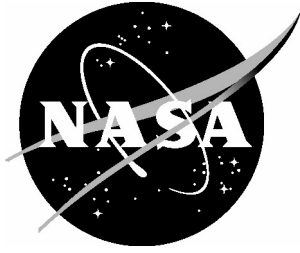# Development of Techniques for Visualization of Scalar and Vector Fields in the Immersive Environment

Hari B. Bidasaria
Central Michigan University, Mount Pleasant, Michigan

John W. Wilson
Langley Research Center, Hampton, Virginia

John E. Nealy
Old Dominion University, Norfolk, Virginia

June 2005

The NASA STI Program Office . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers, but having less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results ... even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at *http://www.sti.nasa.gov*

- E-mail your question via the Internet to help@sti.nasa.gov

- Fax your question to the NASA STI Help Desk at (301) 621-0134

- Phone the NASA STI Help Desk at (301) 621-0390

- Write to:
  NASA STI Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076-1320
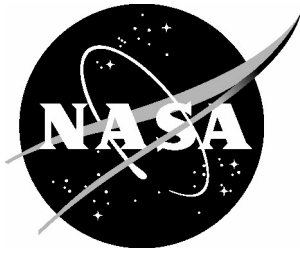
Development of Techniques for Visualization of Scalar and Vector Fields in the Immersive Environment

Hari B. Bidasaria
Central Michigan University, Mount Pleasant, Michigan

John W. Wilson
Langley Research Center, Hampton, Virginia

John E. Nealy
Old Dominion University, Norfolk, Virginia

Available from:

NASA Center for AeroSpace Information (CASI)
7121 Standard Drive
Hanover, MD 21076-1320
(301) 621-0390

National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161-2171
(703) 605-6000

Development of Techniques for Visualization of Scalar and Vector Fields

in the Immersive Environment

Hari B. Bidasaria[1], John W. Wilson[2], John Nealy[3]

[1]*Central Michigan University, Mount Pleasant MI 48858 USA*

[2]*NASA Langley Research Center, Hampton VA 23681 USA*

[3]*Old Dominion University, Norfolk VA 23508 USA*

Abstract

Visualization of scalar and vector fields in the immersive environment (CAVE – Cave Automated Virtual Environment) is important for its application to radiation shielding research at NASA Langley Research Center. A complete methodology and the underlying software for this purpose have been developed. The developed software has been put to use for the visualization of the earth's magnetic field, and in particular for the study of the South Atlantic Anomaly. The methodology has also been put to use for the visualization of geomagnetically trapped protons and electrons within Earth's magnetosphere.

Introduction

Visualization of scalar and vector fields in the immersive environment (CAVE – Cave Automated Virtual Environment) is important for its application to radiation shielding research at NASA Langley Research Center. Research has been performed for the development of a complete methodology and the underlying software for this purpose. Using the technique developed, a vector field can be visualized in two modes:

In mode one, the directional curved lines can be visualized (Fig.1.) in the surrounding 3-D space for any source(s) of a vector field. The size of the surrounding spherical space for visualization of the directional curved line flux as well as the scale for this visualization can be continually varied using the CAVE input controller .

In mode two, the vector field at regularly spaced points on the surface of a surrounding sphere for sources of the vector field is represented correctly through the length and direction of the depicted vectors at these points (Fig.2.). As in mode one, the radius of the surface of the visualization sphere, and the scale for that visualization can be continually varied through the use of selected buttons on the controller .

