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VIEWING MORSE-CG RADIATION TRANSPORT WITH 3-D COLOR GRAPHICS*

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Abstract

In this paper we present the coupling of MORSE-CG with the SLAC Unified Graphics System (UGS77) through an add-on package called MORSGRAF which allows for real-time display of neutron and photon tracks in the Monte Carlo simulation. In addition to displaying the myriad of complicated geometries that can be created with the MORSE Combinatorial Geometry program, MORSGRAF permits color tagging of neutrons (green) and photons (red) with the variation of track intensity an indicator of the energy of the particle. Particle types can be switched off and on by means of a mouse-icon system, and the perspective can be changed (i.e., rotated, translated, and zoomed). MORSGRAF also allows one to display the propagation of radiation through shields and mazes on an ordinary graphics terminal, as well as in documents printed on a laser printer. Several examples will be given to demonstrate the various capabilities of MORSGRAF coupled to MORSE-CG.

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1. Introduction

MORSE-CG¹ is a multipurpose neutron and photon transport code which utilizes Monte Carlo techniques for the solution of the Boltzmann transport equation. The program, which uses multigroup cross-section sets, was originally designed to work with energies below typically 20 MeV (neutrons) and 14 MeV (photons), but extended neutron cross sections are available for energies up to 400 MeV². MORSE-CG includes a generalized three-dimensional Combinatorial Geometry package commonly referred to as COMGEOM which is described in the MORSE manual and in a recent book on Monte Carlo radiation transport techniques³.

As described by Gabriel⁴, applications have been in fusion, reactor shielding, accelerator breeder studies, high-energy nuclear instrumentation design, and accelerator beam-stop activation. More recently MORSE has been used in medical accelerator shielding⁵ and has been coupled to high-energy neutron transport codes, such as HETC⁶.

Three-dimensional color (or 2-D black and white) graphics, using a package called SHOWGRAF^{7,8}, have been reported for the EGS4 Code System⁹ coupled via the SLAC Unified Graphics (UGS77) system¹⁰ to various devices. For example, McIntyre *et al*¹¹ have recently presented photographic examples of high-resolution 3-D color graphics to demonstrate the various capabilities of EGS4 plus SHOWGRAF/UGS77 in the design and use of industrial irradiators (*i.e.*, electron linacs).

In this paper we present the coupling of MORSE-CG with UGS77 through an add-in system similar to SHOWGRAF, called MORSGRAF, which allows for *real-time* display of neutron and photon events in complicated geometries. The system permits color tagging of neutrons (green) and photons (red) with color intensity varied as a function of either particle's energy. Individual particle types can be switched off to view only certain particles (*e.g.*, neutrons turned off to show only capture gamma rays), and the perspective can be changed (*i.e.*, rotated, translated and zoomed).

2. MORSGRAF—The MORSE-CG/UGS77 Connection

Each particle being transported by MORSE carries information about its type, current location, energy and direction. That is, a vector is associated with each transport that takes place. This information, together with data about the geometry itself, is passed to UGS77 by means of appropriate calls within MORSGRAF, thereby providing a way for active viewing of not only the static geometry, but also the dynamics of radiation transport within that geometry.

2.1 BASIC COUPLING STRUCTURE

The method of coupling MORSE-CG to Unified Graphics through MORSGRAF is shown in Fig. 1.

