EXTENDING EGS WITH SVG FOR TRACK VISUALIZATION

R. Cowan, B. White, SLAC, Stanford, California, USA
K. Shrivastava, Stanford University, Stanford, California, USA

Abstract

The Electron Gamma Shower (EGS) Code System at SLAC is designed to simulate the flow of electrons, positrons and photons through matter at a wide range of energies. It has a large user base among the high-energy physics community and is often used as a teaching tool through a Web interface that allows program input and output.

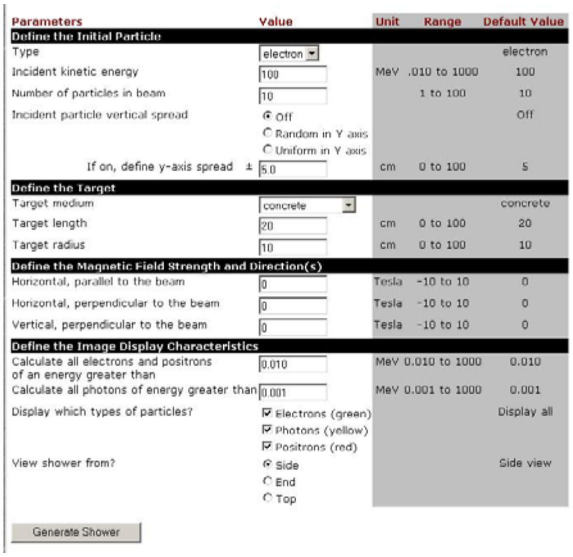
Our work aims to improve the user interaction and shower visualization model of the EGS Web interface. Currently, manipulation of the graphical output (a GIF file) is limited to simple operations like panning and zooming, and each such operation requires server-side calculations. We use SVG (Scalable Vector Graphics) to allow a much richer set of operations, letting users select a track and visualize it with the aid of 3-D rotations, adjustable particle display intensities, panning and zooming etc.

A considerable advantage of our method is that once a track is selected for visualization, all further manipulations on that track can be done client-side without requiring server-side calculations. We hence combine the advantages of the SVG format (powerful interaction models over the Web) with those of conventional image formats (file size independent of scene complexity) to allow a composite set of operations for users, and enhance the value of EGS as a pedagogical tool.

EGS

The Electron Gamma Shower (EGS) Code System developed at SLAC is a widely used Monte Carlo software application designed to simulate the flow of electrons, positrons and photons through matter at a wide range of energies. The current version of the software is EGS4. A history and overview of the EGS4 system is given in Reference [1].

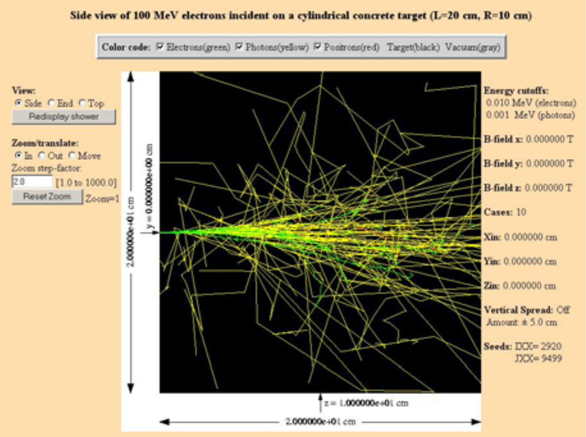
EGS4 has proven valuable in detector design, radiation shielding analysis, and various other accelerator problem areas. Similarly, it has found usage in health physics, radiation medicine, and physics education applications. In order to better serve this expanding audience, one of the authors (Cowan) developed a World Wide Web interface to the code system. Known as “EGS to Order,” this interface is available via the SLAC Virtual Visitors Center Web site [2]. The default interface to this application is shown in Figure 1.



