin=0 Fmax=5
```

Plot acceleration MCSI with table, superimposing the Italian code `itacode.cod`: with a_g of 320 cm/s^2:

```
  plotmcsi.sh -t -a320.0 itacode.cod
```

File `itacode.cod` is listed below. Only the first two columns are used, which are T(s) and amplitude (normalised SA in this case).

```
  0.000E+00  0.100E+01  0.125E+01  0.135E+01
  0.500E-01  0.150E+01  0.188E+01  0.186E+01
  0.100E+00  0.200E+01  0.250E+01  0.236E+01
  0.150E+00  0.250E+01  0.312E+01  0.287E+01
  0.200E+00  0.250E+01  0.312E+01  0.338E+01
…
…
  0.398E+02  0.126E-02  0.197E-02  0.341E-02
  0.399E+02  0.126E-02  0.197E-02  0.340E-02
  0.399E+02  0.126E-02  0.196E-02  0.339E-02
  0.400E+02  0.125E-02  0.196E-02  0.338E-02
  0.400E+02  0.125E-02  0.195E-02  0.338E-02
```

Plot acceleration MCSI with table, superimposing the three codes, each with its own a_g expressed in cm/s^2:

```
   plotmcsi.sh -t -a1.0 -b Tmax=2.0 a.cod b.cod c.cod
```

In the above example, `a.cod`, `b.cod`, `c.cod` must contain in the second column the actual spectral acceleration in cm/s^2, like for instance:

```
  2           75.242
  1          123.606
  0.5        223.668
  0.4        245.250
  0.2        483.633
  0.15       598.410
  0.1        712.206
  0.04       709.263
  0.0303     637.650
  0.01       361.008
```

And, as seen above, T(s) in first column can also be sorted in descending order.