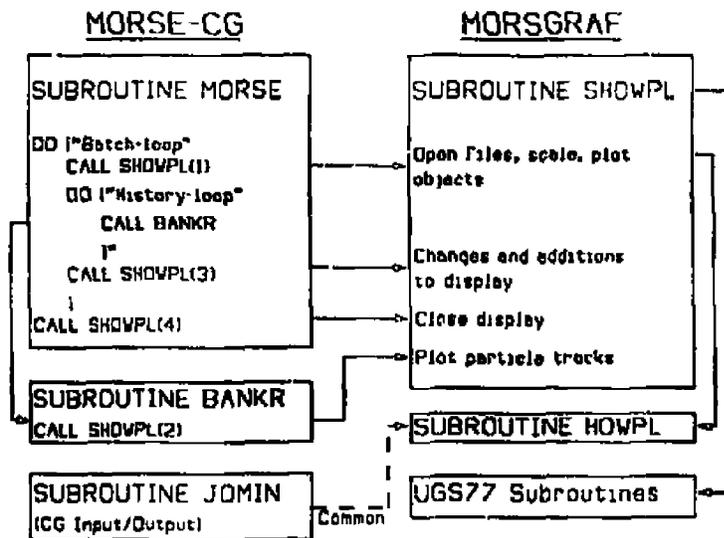


Figure 1. Flow of control between MORSE-CG, Unified Graphics, and MORSGRAF (only important subprograms shown).

MORSGRAF was adapted from SHOWGRAF and essentially consists of two important subroutines, SHOWPL and HOWPL. SHOWPL is called with four different arguments in various places within MORSE-CG (driven by a MAIN routine). At the beginning of each *batch* SHOWPL(1) is called by MORSE, whereupon HOWPL is called to open files, set scales and draw geometry objects.

Subroutine BANKR is called within a *history-loop* for MORSE-CG to score various quantities, and this is also where SHOWPL(2) is called in order to draw the individual particle tracks.

SHOWPL(3) provides a means for interaction with the job *i.e.*, this is where the user can make changes and additions to the display. For example, the user may decide to add more tracks to an already displayed geometry, continuing until the necessary track information has been drawn. SHOWPL(4) closes files and terminates the session. The bulk of the plotting is done by a multitude of calls to Unified Graphics from within SHOWPL.

3. Graphical Outputs

3.1 A TYPICAL 3-D COLOR SESSION ON THE IBM-5080

The IBM-5080 is an independent minicomputer with high-resolution 3-D color display. At SLAC the 5080 is attached to an IBM-3090 mainframe so that MORSE jobs can be run interactively. The geometry for the problem is drawn on the screen in blue using data scaled from the COMGEOM input. Neutron tracks are drawn in green, photon tracks in red, and the higher the energy the more intense the image.

A mouse-icon system is provided for turning the neutron (or photon) trajectories on or off simply by placing the cursor in the given box and marking it. The display can be translated (x and y), rotated (roll/yaw/pitch), and zoomed, the latter providing a nice way of viewing individual interactions in detail.

At SLAC, a MORSE-CG graphics session is started by logging onto the IBM-3090 and "connecting" to the IBM-5080. Everything is automated by means of a command procedure called MORSIN*. Once the interactive session has started, MORSGRAF passes control to the user. In addition to the operations described above (e.g., rotation, etc.), the 5080 keyboard can be used in order to add more batch particles to the display, initiate a new independent display of trajectories, or to end the session entirely.

When the plot is viewed on a graphics terminal, the effect is similar to watching a movie, as the trajectory of each neutron and photon from interaction site to interaction site is shown more-or-less sequentially.

3.2 GRAPHICS OUTPUT ON ORDINARY TERMINALS

Black and white pictures can also be displayed on normal terminals and workstations. For example, at SLAC we can display MORSE-CG graphic output on several devices: an IBM PC with Hercules board, a Macintosh, or an Ann Arbor Ambassador terminal with Graphics Master. In contrast to the 5080 mode of operation, ordinary terminal display is accomplished in two steps. Using the MORSIN command procedure with PDEV option (instead of the 5080 option), a *pseudodvice* file called PDEVLIN is created. Another command procedure (and associated FORTRAN code) called MORSPL is then used in order to actually display the output created by the MORSE-CG/MORSGRAF run. Each picture is two-dimensional in the sense that in order to change the display (e.g., zoom, translate, etc.), one needs to rerun MORSPL on the original PDEVLIN output.