Customized modifications to the developed software have been introduced for application to the visualization of the earth's magnetic field, and in particular, for the study of the South Atlantic Anomaly (Fig.3.).
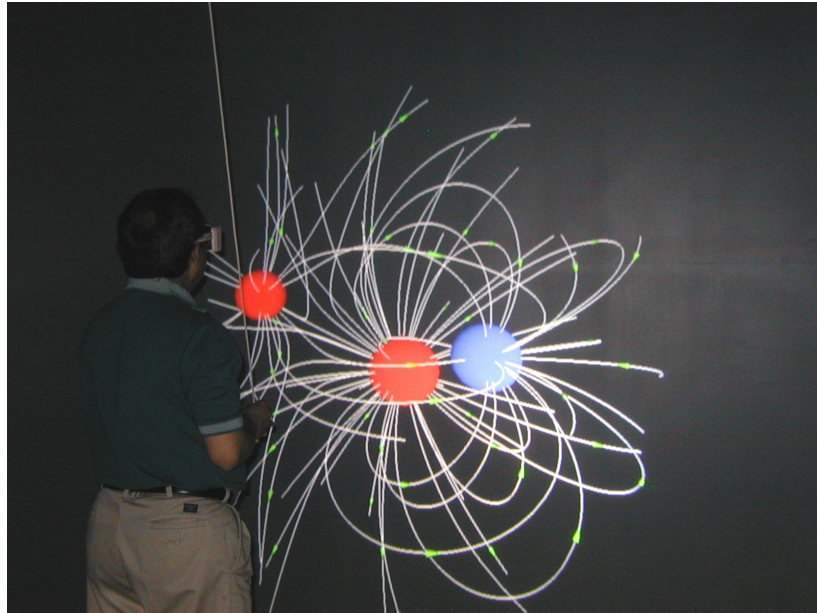
Fig.1: Field lines in the surrounding 3-D spherical region for a group of three electrical charges . The sizes, colors, and centers of the three spheres in the central region represent the magnitudes, polarity, and locations of the charges involved, respectively.
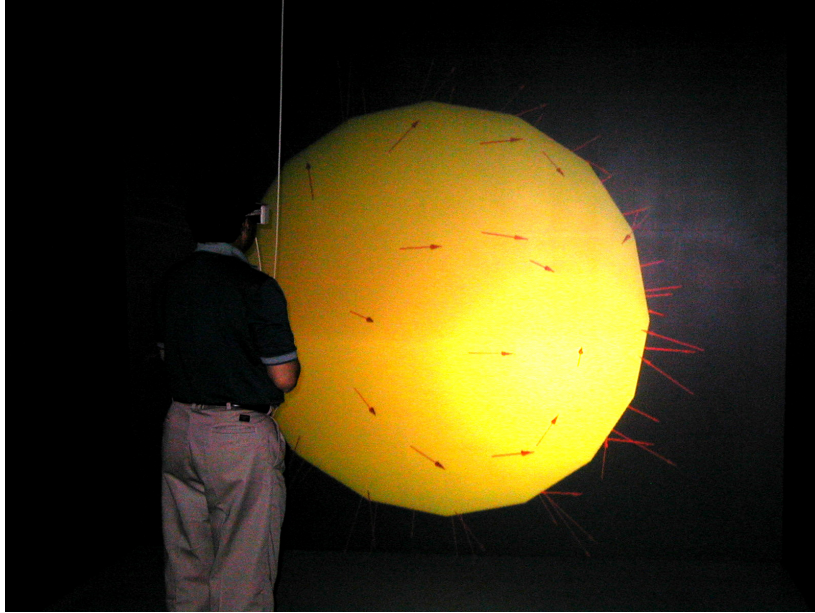
Fig.2: Electrical field vectors on the surface of a surrounding

