TECHNICAL MATERIAL

A New Prototype Display Tool for the Monte Carlo Particle Transport Code TRIPOLI-4

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A new prototype display tool T4G for TRIPOLI-4 Monte Carlo transport code is being developed and validated. This paper explains the basics of the tool and demonstrates its objectives - easy to use, interactive with user, fast display, great help to build and debug geometry and material input data, and useful to check variance reduction parameters and mesh tally output. It improves the final quality of TRIPOLI-4 input by better error checking and reduces the input files maintenance cost for industrial and engineering projects. For the TRIPOLI-4 team, T4G is also a useful tool to speed up considerably the discovering of unknown geometries generated by different users manually and/or by computer programs. The recently introduced CAD conversion interface programs for ITER neutronics and LMJ building shielding calculations generate huge TRIPOLI-4 inputs with more than twenty thousands volume cells and fifty materials. The T4G tool was proven to be very helpful to fast navigate and to quick debug the CAD conversed TRIPOLI-4 inputs, to study the variance reduction techniques, and to check the colorful image results from the mesh tally simulation output.

KEYWORDS: TRIPOLI-4, Monte Carlo, transport code, viewer, importance map, mesh tally map

I. Introduction

In this paper, we present a new display tool T4G for the TRIPOLI-4 Monte Carlo Transport Code. TRIPOLI-4[1] is the fourth generation of the TRIPOLI family of Monte Carlo codes developed from the 60's by CEA. It simulates the 3D transport of neutrons, photons, electrons and positrons as well as coupled neutron-photon propagation and electron-photon cascade showers. The code addresses radiation protection and shielding problems, as well as criticality and reactor physics problems through both critical and fixed source subcritical calculations.[2]

There are several objectives to develop this new display tool. The primary purpose of this tool is to help the users of TRIPOLI-4 code to navigate and to debug their complex geometry and material input data generated by the CAD conversion softwares for ITER applications and by the users' programs for EPR[TM] and GEN-IV reactors. The second objective is to improve variance reduction parameters in radiation shielding calculations by using the projection of the 3D collision points and importance data on the background geometry maps. To analyze TRIPOLI-4's output results from 3D mesh-tally calculations on criticality or radiation shielding modes, this new interactive viewer has been developed to help users to navigate their colorful simulation results with different geometry dimensions and cutting planes for local and global views.

The following points have been considered in this study:

- the possibility to display different kinds of Monte Carlo codes geometry.

- the possibilities to navigate in the 3D geometry.

- the various inspection features: the viewer allows different kinds of checks on volume cell, material, surface intersections, fission rate distribution, and other things.

- the coloring features: the viewer allows the user to define very specific and versatile coloring strategies for his geometry.

- the possibilities to superimpose meshes: it is possible to superimpose any number of mesh results from intermediate and/or final output. Various combinations available will be detailed. Different kinds of meshes used with TRIPOLI-4 will be presented.

- the possibilities to superimpose particle source sampling points and collision sites.

- data exchange formats : the standard plain text exchange formats for mesh and point data will be explained.

- tests: the close users feedback help the fast debug

- implementation cycles for verification and validation.

II. General Considerations

The T4G prototype display tool has been written in the OCaml language[3] under Linux OS and may be coupled with a geometry written in other languages with a C/C++ interface. It is currently coupled with the TRIPOLI-4 geometry written in C and another simple geometry written in OCaml.

The viewer in itself is about 3,000 lines and the glue with the TRIPOLI-4 geometry is about 900 lines. As it is considerably faster than the original geometry display tool of TRIPOLI-4 coded with native X11 graphics library twenty years ago, T4G is especially useful for complex geometry display.

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We followed some guide lines to develop the viewer:

- Debugging code geometry: the main aim of visualization is to allow the user to get correct geometries built in the TRIPOLI-4 geometric language. The main issue with any external visualization tool is to be sure that the tool can understand the geometry rigorously in the TRIPOLI-4 way. In order to do this, the best method is to use TRIPOLI-4 itself to interpret its geometry. This has been done by inbedding the TRIPOLI-4 geometry library in the display tool.