Parameters	Value	Unit	Range	Default Value
Define the Initial Particle				
Type	electron ▾			electron
Incident kinetic energy	100	MeV	.010 to 1000	100
Number of particles in beam	10		1 to 100	10
Incident particle vertical spread	● Off ○ Random in Y axis ○ Uniform in Y axis			Off
If on, define y-axis spread ±	5.0	cm	0 to 100	5
Define the Target				
Target medium	concrete ▾			concrete
Target length	20	cm	0 to 100	20
Target radius	10	cm	0 to 100	10
Define the Magnetic Field Strength and Direction(s)				
Horizontal, parallel to the beam	0	Tesla	-10 to 10	0
Horizontal, perpendicular to the beam	0	Tesla	-10 to 10	0
Vertical, perpendicular to the beam	0	Tesla	-10 to 10	0
Define the Image Display Characteristics				
Calculate all electrons and positrons of an energy greater than	0.010	MeV	0.010 to 1000	0.010
Calculate all photons of energy greater than	0.001	MeV	0.001 to 1000	0.001
Display which types of particles?	☑ Electrons (green) ☑ Photons (yellow) ☑ Positrons (red)			Display all
View shower from?	● Side ○ End ○ Top			Side view

Figure 1: Default Interface to Web-Based EGS4 Application

The EGS4 application generates a three-dimensional vector metafile containing particle track information. An example of this file is shown in Appendix A. This metadata file is post-processed into a graphics file in GIF format, embedded into an HTML template, and returned to the requesting client. An example of the resulting output is shown in Figure 2.



Side view of 100 MeV electrons incident on a cylindrical concrete target (L=20 cm, R=10 cm)

Color code: ☑ Electrons(green) ☑ Photons(yellow) ☑ Positrons(red) Target(black) Vacuum(gray)

View:
● Side ○ End ○ Top

Zoom/translate:
● In ○ Out ○ Move
Zoom step-factor: 2.0 [1.0 to 1000.0]
Zoom=1

Energy cutoffs:
0.010 MeV (electrons)
0.001 MeV (photons)

B-field x: 0.000000 T
B-field y: 0.000000 T
B-field z: 0.000000 T
Cases: 10
Xin: 0.000000 cm
Yin: 0.000000 cm
Zin: 0.000000 cm
Vertical Spread: Off
Amount: ± 5.0 cm
Seeds: IXX= 2920
JXX= 9499

Figure 2: Example Output from Web-Based EGS4 Application

The metafiles generated by the EGS4 application are typically on the order of 140K points representing 9K tracks. These files are retained for a short time on the server to support simple image panning, rotation, and zooming. The retention period of the files is a function of server file space.

Since the metafile resides on the server, all image manipulation (e.g., panning, scanning, zooming), originates as a client-side request and is accomplished on the server. Hence, there is no direct manipulation of the image output and client-server-client response time can appear to the user to be excessive (i.e., > 10 seconds).

The goal of this project was to enhance the interactivity of the EGS4 interface by accomplishing output image manipulation client-side rather than server-side.

SVG

SVG, Scalable Vector Graphics, is a system developed by the World Wide Web Consortium (W3C) to handle two-dimensional vector graphic display and animation as an XML instance [3]. Due to its development in the W3C, SVG is an open, standards-based solution for vector graphics. Because SVG is a vector graphic technology, it is resolution-independent. This means that the display of graphical content is not visually diminished when scaled to extremely large or small sizes.

Since SVG is an XML instance, it is supported by XML-compliant clients such as Mozilla [4]. It can also be utilized with the SVG plug-in developed by the Adobe Corporation [5].

PROJECT SCOPE

Phase 1

The original scope of this project was to:

1) Modify the EGS4 post-processing to include metafile conversion to SVG; all of the necessary SVG data is present in the EGS4 metafile.
2) Embed the resulting SVG file as an object in the HTML file transmitted from the server to the client;
3) Redesign the client-side interface in SVG; SVG allows a far richer interface than that supported simply using HTML mark-up.

The incorporation of these steps in the "EGS to Order" system would therefore:

1) Dramatically increase user interactivity of the EGS4 output;
2) Transfer all image manipulation operations from the server to the client thereby improving user response.

Implementation of these modifications led to the following observations:

1) The server-side generated SVG file was significantly larger than that of the GIF file previously utilized.
2) Transmission time of the SVG file to the client was excessive, comparable to that of the server processing time in the previous model.
3) While client-side manipulation was now possible, the size of the SVG file led to significant "sluggishness" of the interactive operations.

Phase 2

A survey of the users of "EGS to Order" suggested that the types of interactive operations required are dependent upon whether the user's area of interest is at the "shower level" or the "track level." Operations within these areas of interest can also suggest the most suitable graphics format at that level. Table 1 contains a survey of these observations.