spherical surface for the same three-charge group as
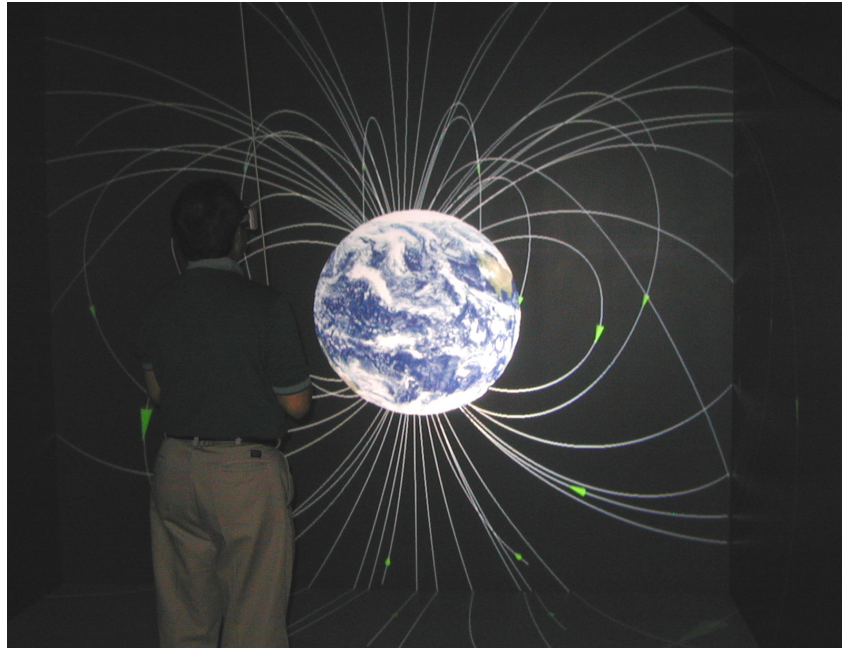
described in the caption of Fig.1.

Fig.3: Magnetic field of the earth in the surrounding 3-D
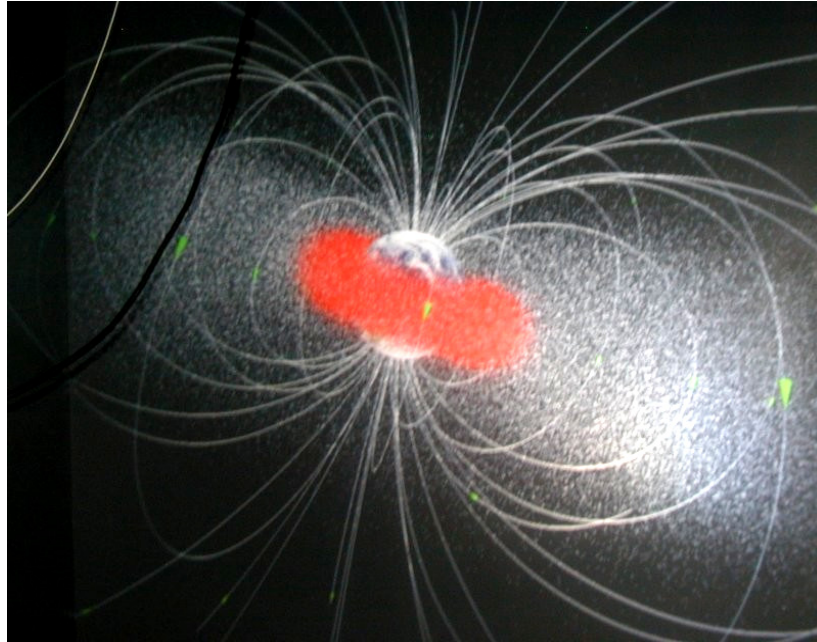
spherical region.

Fig. 4: Geomagnetically trapped protons (red cloud) and electrons (white cloud) together with the magnetic field of the earth in the surrounding 3-D spherical region.

A scalar field by itself can be visualized through the depiction of points with their number density proportional to the strength of the scalar field distribution in 3-D space. One other way the field can be visualized is through the depiction of small spheres in 3-D space with sizes proportional to the magnitude of the scalar field. The differentiation between positive and negative values of the field can be made through the use of two colors for plotted points or spheres, one color for the positive values of the scalar field, and the other color for the negative values. As an example of scalar field visualization, in Fig. 4, we show the visualization of the geomagnetically trapped protons and electrons

during solar maximum and minimum respectively, together with the earth's magnetic field in the surrounding 3-D space of the earth.

