The Role of Graphical Supporting Tools for Monte Carlo Analysis

Malcolm Armishaw, Adam Bird, Hazel Crofts and Nigel Smith

The ANSWERS Software Service, AEA Technology plc
Winfrith Technology Centre, Dorchester, Dorset DT2 8ZE

Abstract. The increasing power of computer systems continues to give users of the Monte Carlo method the ability to model complex three-dimensional systems in ever greater detail. In support of this more exacting use of the Monte Carlo method, three requirements have been identified:

- The need to demonstrate the validity of the geometry models employed;
- The need to easily interpret large volumes of calculation output;
- The need to prepare calculation data from a range of available options.

The graphical tools summarised in this paper have been developed to address these requirements and are designed for use with the MONK and MCBEND Monte Carlo codes [1] for criticality/reactor physics and radiation shielding/dosimetry/general radiation transport applications respectively. All codes described in this paper are licensed and actively supported in use by the ANSWERS Software Service of AEA Technology, with the development of several of the codes continuing within a partnership between AEA Technology and BNFL.

1. Background

The Monte Carlo method is ideally suited to analysing complex three-dimensional systems. This capability has been exploited in many codes and the increasing power and availability of desktop computer systems over the last decade has enabled the user to model ever more complex systems in greater detail. An unfortunate side-effect is the rise in the likelihood that errors are introduced into a model, some that cause the code to fail and others that do not. A typical example of an error that causes the code to fail is when the content of a region of the model remains undefined by the user (i.e. there is no material allocated to it). The opposite effect is when the content of a region is ambiguous, such that two or more materials have been allocated to the same volume; these are referred to as multiply defined regions. An error that does not cause the code to fail is when components are legitimately entered but misplaced within the model (i.e. the model is acceptable to the code but not as the user intended). Other examples of potential problems that need to be checked include ensuring that the specified source geometry is located correctly, and, where the user has overlaid an independent three-dimensional splitting/roulette mesh (as used in MONK and MCBEND), that it also is

correctly positioned. These requirements for model verification have led to the development of a range of graphical tools: VISAGE, VISTA-RAY, VISTA-MOVIE and VISTA-WIRE.

The increasing range of options available within a typical Monte Carlo code for scoring results can mean that the user can be inundated with tables of numbers to be analysed (e.g. flux or dose-rates in many regions, in many energy groups). An option exists in MONK and MCBEND to enable the user to control the quantity and order of these data, principally for aiding their transfer to a spreadsheet. In addition, VISTA-GRAPH has been developed to provide a linked graphical facility for MONK and MCBEND to view selected results graphically. A further consideration in output analysis is to verify the adequacy of the Monte Carlo sampling performed. In-built sampling analysis exists in both MONK and MCBEND to assist with the identification of such problems. In addition, use can be made of VISTA-TRACK for displaying and selectively analysing the location of selected tracks overlaid on an image of the geometry model.

Turning to the selection of calculation requirements, increasing emphasis is now placed on cross-checking, for example by the use of alternative nuclear data libraries. In the case of MONK and MCBEND, a range of nuclear data libraries are available (UKNDL, JEF2.2, JENDL3.2, ENDF/B-VI) and the task of selecting and assigning appropriate versions of these files can be a source of error. Correct matching of physics code and graphical tool is clearly a further pre-calculation requirement, as is the assignment of additional files needed for the particular calculation. These problems have been addressed by the development of LAUNCHPAD, an intelligent graphical tool that searches through the user's input and identifies all the files required. Where two or more valid choices are available these will be put into a list for user selection.

This paper reviews the role of these supporting tools for use with MONK and MCBEND to address the three requirements of geometry verification, output analysis and calculation preparation.

2. VISAGE

VISAGE provides the user with the capability for interactively viewing two-dimensional slices through a geometry model (see Figure 1). The images are produced using the same tracking processes that are used in the corresponding Monte Carlo codes and ensures VISAGE displays exactly what the code will track through. This use of the Monte Carlo tracking processes allows VISAGE to identify multiply defined or undefined regions in the model (see Figure 2) as they would be processed during a MONK/MCBEND calculation. The facility to display the material or zone at any point on the

image allows the user to identify quickly the offending components and rectify their model.

