FUSION FOR ENERGY

Memorandum

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Subject: **iWW-GVR: A tool to manipulate MCNP weight window (WW) and to generate Global Variance Reduction (GVR) parameters**

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To: **Everybody interested**

In order to keep F4E nuclear analysis capabilities up-to-date with the latest, state-of-the-art method and post-processing tools, a new practical tool called iWW-GVR to manipulate MCNP weight window and to generate global variance reductions format has been developed.
The tool is a python 3.6 based script able to generate global variance reductions weight window (WW) using any mesh format in meshtally by D1SUNED, MCNP5 or MCNP6. Mesh format includes usual MCNP column or matrix format and also specific D1SUNED format including cell or isotope contribution binning and source mesh importance format. Only Cartesian meshes can be read. The tool incorporates also simple functions to operate with weight windows (e.g., analyse, add and remove WW set, write, plot).
The tool is used through a text based interactive menu, and it can be run under Windows system. It is worth reminding that this tool employs the Cython package to improve the efficiency of the operations taking advantage of C native libraries and functions.

What iWW-GVR does

Capabilities of iWW-GVR are divided in four categories:

- WW information
- WW analysis
- Operation on WW
- Generation of GVR WW

WW information:
Display a summary of the WW sets contained and the correspondent detailed information (No. sets, dimensions, No.bins, No. Voxel).

WW analysis:
Analysis of the WW sets providing to the user the minimum and maximum value, the maximum ratio between nearby voxels and the corresponded histogram , the per cent No. of bins with value bigger that zero, reports the negative values (if present), the voxel average dimensions and volume.

Operation on WW
Operation on WW allows performing various operations as[1]:

- Add: to add a WW set copying the first one, normalizing hence soften it according to the parameters inserted. In addition, the user has also the possibility to fill automatically "all the holes" present within the domain using the closest value different from zero[2].
- Remove: to remove the first or the second WW set[3].
- Mitigate: to decrease the ratio between nearby voxels which are bigger than the threshold inserted by the user. The single WW_{value} is computed as follow:

$$WW_{value} = \frac{\max|WW_{nearby}}{\max|WW_{ratio}*0.9}$$

  Where:
  - $\max|WW_{nearby}$ is the maximum value of the nearby cell
  - $\max|WW_{ratio}$ is the maximum ratio with the nearby cell

- Plot: to plot in an external JPEG file a user defined plane of a specific particle and energy.
- Write: to write the modified WW in the MCNP ASCII format or to VTK format which can further analyzed/manipulated in dedicated readers (e.g., Paraview)

Generation of GVR WW:
To generate GVR WW employing a meshtally file given by the user[4] [1-2-3]. Taking advantage of the mesh2vtk libraries [4], the meshtal is loaded, selected and hence processed as follow:

$$WW\_GVR_i = \frac{\Phi_i}{\max|\Phi_{\text{value}}} * \frac{2}{\beta + 1} * softening_{factor}$$

where:

- Φ_i is the mesh tally voxel value at the generic position i
- $\max|\Phi_{\text{value}}$ is the maximum value of the mesh tal selected
- β is the maximum splitting ratio
- $softening_{factor}$ is a factor between]0,1] to mitigate the splitting/russian roulette [5]

The WW-GVR generated has a single energy bin and the dimension/discretization of the meshtally selected. If necessary, the WW can be further manipulated by the routine.

[1] WW headers are updated if necessary according to the user selections.
[2] This operation can be done if only one WW set is present.
[3] This operation can be done if only two WW sets are present.
[4] The meshtally selected shall have only one energy bin.

How to create a new package

1. Install proper tools, from command line execute:

```
$ python -m pip install --user --upgrade setuptools wheel
```

2. Go to iww_gvr/iww_gvr: add new scripts and modify main.py accordingly if necessary
3. Go to iww_gvr parent folder
4. Open 'setup.py'.
5. Modify the version number in the variable 'version' and save.
6. Go to the same folder where setup.py is located and from command line execute:

```
$  python setup.py sdist bdist_wheel
```

7. A new version ready for installation has been built and stored in the "dist" folder.

How to install it

The iWW-GVR is distributed in a preassembled package which automatically installs the script itself and all the related modules (i.e., dependencies) if not already present. So, browse to the dist folder and type following command line:

```
$ pip install iww_gvr-<<version>> --user
```

Moreover, it is recommended to create a dedicated virtual environment or a conda env to employ all the tested versions.