3.3 GRAPHICS OUTPUT ON LASER PRINTER

The same display viewed on an ordinary terminal, as described above, can be changed into a device-independent file for subsequent printing on a laser printer. The pictures that are presented in this paper have been created in such a manner.

4. Examples of Radiation Transport Graphics

Various types of Combinatorial Geometry bodies are shown in Fig. 2 to demonstrate the ability of MORSGRAF. Shown are a sphere, truncated cone, ellipsoid, wedge, cylinder, right parallelapiped, and a right elliptical cylinder enclosed within a right parallelapiped which, in turn, is enclosed within an arbitrary shape. These have been rotated slightly to show the three-dimensionality of the shapes.

* MORSIN is an EXEC file written in the Rexx language.

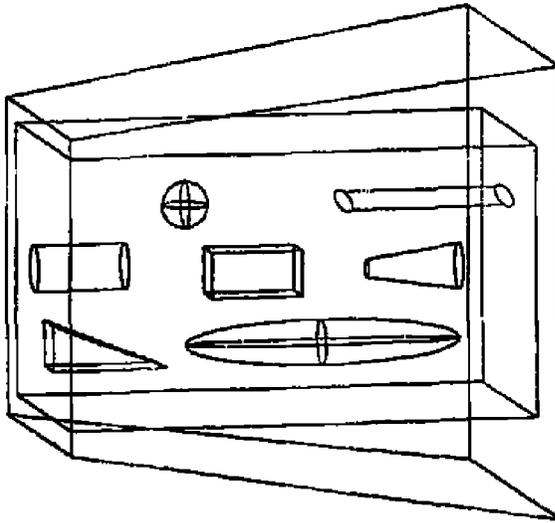


Figure 2. Some COMGEM bodies¹ (e.g., RPP, SPH, ARB, etc.) drawn with the MORSGRAF package.

Fig. 3 is a COMGEM representation of a typical radiation therapy accelerator room with maze shown from the top view.

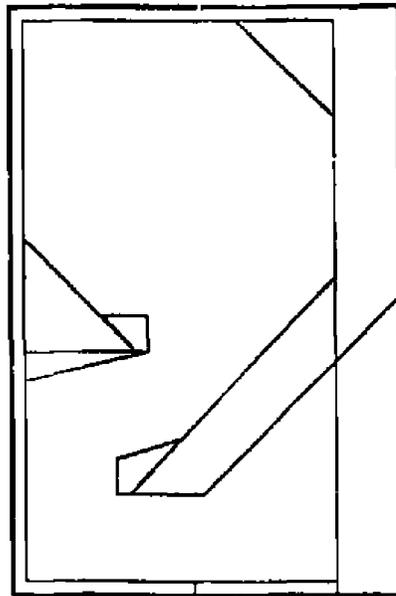


Figure 3. Plan view of concrete medical accelerator room ($9.2 \times 14.0 \times 5.5 \text{ m}^3$) with maze.

In this figure, the individual shapes making up the room walls (RPPs, WEDges, and ARBItrary shapes) are shown as separate entities simply to demonstrate how a complicated geometry is generated from the basic shapes. In the actual MORSE geometry, they would be merged into one material or zone (assuming it was an all-concrete room) and the resulting picture would show only the room outlines. In such a geometry, the lower right-hand corner (side and bottom of the room) would have been removed (i.e., this region would have been handled by MORSE as a vacuum or air the same as in the interior of the room).

In Fig. 4, neutron tracks from an isotropic ^{252}Cf source, placed in the center of the room, are observed to penetrate and scatter in the concrete walls. The dots in the picture represent tracks from the capture gamma-rays. Only 100 neutrons were used in this representation, and as can be seen, none of them and no capture gamma rays scatter down the maze and escape from the room.