- Generic programming: special care has been taken in order not to depend on a particular type of geometry. Monte Carlo particle transport geometry can be normalized to use standard questions (For example: Where am I going from current volume cell ? Where am I ? ... etc.). As a result, the tool is currently available with one simple but fast surface geometry interpretor and with the TRIPOLI-4 geometry interpretor (combinatorial and surface geometry). It is also planed to include the ROOT geometry,[4] another modeling possibility for TRIPOLI-4 code.

- Data exchange formats are chosen to be ASCII for readability purpose. For the mesh and point parts, they are based on the general format used by the OpenDX program of IBM.[5] Meshes and points can thus be viewed also with the OpenDX program.

III. Navigation and Ergonomy

The viewer display is composed of two parts, the image display of the user geometry and the right side panel for meta-information. Navigation in the geometry is essentially based on keyboard shortcuts (see **Fig. 1**). It allows to perform the full featured 3D navigation by direct key access:

- right, left, up, and down moving;
- forward and backward moving to obtain 2D slices at different depths;
- zoom/unzoom to check the local and the global zones;
- change of cutting plane either xOy, xOz, and yOz;
- rotation around the horizontal or vertical axis of the current cut;
- recenter in the plane using mouse hovering;
- rotation arbitrary in the cutting plane using mouse hovering.

Important efforts have been spent to develop this user-friendly tool. We can for example cite:

- a fast online help, "?" key, on every command;
- the recall of main shortcuts on side panel;
- the strategically placed shortcuts on keyboard to allow fast navigation on complex 3D geometry (see **Fig. 2**).

IV. Inspection and Coloring Features

Geometry and material inspection are done by mouse hovering. Information is available in the image by suitable colors and it is written on the fly in the upper part of the side panel. The informations ("info" and "p") are updated continuously while the mouse is moving.

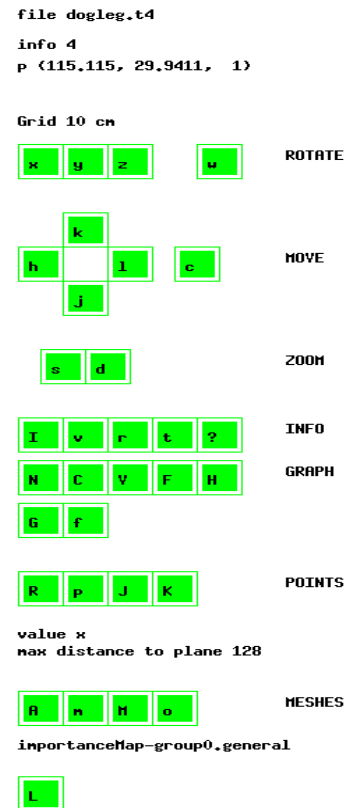The information types available are:

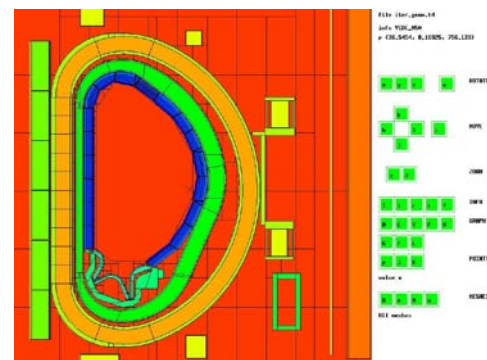**Fig. 1**   Screenshot of the side panel of the T4G display tool

Fig. 2   T4G screenshot of the TRIPOLI-4 ITER model[6]