Project Description and Formulation

Visualization of a Vector Field

As stated in the introduction, a vector field can be visualized in two modes. In mode one, the directional curved lines are visualized in surrounding 3-D spherical space of chosen radius. To create, an approximately uniform density of these lines in the 3-D space, we do the following:

The 3-D spherical surface is covered with an imaginary three-dimensional grid (say 5 X 5 X 5) with grid elements being cubes of the same size. For each grid element, an associated counter keeps count of the number of field lines created up to that point that have intersected that cubical grid element. For each of the grid elements, we create a new field line passing through its center only if none of the previously created lines have intersected that grid element. The direction of the field along each curved field line is indicated through an arrowhead.

In mode two, the vector field is visualized only on the surface of the selected spherical region. The spherical surface is divided into an imaginary, approximately uniform, surface grid. The vector field is depicted at each of these points by drawing a vector of

length proportional to the strength of the field at that point and in the direction of the field at that point. For the imaginary grid on the spherical surface defined in terms of θ and ϕ, and for a given r, θ is incremented by equal amounts, $\Delta\theta$, and for a given value of θ, ϕ is incremented by equal amounts of $\Delta\theta/\sin(\theta)$.

Visualization of a Scalar Field

A scalar field is also visualized in two modes. In mode one, the scalar field is visualized through depiction of points with density proportional to the strength of the scalar field at the corresponding location in 3-D space. In mode two, small spheres with volume proportional to the magnitude of the field are drawn at the centers of the same imaginary grid elements as used to control the density of flux lines for the vector field. The differentiation between positive and negative values of the field is made through the use of two colors one for the positive values of the scalar field and the other for the negative values of the scalar field.

Navigation Through the Fields

Navigation is accomplished by using the electronic controller/pointer ("wand"); the wand as programmed for this application is as follows:

Wand Button 1: Press and release to change viewing mode

    Button 3: Press and release to reset to initial settings

Button 2: Press and release to change joystick mode

joy_stick_mode == 1:

joy_stick_x: translates in the direction of the wand

joy_stick_y: rotates about CAVE's y-axis

joy_stick_mode == -1:

Joy_stick_x: To change scale factor

joy_stick_y: To change the radius of the view sphere

Visualization of the Earth's Magnetic Field

For the computation of the earth's magnetic field, we use the International Geomagnetic Reference Field (IGRF) FORTRAN program to compute the magnetic field at any given point in the surrounding 3-D space of the earth. A FORTRAN subroutine can be called within a C-program as follows:

Subroutine in FORTRAN:

Subroutine sub1(x, y, z, arr1, arr2,..)

Calling the above subroutine in a C-program:

Sub1_(&x, &y, &z, arr1, arr2,…), i.e. the name of the subroutine needs to be extended by the addition of an "_" (underscore) character, and pointers to call time parameters of the

matching type need to be used instead of the parameters themselves. Array names (e.g.

arr1, arr2) are to be used as they are, because these are pointers to start with.

In the IGRF subroutine, given an exterior point to earth's surface in terms of its latitude,

longitude, and height (lat, long, height), returns the magnetic field at that point as $B =$

$(B_{North}, B_{East}, B_{Down})$. Given the (x, y, z) values in the CAVE's world coordinate system,

(lat, long, height) are obtained as follows:

$r = sqrt(x^2 + y^2 + z^2)$

height $=$ r * 2000.0 – 6378.0 Km., where 2000.0 is a scaling factor used

lat $= sin^{-1}(z/r)$

long $= tan^{-1}(y, x),$ $-180° \le long \le 180°$

if (long < 0.0) long $=$ long $+ 360,$ $0° \le long \le 360°$

The returned value of the magnetic field in the $(B_{North}, B_{East}, B_{Down})$ format can be

transformed to (B_X, B_Y, B_Z) as follows:

$B_X = -sin(lat) * cos(long) * B_N - sin(long) * B_E - cos(lat) * cos(long) * B_D$