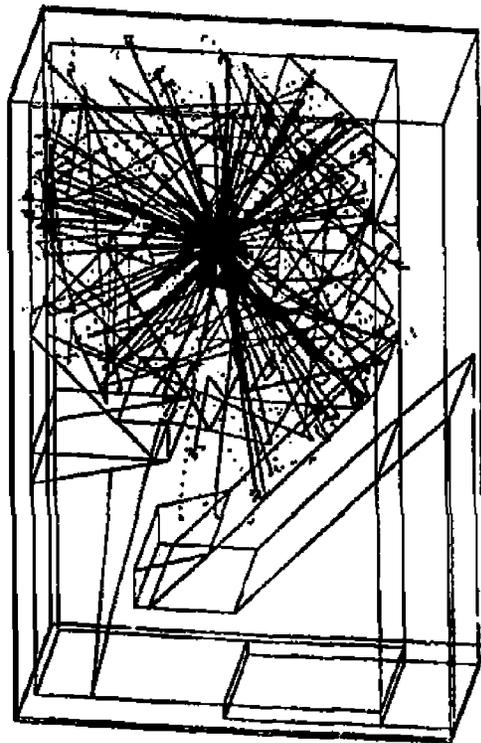


Figure 4. Isometric view of 100 neutrons from a ^{252}Cf source (solid= n , dots= γ).

4.1 ^{252}Cf AND IRON-POLYETHYLENE SHIELD

A recent experiment by Ueki and Namito¹² was performed to investigate the effect of material arrangement on the performance of Fe-moderator shields. The moderator/shield arrangement consists of a polyethylene cylinder into which a conical cavity has been cut out. As seen in Fig. 5, a ^{252}Cf neutron source is placed

inside the conical cavity (near the apex of the cone) putting it at the center of the polyethylene collimator, with slabs (25-cm Fe, 5-cm polyethylene, 7-cm Fe) located between the collimated source and detector. The purpose of the polyethylene/conical cavity is to direct all neutrons upon the Fe-polyethylene-Fe attenuator being studied while eliminating any neutrons which might scatter around the shield to the detector.

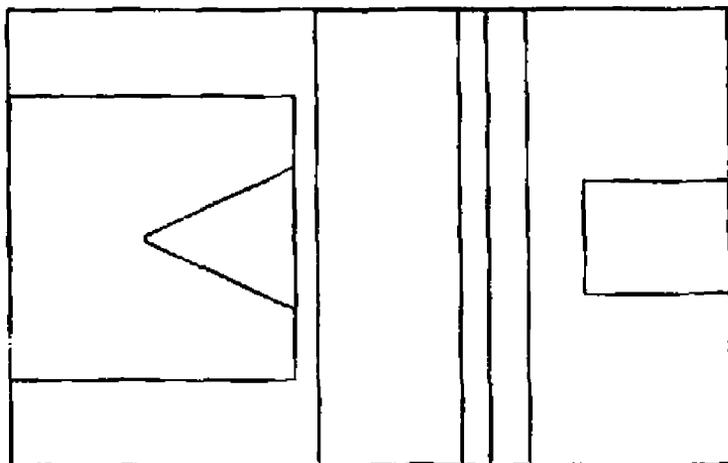


Figure 5. Plan view of geometry setup for experiment by Ueki and Namito¹². Detector is represented by cylinder, source location is at apex of cone, and Fe-moderator slabs are situated in between.

Fig. 6 shows 100 neutron tracks along with the resulting capture gamma-rays. As this figure demonstrates, some neutrons scatter inside the polyethylene collimator while others emanate through the conical opening and strike the Fe-polyethylene-Fe shield. In this picture, only four neutrons reach the polyethylene layer sandwiched between the iron, while none emerge from the downstream iron. Only one gamma-ray gets through the entire shield (and misses the detector).