- volume cell number or name: they are available in full name or number on the side panel in the "info" field or by a unique color on the image. The color was chosen by the viewer to enhance contrast and visibility (see **Fig. 1** and **Fig. 3**);
- material name: they are available in the same manner as volume cell. The user can choose this information type to debug material arrangement in geometry (see **Fig. 2** and **Fig. 4**);
- the color for each volume cell can also be chosen by the user from an external file. TRIPOLI-4 colors have been extended up to the 750 colors available on Unix/Linux;
- numerical score colors (given by an external ASCII file): The score value is available on the side panel and color
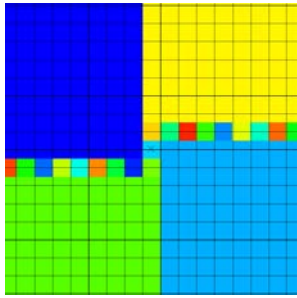
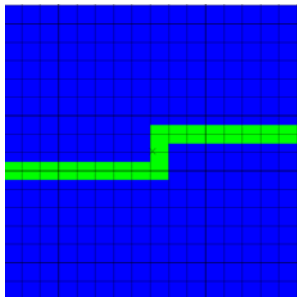**Fig. 3** T4G screenshot of the TRIPOLI-4 modeling – a dog leg geometry in volume cell mode

Fig. 4 Screenshot of the dog leg geometry in material mode

Fig. 5 T4G display of the ITER divertor in TRIPOLI-4 model[7]

Fig. 6 Dog leg geometry is used to demonstrate the TRIPOLI-4 weighting techniques. The iso-importance curves are clearly showing the neutron transport ways through the void tunnel.

coded on the image with the standard rainbow color to define numerical values.

The user can choose among the above information types displayed in the image by using the C key. He can also choose the information written on the fly among the above information types by using the N key.

It is also possible to draw an automatically resizing grid so that the user immediately has an idea of the dimensions in the geometry (**Figs. 1** and **3**).

On the side panel of **Fig. 1** the user can also identify:
- file name (dogleg.t4);
- volume cell or material (cell 4 – mouse position);
- on the fly coordinate of the mouse (in cm);
- grid dimension (squares of 10 cm by 10 cm).

Extra information can be asked:
- display window dimensions and position to be able to restart the viewer on exactly the same cut;
- scanning information from the left limit of the window to the right limit of the window or from the center of the window to any other point. The required position information is given by mouse clicking. The viewer gives all the volume cells and the surfaces crossed between the two points with all traveling segment lengths and surface crossing positions in the opening terminal. This is used especially for discovering and debugging geometry input.

The user can also ask for contour (wire-framed) representation of its geometry (**Fig. 5**). This mode is useful to better understand complex geometries. It can be also used as a geometry background for meshes output (**Fig. 8**).

For reporting purpose, the user can print out an image in an external file with (**Fig. 2**) or without (**Fig. 5**) the side panel.
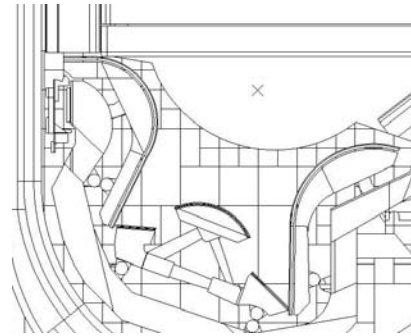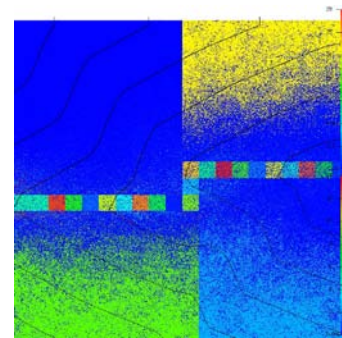
V. Meshes and Points Display

To demonstrate the intermediate or final TRIPOLI-4 simulation results on the background geometry, the T4G tool is also helpful. This section explains how to superimpose any number of meshes or iso-importance curves on the background geometry (**Fig. 6** and **Fig. 8**) and how to display color points on the geometry (**Fig. 6** and **Fig. 7**).

1. Mesh Results on Color Map and Iso-Value Curves

Mesh tally results from TRIPOLI-4 transport calculations and importance maps from variance reduction calculations can currently be displayed with the tool. Any number of meshes in any order can be superimposed on the geometry to allow the user to dress a view of its mesh tally results.