	Type of Operation	**Acceptable User Response Time**	**File Size**	**Suitable Graphics Format**
Shower Level	Pan, zoom, view parameters	< 10 sec	Large (complete shower)	GIF
Track Level	3-D rotation, adjust intensity, pan, zoom, time-based animation	<1 second (interactive)	Small (one track + descendants)	SVG

Table 1 Categorization of "EGS to Order" Operations

The result of this analysis was to develop a "hybrid model" wherein user interactivity would be focussed on observations made at the particle track level. Operations at the shower level would be the same as that in the original "EGS to Order." This model is summarized in Figure 3.

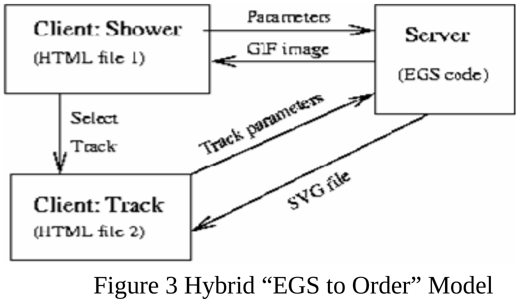


Figure 3 Hybrid "EGS to Order" Model

The consequences of this model are that:

1. The system only sends a constant file size GIF of the entire shower.
2. There is no server-side image processing after a track is selected from the full shower.
3. Interactivity is maintained at the “track level” and in the client where it is most needed.

In order to implement this model, the following modifications were required to the metafile generated by the EGS4 application:

1. Each track is assigned an ‘ID’ and a ‘parentID’ for future identification. The ‘parentID” reflects the ‘ID’ of the ‘parent’ of the track.
2. Since SVG is inherently 2-dimensional, add a z-coordinate as an attribute. This z-coordinate simulates 3-dimensional rotation by means of axis translation.

Figure 4 through Figure 7 illustrate the new interactive features of this model.

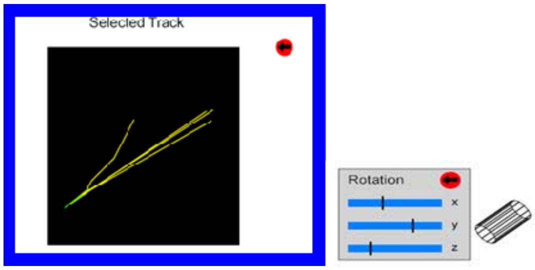


Figure 4 Selected Track 3-D Rotation

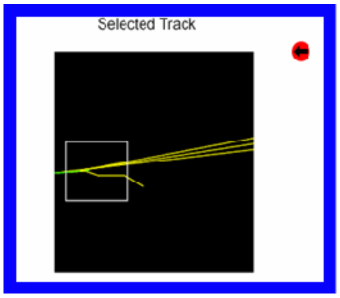


Figure 5 Track Selection

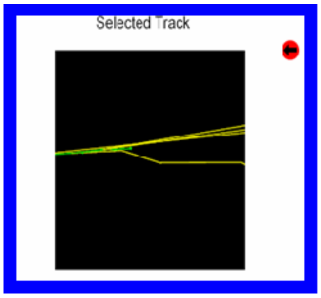


Figure 6 Selected Track Panning and Zooming

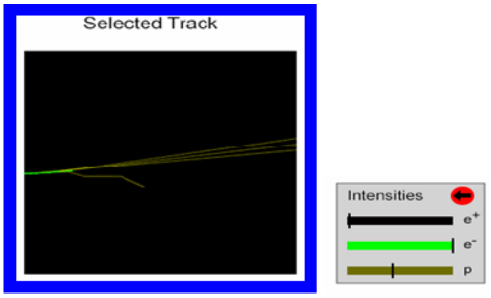


Figure 7 Adjusting Selected Track Color

CONCLUSIONS

The work done in this project has established that fact that SVG can be a useful technology for physics event visualization. Even though it is fundamentally for 2-dimensional graphics, it does have the capability to provide satisfactory 3-dimensional viewing.

In addition, this project has shown that SVG can be used to build extremely rich interfaces for Web-based analysis and educational tools. Such interfaces can be a substantial improvement to those available using the familiar HTML mark-up “widgets.”