$B_y = -sin(lat) * sin(long) * B_N + cos(long) * B_E - cos(lat) * sin(long) * B_D$

$B_z = -cos(lat) * B_N - sin(lat) * B_D$

<u>Visualization of the Distribution of the Trapped Protons and Electrons in the Earth's Magnetic Field</u>:

Geomagnetically trapped protons have been specified by the NASA standard AP8MIN[3] database; the electrons use the AE8MAX[4] model. These data are consistent with maximum observed fluxes, which occur at different times during the solar cycle, and relate directly to the local magnetic field strength and L-shell values. To achieve the visualization of the trapped particles, the 3-D space around earth was divided into a three dimensional grid of rectangular cells. In each cell, a number of points proportional to the inward flux of these particles in that cell was plotted.

<u>Texture Mapping (of earth's texture) on a spherical surface from an RGB File:</u>

The texture on the sphere representing the earth was rendered by mapping an RGB file "land_ocean2.rgb" on to the texture file in OpenGL, the graphics modeling and rendering software, and then mapping that on the sphere representing the earth through automatic generation of corresponding texture coordinates for the surface of the sphere.

Conclusion

A system for the visualization of vector and scalar fields in the CAVE has been developed. The system has been successfully used for the visualization of the earth's magnetic field, and the visualization of geomagnetically trapped protons and electrons in

the space surrounding earth. The future plans for the use and extension of the system include the study of the magnetic field around the revolving ISS (International Space Station).

References

1. Sandridge, C.A.: Immersive Design and Simulation Laboratory (IDSL): Overview and Examples, *Presentation to Electronics Systems Branch, Langley Research Center*, March 7, 2003.

2. Verhage, J.E.; Sandridge, C.A.; Qualls, G.D.; Rizzi, S.A.: ISS Radiation Shielding and Acoustic Simulation Using an Immersive Environment, *Immersive Projection Technology 2002 Symposium*, March 24-25, 2002, Orlando, FL.

3. Sawyer, D. and J. Vette, AP-8 trapped proton environment for solar maximum and solar minimum, National Space Science Data Center, Report 76-06, Greenbelt, Maryland, 1976.

4. J. Vette, The AE-8 trapped electron model environment, National Space Science Data Center, Report 91-24, Greenbelt, Maryland, 1991.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
01- 06 - 2005	Technical Memorandum	

4. TITLE AND SUBTITLE

Development of Techniques for Visualization of Scalar and Vector Fields in the Immersive Environment

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Bidasaria, Hari B.; Wilson, John W.; and Nealy, John E.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

23-101-15-10

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

NASA Langley Research Center
Hampton, VA 23681-2199

8. PERFORMING ORGANIZATION REPORT NUMBER

L-19123

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSOR/MONITOR'S ACRONYM(S)

NASA

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

NASA/TM-2005-213753

12. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited
Subject Category 93
Availability: NASA CASI (301) 621-0390

13. SUPPLEMENTARY NOTES

Central Michigan University: Bidasaria; Langley Research Center: Wilson; Old Dominion University: Nealy
An electronic version can be found at http://ntrs.nasa.gov

14. ABSTRACT

Visualization of scalar and vector fields in the immersive environment (CAVE – Cave Automated Virtual Environment) is important for its application to radiation shielding research at NASA Langley Research Center. A complete methodology and the underlying software for this purpose have been developed. The developed software has been put to use for the visualization of the earth's magnetic field, and in particular for the study of the South Atlantic Anomaly. The methodology has also been put to use for the visualization of geomagnetically trapped protons and electrons within Earth's magnetosphere.

15. SUBJECT TERMS

Dynamic immersive visualization; Geomagnetic fields; Trapped radiation fields; Planetary science

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			STI Help Desk (email: help@sti.nasa.gov)
U	U	U	UU	17	19b. TELEPHONE NUMBER *(Include area code)* (301) 621-0390

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18