When the geometry model is complete it is useful to check the placement of the components in the model. VISAGE provides the user with the capability to use the mouse pointer both to identify the co-ordinates of any point on the image, and to measure the distance between two selected points. These features allow the user to check their model for inaccuracies. Where there is fine detail to be inspected, the option to zoom in on selected parts of the image prior to measuring the component placement is available. To check the model thoroughly it is necessary to draw several slices through the model perpendicular to each of the axes to ensure that all the components are positioned correctly. VISAGE provides a range of options to simplify the process of generating multiple slices, easing the task of checking the model.

Figure 1: Main VISAGE screen and colour map

Figure 2: Multiply defined region (dithered area)
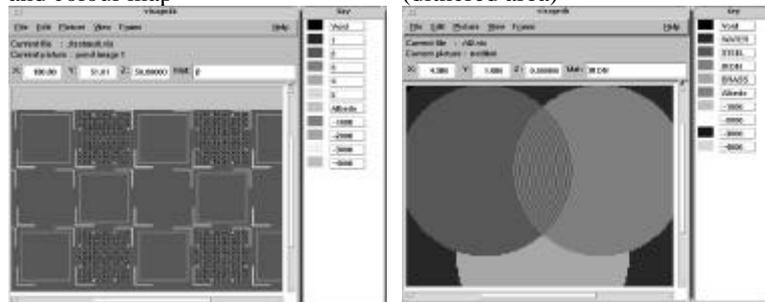
Both MONK and MCBEND allow the source locations to be defined independently of the geometry definition. Similarly an independently defined splitting/roulette mesh can be overlaid on the geometry. The need to check the location of both of these components has led to the requirement for an option to enable them to be overlaid on the image from the geometry data so their placement can be verified.

The above range of options make VISAGE the front-line visualisation and verification tool used with MONK and MCBEND. Through its use the user can increase their confidence in the model and can rapidly provide verification data for Quality Assessment purposes.

3. VISTA-RAY

The two-dimensional slices produced by VISAGE do have some limitations. The main ones are that many slices can be required to image enough of the model before the user can be confident it is correct, and that it can sometimes

be difficult in a two-dimensional slice to check the relative position of arbitrarily placed components. The development of VISTA-RAY (Figure 3) overcomes these limitations by providing the user with the capability to interactively view three-dimensional images of the geometry model.

Figure 3: VISTA-RAY Main   Figure 4: VISTA-RAY close-up
window
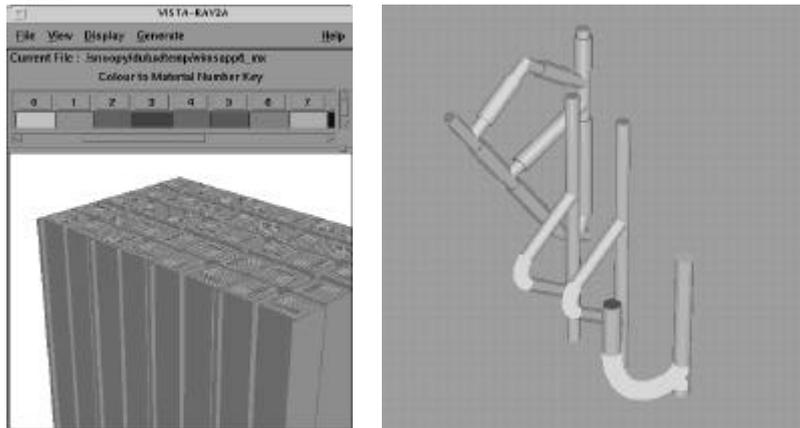
As in VISAGE, the images are produced using the same tracking processes as are used in the Monte Carlo codes, but in this case they provide a three dimensional ray-tracing capability. The ray-tracing process tracks a series of lines, one for each point on the image, from the user's viewpoint to the image. The angle between the track and the surface normal is used to apply shading to the surface, thus highlighting its angle or curvature. By changing the user's viewpoint the image can easily be manipulated and the component placements checked. The option to zoom in (Figure 4) on small components is available. Selected materials can be made transparent if it is necessary to allow inspection of components buried within the model. An alternative to transparent materials is the cutaway, that allows the user to selectively remove sections of their model and inspect the internal arrangement of the components.