4.1.1 Therapy X-Ray Beam Shield/Scatterer

An x-ray beam from a 6-MeV electron linac placed inside a therapy room is shown in Fig. 7. The beam is collimated upwards into a cone ($\theta_{1/2} = 15^\circ$) (collimator not shown) where it strikes a 0.9 m thick concrete ceiling (target-to-shield distance = 2.8 m). A diesel tank (2.8 m diameter, 4.0 m long) is located (off-center) on the roof above the linac. Personnel are restricted from the roof itself, but photons penetrating the concrete shield could scatter 90° from the tank into an occupied area located somewhere to the right of the figure. MORSE-CG was used in order to determine the dose rate in this potentially occupied area.

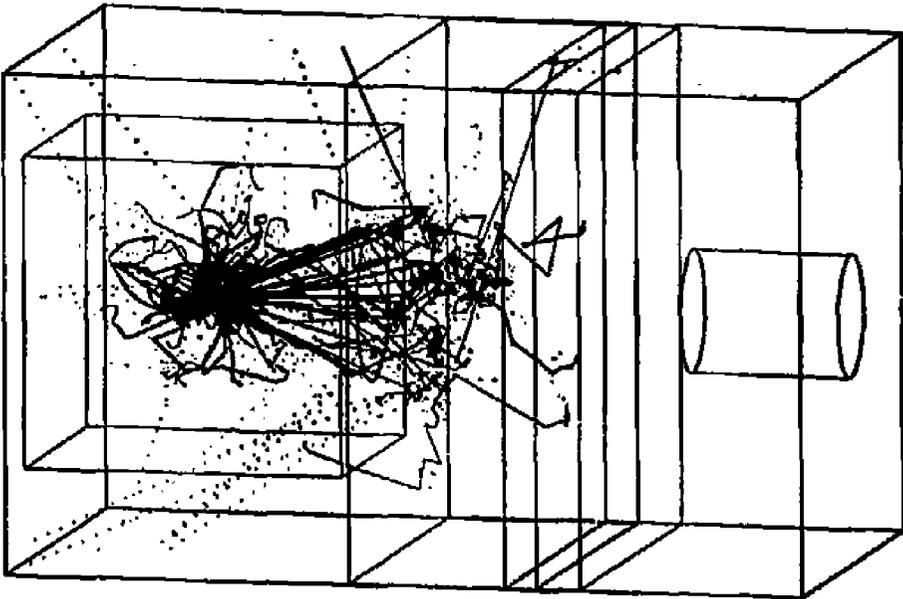


Figure 6. Isometric view of resultant of Ueki-Namito experiment: 100 neutrons (and capture gamma-rays).

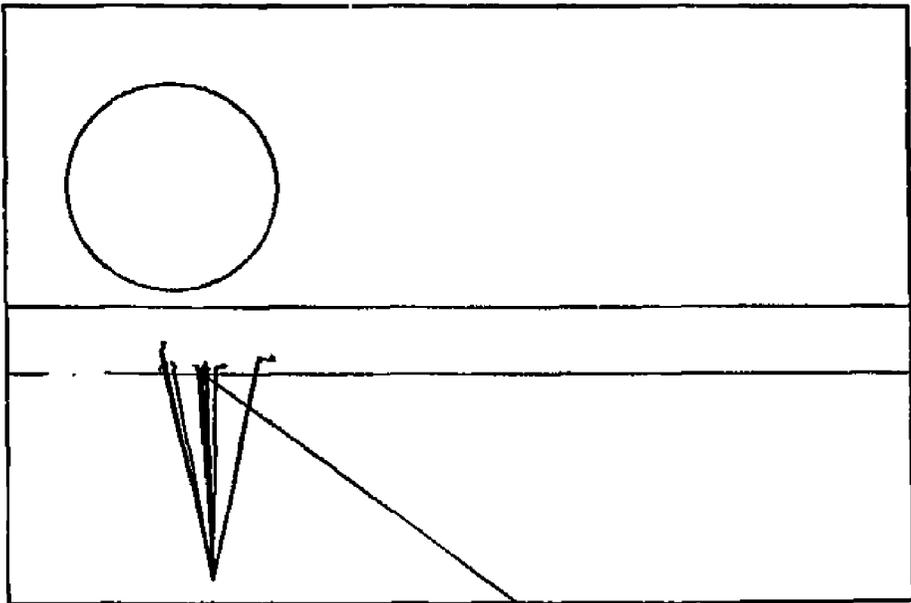


Figure 7. Side view of therapy room with a collimated x ray beam from an electron linac aimed at the ceiling. A diesel tank is located on the roof. Ten photon tracks are shown (solid lines).