This work has also established that EGS4 can be enhanced as a pedagogical tool by using methods such as those demonstrated for improving track visualization. By carefully choosing the graphical formats of its output data, EGS4 can provide greater functionality to its users in various disciplines.

EXTENSIONS AND FUTURE WORK

The authors believe that there are interesting possibilities for additional work in this area. Among those identified are:

- Modification of the EGS4 software to support native output of SVG; such an extension would reduce the server-side post-processing time currently encountered. In addition, the entire shower dataset, currently available as the EGS4 metafile, could be partitioned into smaller SVG datasets for areas of particular interest.
- Since SVG is an XML instance, additional EGS4 information could be readily provided to the user interface. For example, the SVG/XML file could contain information identifying interaction type (e.g., Compton scattering, pair production, etc.). Such information could provide descriptive and semantic information to the application user.
- The extensions made to the EGS4 software to provide track ID and parent ID have potential applications beyond the support of the Web interface.

- The animation features of SVG have the potential to allow a time-based animation of the EGS4 output. Such animation could be extremely useful in educational applications of the software.

ACKNOWLEDGEMENTS

The authors wish to thank Dr. Robert Hopgood of Oxford Brookes University for his suggestions and examples of how to use SVG to improve the user interface with direct manipulation.

This work was supported by Department of Energy contract DE-AC02-76SF00515")

REFERENCES

[1] A. Bielajew, H. Hirayama, W. Nelson, and D. Rogers, "History, overview and recent improvements of EGS4," SLAC-PUB-6499, June 1994, http://www.slac.stanford.edu/egs/docs/pdf/nrcpirs0436.pdf

[2] The SLAC Virtual Visitors Center, "EGS to Order," http://www2.slac.stanford.edu/vvc/egs/basicsimtool.html