Iso-importance curves are especially important for tuning the weighting scheme with TRIPOLI-4 on radiation shielding calculations. Any incoherence in the importance map, any insufficiently meshed map will be shown. This can help the user to ensure that his mesh structure really "sees" all important details.

Extra information is available on the side panel to show the name of the mesh being selected. We can include iso-importance map of different energy groups (**Fig. 6**), tally map of different particles, or different geometry domain (**Fig. 8**). The log mode flag, key L, can be used to improve the contrast in image display.

2. Point Results on Background Geometry

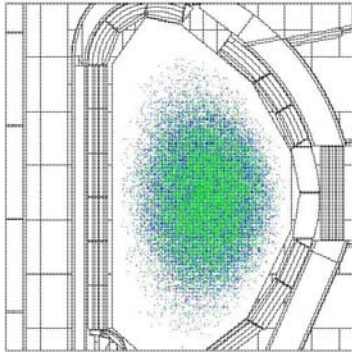Colorful points can currently be displayed for showing

Fig. 7 Display of the ITER D-T fusion neutron source sampling with the TRIPOLI-4 code[8]

Fig. 8 T4G display of the 5 x 5 fuel pin power map on the geometry of TCA MOX fuel benchmark model with TRIPOLI-4[9]

particle sources sampling (**Fig. 7**) or collision sites (**Fig. 6**). A color bar is placed on the right side of the image to specify the numerical color legend. Many physical aspects may be investigated through points displaying. The points to be displayed are the ones for which the projection distance to the cutting plane is inferior to a value defined by the user.

On the side panel of **Fig. 1** the user can also identify the maximal distance to the cutting plane for points projection.

VI. Verification and Validation

This display tool was first used by graduate school students in TRIPOLI-4 training sessions. Test cases include simple criticality configurations from ICSBEP handbook, concrete modular vaults for gamma rays streaming, and neutron reactor dosimetry for PWR pressure vessel fluence applications. Both analog and variance reduction cases were taken into account. It was also validated by the TRIPOLI-4 team for basic and advanced options in different application fields - ITER fusion neutron source sampling[8] and equatorial port shielding calculations, ITER-TBM (Test Blanket Module) mock-up benchmarks,[10] Gen-IV fission reactors designs, SILENE criticality facilities safety studies,[11] OSIRIS material testing reactor irradiation designs,[12] and MOX fuel power map in LWR reactor physics.[9]

VII. Conclusion

A new display tool T4G for TRIPOLI-4 Monte Carlo transport code has been developed and validated. The T4G tool was proven to be of great help to fast navigate and to quick debug the complex TRIPOLI-4 inputs generated by the CAD conversion softwares for ITER applications and by the users' programs for PWR and GEN-IV reactors. The integration of the available graphical TRIPOLI-4 tools into the T4G tool can reduce the engineer's work for variance reduction tuning. To check the calculation results from the 3D mesh tally output, T4G supports the interactive colorful image for analysis of the local and the global trends of the neutron flux, fission rate, dose rate, and other things.

This study is still in progress. As the T4G TRIPOLI-4 display tool can be coupled with a geometry written in other languages, the future step of development will include the display of ROOT geometry which was already included in
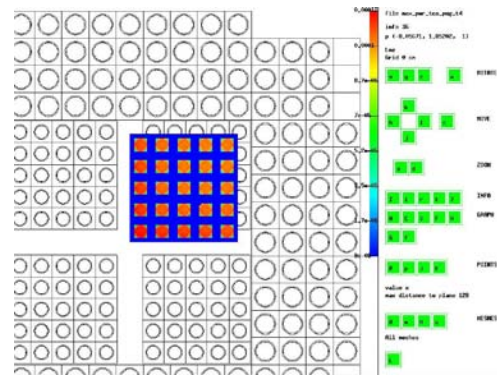
the TRIPOLI-4.5. It will also be converted to C++ and integrated in the future versions of TRIPOLI-4.

References

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