The three-dimensional images produced by VISTA-RAY have proved useful in increasing the confidence that components are correctly positioned within the model.

4. VISTA-MOVIE

Experience has shown that most users view their models from several different viewpoints when using VISTA-RAY. This led to the development of VISTA-MOVIE which provides the capability for automatically generating a series of

three-dimensional images from a moving viewpoint through the model (animated GIFs). These images are then displayed sequentially (using either a web browser or GIF-viewer) to give the impression of moving either through or around the model.

The input required from the user to generate these images can be as little as giving the start and end co-ordinates of a track. For a more complex animation several intermediate points can be specified to give a complete journey through and around the model. The viewpoint is not the only item that can be varied between images. Any co-ordinate used by VISTA-RAY can be changed from image to image, such as the location of cutaway planes. By changing the cutaway plane position from image to image it is possible to slice through the model in consecutive images and view the models interior.

5. VISTA-WIRE

VISAGE and VISTA-RAY both use the Monte Carlo tracking processes to determine what should be displayed and where. This can sometimes be time-consuming if fine detail is required. In many cases a wire frame representation of the geometry is adequate to check the component positions. This led to the development of VISTA-WIRE, which displays a wire frame representation of the geometry model. The speed of VISTA-WIRE enables component location and orientation to be quickly verified and can provide a convenient starting point for more detailed visualisation using the other VISTA package components.

6. VISTA-TRACK

There are occasions where a calculation has been done but there is some question about the results, perhaps they do not agree with the expected values. In these cases it is useful to be able to inspect the Monte Carlo tracking process itself. This might be to ensure that the splitting/roulette mesh is not inappropriate and caused over splitting, or that many sources of different strengths and source spectra have been used and the user wishes to ensure that they have been sampled correctly in space and energy. These requirements led to the development of an interactive graphical tool for displaying particle histories, VISTA-TRACK, which overlays the selected particle tracks on a background image generated by VISAGE.

7. VISTA-GRAPH

The output from a MONK or MCBEND case is text based and often comprises several large tables of values such as flux or dose-rate by region and energy group. The default format for these tables is not always appropriate for the

user so VISTA-GRAPH was developed to provide a rapid interactive tool for displaying selected results graphically. VISTA-GRAPH itself enables the creation of custom output suitable for pasting directly into reports.

8. LAUNCHPAD

The minimum data required to run a typical Monte Carlo calculation comprises a nuclear data library, the user's input file and an output file for the results. More typically there will be additional thermal data, gamma production data, and perhaps a dump file for continuing the run later if necessary. For both MONK and MCBEND there is a range of neutron data libraries to choose from, each with its corresponding thermal library. A further need is to ensure that matching graphics and Monte Carlo code versions are employed. These requirements have led to the development of a graphical tool to aid the user in assembling the files required for their Monte Carlo calculation.

The tool is called LAUNCHPAD and provides a graphical user interface through which all of the analysis and graphical tools can be launched. The first step is to select the Monte Carlo code and input file to be used. LAUNCHPAD scans the input file and determines which data library type (e.g. neutron or gamma) and other channel connections are required for the selected code. When the scan is complete the required files are displayed on the main screen of LAUNCHPAD (see Figure 5).

Where appropriate, a list of possibilities will be presented to the user from which to select (e.g. neutron data library from JEF2.2, UKNDL, ENDF/B-VI, JENDL3). On completion of the calculation, the output can be viewed in a browser or the results processed using one of the VISTA post-processing packages, also started from within LAUNCHPAD.

Figure 5: LAUNCHPAD main window with MCBEND selected

9. Summary

This paper has reviewed a range of supporting graphical tools for the Monte Carlo codes MONK and MCBEND that have been developed and refined over a number of years. These tools enable Monte Carlo models to be verified, executed and analysed with significantly increased confidence. This not only increases the efficiency of the analysis but also reduces the scope for error, a major consideration in all nuclear operators.

References

1. NR Smith et al, 'The Current Status and Future Plans for the Monte Carlo Codes MONK and MCBEND', Proceeds of MC2000 (Lisbon), October 2000