[3] http://www.w3.org/Graphics/SVG/

[4} http://www.mozilla.org/

[5] http://www.adobe.com/svg/

APPENDIX A

```
                        +----------------------------------------+
                        | EGS4 User Code using subroutine GetRTZ |
                        +----------------------------------------+
                        |  NOTE:  Cylinder-slab geometry with    |
                        |         azimuthal-angle planes.  X-Y   |
                        |         plane on the page (X to the    |
                        |         right, Y upwards, Z out).      |
                        +----------------------------------------+

 TITLE:  ucRTZ.data (example) - Documentation in SUBROUTINE GetRTZ of ucRTZ.mortran

 NMED=    1

 MEDIUM=    1 ==> CONCRETE

 ECUT(I) has been changed to ECUTin + RM=    0.52100     for I=2,$MXREG
 PCUT(I) has been changed to PCUTin     =    0.10000E-02 for I=2,$MXREG

 Imax=    1     Jmax=    1     Kmax=    1 (indices maxima)

 IRmax=    2 (total # regions (including exterior) = NREG)
 IJmax=    1

 Input boundaries in the RADIAL direction:

     I=  1     CYRAD=   10.00000     cm

 Input boundaries in the AZIMUTHAL direction:

     J=  1     THEPL=   0.000000     degrees

 Input boundaries in the Z direction:

     K=  1     ZPL=   0.000000     cm
     K=  2     ZPL=   20.00000     cm

 Groups of Regions for assigning/changing MEDIUM (and DENSITY):

 (LOWER,UPPER)-I,J,K-values and MEDTMP, RHOTMP
 (  1   1)     (  1   1)     (  1   1)         1       0.0000

 Xin=   0.000000         Yin=   0.000000         Zin=   0.000000     (incident coordinates)

 Ispread=         0     Yspread=     5.0000     cm

 Iin=    1     Jin=    1     Kin=    1 (incident indices)

 IRin=    2 (incident region)

 Uin=   0.000000         Vin=   0.000000         Win=   1.000000     (incident direction cosines)

 IXX=19695     JXX=23268 (starting random-number seeds)

 Ncases=          10

 MONOENERGETIC case has been selected with:

    IQin=   -1 (incident charge of beam)
    EKEin=     100.00     MeV (incident kinetic energy)


1
 HATCH-call comes next


 IBRDST= 1
 IPRDST= 2
 IBRSPL= 0 (NBRSPL=    0)
 EGS SUCCESSFULLY 'HATCHED' FOR ONE MEDIUM.

 *** PRESTA INPUTS ***
 IPLC,IBCA,ILCA,IOLDTM,BLCMIN:
            0           0           0           0   2.908

 -----------------------------------------------------------------

 PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS

                     MEDIUM NO.         t,prime,min for E=Emax=   100.000 MeV
```

```
                         1                   0.106E-02 cm
 -----------------------------------------------------------------


 -------------------------------------------------------------------------------
                   ***** PRESTA INPUTS *****
                             NEW PRESTA PATH-LENGTH CORRECTION USED
                             BOUNDARY CROSSING ALGORITHM INVOKED
                             BLCMIN=    2.908
                             LATERAL CORRELATION ALGORITHM INVOKED
                             NEW TMXS CALCULATION USED


 PRESTA CALCULATED MINIMUM STEP SIZES FOR MAXIMUM ENERGY ELECTRONS
                     MEDIUM NO.         t,prime,min for E=Emax=   100.000 MeV
                         1                   0.106E-02 cm

                   ***** END OF PRESTA INPUTS *****
 -------------------------------------------------------------------------------



 BfieldX(2)=     0.0000     Tesla
 BfieldY(2)=     0.0000     Tesla
 BfieldZ(2)=     0.0000     Tesla


 Quantities associated with each MEDIA:


 CONCRETE
      RHO=   2.260000     g/cu.cm     RLC=   11.34520     cm
      AE=  0.5160000     MeV    UE=   10000.00     MeV
      AP=  0.1000000E-02 MeV    UP=   10000.00     MeV


 Quantities associated with each REGION:

 IRL=    1     MED(IRL)=    0
 IRL=    2     MED(IRL)=    1
1

 ENERGY/COORDINATES/DIRECTION COSINES/ETC.
      E               X              Y              Z              U              V              W
IQ    IR   IARG

   100.5110          0.000000          0.000000          0.000000          0.000000          0.000000
1.000000       -1    2   -1
 INTACT(1)= 0
 QINTER= F
   100.5110          0.000000          0.000000          0.000000          0.000000          0.000000
1.000000       -1    2    0
   100.5082          0.000000           0.000000         0.1057723E-02  -0.4007189E-04  -0.6950570E-04
1.000000       -1    2    0
   100.5054         -0.4238496E-07  -0.7351777E-07    0.2115446E-02    0.5688493E-03  -0.6544873E-04
0.9999998       -1    2    0
   100.4997          0.2120487E-05  -0.1393250E-06    0.4230886E-02    0.1475991E-02    0.3232570E-05
0.9999989       -1    2    0
   100.4884           0.2478930E-05  -0.4674584E-05    0.8461758E-02  -0.1306546E-02  -0.2147114E-02
0.9999968       -1    2    0
   100.4658          -0.9045613E-05  -0.3299123E-04    0.1692339E-01  -0.1417386E-02  -0.4545769E-02
0.9999886       -1    2    0
  0.5183584        -0.2353257E-04  -0.6539348E-04    0.2413318E-01    0.9961596         -0.1022514E-02
0.8754836E-01   -1    2    1
   100.4392          -0.2353257E-04  -0.6539348E-04    0.2413318E-01  -0.3464431E-02  -0.4441971E-02
0.9999841       -1    2    0
   100.3748         -0.1223851E-03  -0.5530916E-04    0.4826584E-01  -0.4727828E-02    0.5277684E-02
0.9999748       -1    2    0
  0.5182818         -0.1357902E-03  -0.4043541E-04    0.5129197E-01  -0.9087587            0.4097956
0.7890167E-01   -1    2    1
   100.3594         -0.1357902E-03  -0.4043541E-04    0.5129197E-01  -0.3348058E-02    0.4199214E-02
0.9999856       -1    2    0
   100.2225        -0.2856223E-03  -0.3418110E-03    0.1025827         -0.2493939E-02  -0.1595100E-01
0.9998697       -1    2    0
  0.5264781         -0.2948701E-03  -0.3953564E-03    0.1059752            0.1037513E-01  -0.9941751
0.1072769       -1    2    0
  0.5259763        -0.2959332E-03  -0.4123224E-03    0.1059774         -0.1279461         -0.9797778
0.1538363       -1    2    0
```