How to use it

The iWW-GVR tool operates through an interactive text menu interface. To be launched the user has to type the command:

```
$ python -m iww_gvr.py
```

The principal menu has seven options (plus “Exit” option), see figure 1. The keywords between parentheses displayed in the menu are to be used to select the operation whichs are described hereinafter.

```
************************************************
       Weight window manipulator and GVR
************************************************

* Open weight window file    (open)
* Display ww information     (info)
* Write                      (write)
* Analyse                    (analyse)
* Plot                       (plot)
* Weight window operation    (operate)
* GVR generation             (gvr)
* Exit                       (end)
```

Figure 1: main menu of iWW-GVR

- **open:** to append weight window files to be processed. This action is carried out with the keyword “*open*” hence followed by the “filename” of the WW once requested. The user can monitor the status of the operation by means of the progressing bar which also provides further information as the estimated time to finish the operation and the overall time passed.

```
************************************************
       Weight window manipulator and GVR
************************************************

* Open weight window file    (open)
* Display ww information     (info)
* Write                      (write)
* Analyse                    (analyse)
* Plot                       (plot)
* Weight window operation    (operate)
* GVR generation             (gvr)
* Exit                       (end)

enter action :open
enter ww file name:wwinp_V001
Reading: 100%|##########| 277208/277208 [00:01<00:00, 174436.92 lines read/s]
enter action :
```

Figure 2: “end” selection

- **info:** to display basic information about the WW selected[5]. Data as axis ranges and discretization, No. of voxel, No. of particle contained and maximum energy are printed in screen.

```
************************************************
       Weight window manipulator and GVR
************************************************

* Open weight window file    (open)
* Display ww information     (info)
* Write                      (write)
* Analyse                    (analyse)
* Plot                       (plot)
* Weight window operation    (operate)
* GVR generation             (gvr)
* Exit                       (end)


Input files present:
- [1] wwinp_V001
- [2] wwinp_V007
enter ww index:1

The following WW file has been analysed:  wwinp_V001

                ------From----- -------To------ ----No. Bins---
    X -->           500.00         1700.00           120
    Y -->          -420.00          420.00           84
    Z -->          -700.00          950.00           165

The file contain 1 particle/s and 1663200 voxels!

***** Particle No.1 ****
Energy[1]: [50.0]
```

Figure 3: "info" selection

- **write:** to export the modified WW in the MCNP ASCII format or to VTK format which can further analyzed/manipulated in dedicated readers (e.g., Paraview)

```
Input files present:
- [1] wwinp_V001
- [2] wwinp_V007
enter ww index:1

* Write to wwinp             (wwinp)
* Write to VTK               (vtk)
* Exit                       (end)

enter action :vtk
VTK... written!
```

Figure 4: "write" selection

The exported MCNP ASCII file is named as "filename_2write" whereas the vtk as "filename.vtr".

- **analyse:** to specifically analysis the WW providing to the user the minimum and maximum value, the maximum ratio between nearby voxels and the corresponded histogram , the per cent No. of bins with value bigger that zero, reports the negative values (if present), the voxel average dimensions and volume. In addition, it exports the distribution of the ratio between nearby voxels per energy bin and particle in a dedicated histograms in file named as "filenameWW+ParNo+E=ENERGYMeV+Ratio_Analysis.jpeg", Fig. 5.

[5] If only one WW is appended the selection step is skipped to improve the user experience.

```
Input files present:
- [1] wwinp_V001
- [2] wwinp_V007
enter ww index:1
Insert the toroidal coverage of the model [degree, all, auto]: 40
Ratios: 100%|##########################| 165/165 [00:05<00:00, 31.29 Z slices/s]

The following WW file has been analysed:  wwinp_V001

----------------Par.No 1----------------

Min Value        : [0.0]
Max Value        : [0.333333]
Max Ratio        : [4521.467125180551]
No.Bins>0 [%]    : 177.65
Neg.Value        : NO
Voxel Dim[X,Y,Z]: [10.0, 10.0, 10.0] cm
Voxel Vol[cm3]   : 1.0000e+03

----------------------------------------
```