Ten photon tracks are observed in the side view shown in Fig. 7. Since the spectrum starts at 6 MeV and is cut off (in our example) at 300 keV, most of the photons will interact and get absorbed within the shield. In order to see photon penetration in our picture, therefore, we must increase the number of incident x-rays substantially.

We have done this in Fig. 8, which is an isometric view of the geometry showing 2000 incident x-rays. Most of the photons penetrate into the shield where they are absorbed. A large fraction backscatter into the therapy room. In this simulation only two photons scatter into the area of interest, one from the tank and one from the shield itself.

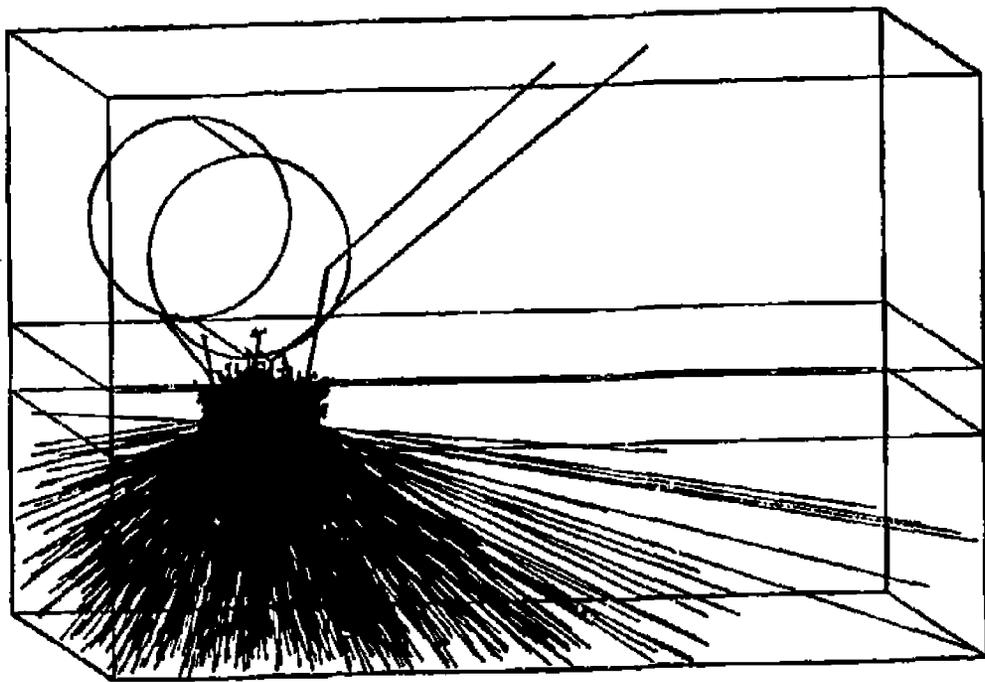


Figure 8. Isometric view of therapy room/diesel tank showing 2000 incident x-rays.

4.2 CONCLUSION

As shown in these examples, MORSGRAF can be used to visualize the geometry setup in a MORSE-CG computer run. It can also show the trajectories of neutrons and photons in this geometry. MORSGRAF is a package that requires the SLAC Unified Graphics system and devices for visualizing the output. Both 2-D black and white as well as 3-D color displays can be obtained. MORSGRAF/UGS77 provides a very useful tool for the physicist/engineer trying to better understand the radiation transport problem at hand. As a teaching tool, it is invaluable.

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