Figure 5: "analyse" selection

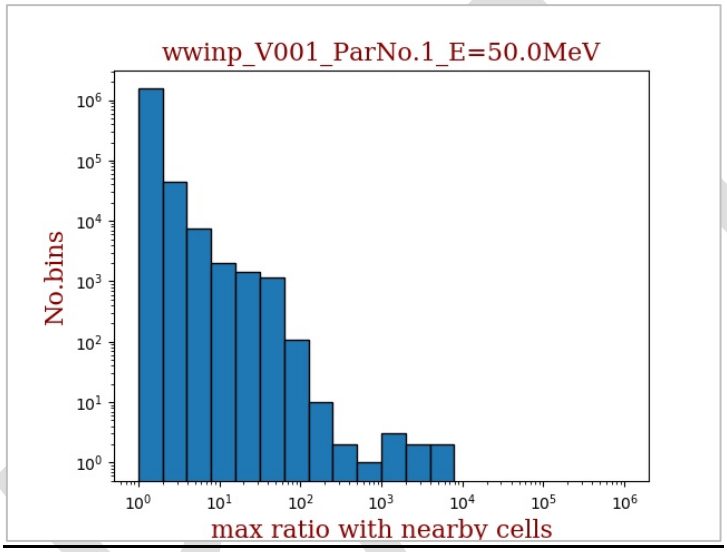

Figure 6: "ratio" histogram distribution selection

To properly compute the analyzed parameters, the user shall define the toroidal coverage of the model by one of the three options provided[6]:

- all: the WW is completed contained within the MCNP model
- No.degree: insert the toroidal coverage of the model assuming that the toroid is developed in the XY plane having the middle plane over X.
- auto: the script automatically computes the coverage of the model assuming that an XY point belongs to the domain if at least a voxel in the Z direction is different from zero.

As for the "open" function, the status of the operation can be evaluated by means of the progressing bar which also provides further information as the estimated time to finish the operation and the overall time passed.

- **plot:** to export a logarithmic plot of a specific plane which is defined under the guidance of the iWW-GVR tool. The file is named as "filenameWW+Plane +Pos+ParNo+E=ENERGYMeV.jpeg", Fig.7. Position, No.Particle and energy are requested only if more than one option is present.

[6] The routine considers one an XY plane which is representative for all the Z planes.

```
Input files present:
- [1] wwinp_V001
- [2] wwinp_V007
- [3] test2
enter ww index:3
Select the plane[X,Y,Z] :Y
Select the quote [Y-->-50.0, 5.0 cm]:0
Select the energy [MeV]:10
Plot...Done!
```

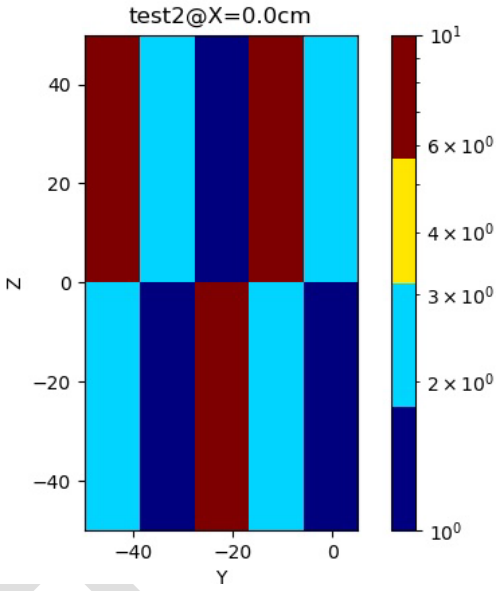

Figure 7: “plot” option: command line vs plot

- **operate:** to perform operation and manipulation on meshes. In Fig.8 the operate menu is shown.

```
* Softening and normalize    (soft)
* Mitigate long histories    (mit)
* Add                        (add)
* Remove                     (rem)
* Flipping                   (flip) >> To be completed
* Exit                       (end)
```

Figure 8: "operate" menu

The "soft" function creates a copy a previously appended WW which is modified by with the normalization, the softening and the hole-filling is requested.

```
enter action :soft
Name of the result file:soft

Input files present:
- [1] wwinp_V001
enter ww index:1
Hole Filling approach [Yes, No]: No
Insert the softening factor: 0.5
Insert the normalization factor: 1
Softening done!
```

Figure 9: "soft" options

The "mit" options decreases the ratio between nearby voxels which are bigger than the threshold inserted by the user displaying also how many voxel values have been modified. An example on a typical WW for C-Model with a maximum value of 100 is reported next.

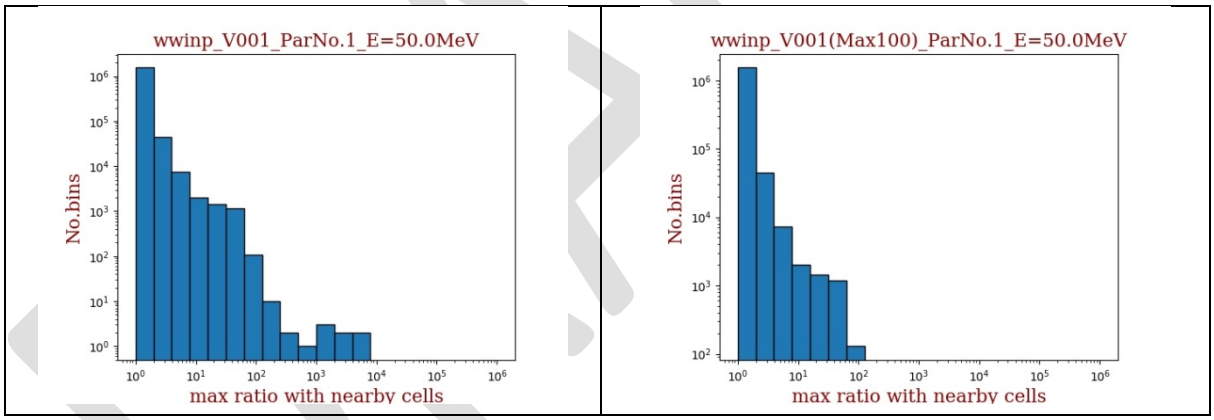

Figure 10: "mit" options effect

To conclude, the "add"/"remove" options are very useful is adding or removing WW set from the file to prepare the simulation for instance for coupled transport giving the user also the possibility to soften, normalize or hole-fill the WW set.

- **GVR:** to generate WW by means of the global variance reduction techniques importing the fluxed directly from a MCNP meshtal file which is used as a skeleton (i.e., dimension, discretization, which are also printed in screen). The user has also the possibility to select the tally to use, normalization and softening factor and to hole-fill the mesh.

```
Please write the name of the resulting GVR: GVR2WW
Insert the maximum splitting ratio (beta): 5
Insert the softening factor: 0.5
Enter the meshtally file to load:V000_MODE-0_PLASMA_5e9.mesh
The following tallies have been found:

 14

Choose the mesh tally to use for the GVR: 14

The following WW file has been analysed:  GVR2WW

                ------From------ -------To------ ----No. Bins---
    X -->              0.00         1700.00           85
    Y -->           -580.00          580.00           58
    Z -->          -1310.00         1690.00           150

The file contain 1 particle/s and 739500 voxels!

***** Particle No.1 ****
Energy[1]: [100]


 Insert the toroidal coverage of the model [degree, all, auto] for Hole Filling
approach or [No]: No
 GVR: 100%|##############################| 150/150 [00:03<00:00, 44.97 Z slices/s]
```

- **end:** it is used to terminate the usage of the iWW-GVR which, by the way, can be abnormally interrupted by Ctrl+C.

```
**************************************************
       Weight window manipulator and GVR
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* Display ww information     (info)
* Write                      (write)
* Analyse                    (analyse)
* Plot                       (plot)
* Weight window operation    (operate)
* GVR generation             (gvr)
* Exit                       (end)

enter action :end

Thanks for using iWW-GVR! See you soon!
```

Figure 11: "end" selection

Recommendations and warnings

- Testing only done over neutron/photon/neutron&photon WW sets
- The “voxel volume” parameter reported in the “analyse function” is averaged all over the domain.
- The mitigate option may leave ratio cells values bigger than the imposed value as it is done not iteratively.
- The GVR option cannot employ meshtal with more than one energy bins.
- Plot are not allowed for cylindrical mesh

Further developments

- Insert the flipping methodology as a further option of the WW manipulation
- Capacity to parse and manipulate cylindrical meshes
- Flipping to be incorporated from previous work done in Matlab

iWW-GVR verification process

By Alvaro

Reference

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