

GeoVRML: Open Web-based 3D Cartography

Martin Reddy

Lee Iverson

Yvan G. Leclerc

Aaron Heller

SRI International, Menlo Park, CA 94025, USA.

{reddy|leei|leclerc|heller}@ai.sri.com

1. Introduction

Dealing with 2D maps and simple feature overlays has long been a common task for traditional Geographic Information Systems (GISs). However, enabling interactive, accurate, and dynamic 3D visualizations of geospatial data that can be disseminated over the Web is only now becoming a reality. The GeoVRML working group of the Web3D Consortium recently announced an extension to the ISO standard Virtual Reality Modeling Language (VRML) to enable just these capabilities. This extension is called GeoVRML 1.0. GeoVRML is an official recommended practice of the Web3D Consortium and is planned to be included in an upcoming amendment to the VRML97 ISO standard.

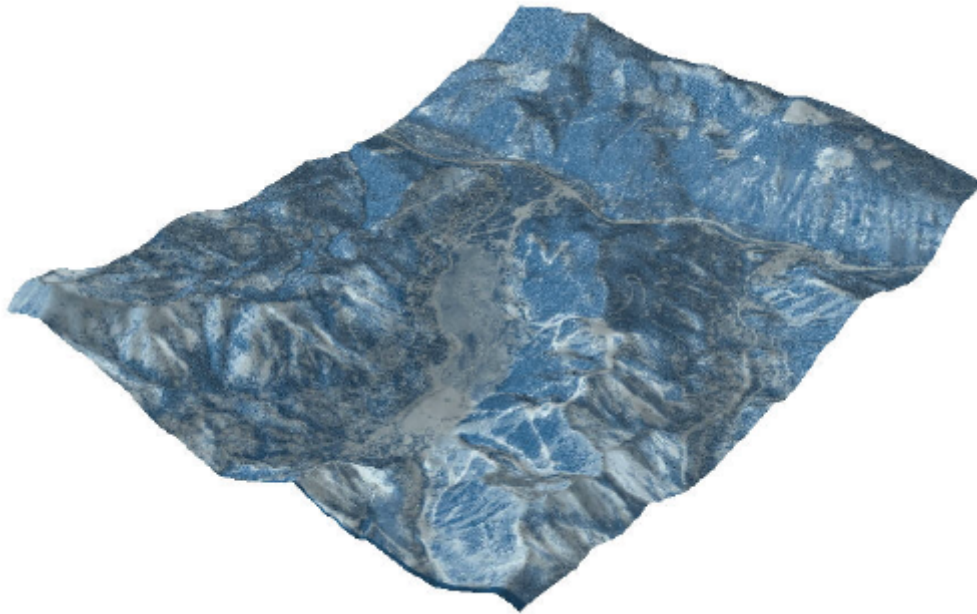


Figure 1: A GeoVRML model of Squaw Valley, CA, output by ESRI's ArcInfo 8.1 product (with 3D Analyst Extension). Model provided courtesy of ESRI.

GeoVRML 1.0 content can be browsed interactively in any standard VRML97 browser. A number of these browsers exist as freely-available plugins for common Web browsers such as Netscape Communicator and Microsoft Internet Explorer. Tools have been written to simplify the authoring and conversion of geospatial data to GeoVRML. In addition, GeoVRML is an open standard: its specification is published openly and a source-level sample implementation is provided. In this paper, we will concentrate on a few of the commercially available tools that support the GeoVRML format, and also describe some of the capabilities that this solution provides geoscientists for the purpose of integrating their geographic data directly into a three-dimensional (3D) computer graphics scene graph.

2. Tools

A number of companies have developed tools that support the GeoVRML file format. These include modeling tools that can export to GeoVRML, conversion tools to take standard mapping products and produce GeoVRML representations of these, and visualization technologies that allow the user to browse GeoVRML content. The follow sections present a selection of these tools. More examples can be found from the GeoVRML home page (<http://www.geovrml.org/>).

2.1 ArcInfo / ArcView

With version 8.1 of the 3D Analyst extension for the ArcView and ArcInfo products, released in April of 2001, ESRI added GeoVRML support to their range of capabilities. These products now allow export of GIS data to the GeoVRML file format for viewing over the Web. Figure 1 was created with ArcInfo 8.1 by combining an orthographic image (retouched to have a blue color) with a DEM of the Squaw Valley ski resort, near Lake Tahoe. The ESRI home page is at <http://www.esri.com/>.

2.2 ShapeViz

Bashir Research produce a tool that allows you to view Shape files. This file format was created by ESRI as a way to interchange geometry data and is supported by their range of GIS products. ShapeViz can take Shape files and convert these to VRML for interactive visualization over the Web. With version 1.2 of ShapeViz, GeoVRML export support was added, along with the ability to specify the coordinate system of the Shape file (as this information is not ordinarily included in the Shape file). Figure 2 shows an example Shape file converted to GeoVRML using the ShapeViz tool. The Bashir Research home page is at <http://www.my3d.com/>.

2.3 Cortona

ParallelGraphics produce a popular VRML browser caller Cortona, which is provided as a plug-in for Netscape and Internet Explorer. With version 3 of the Cortona browser, ParallelGraphics added a native implementation of the GeoVRML extensions. The implementation for these nodes can be automatically downloaded and installed when GeoVRML nodes are first used. The original GeoVRML implementation is written in Java so that it can run within any VRML browser that supports Java as a scripting language. With a native implementation, the Cortona browser offers more integrated and efficient support for this geospatial format. Figure 2 shows

the converted Shape file being viewed with the Cortona browser. The Cortona browser can be found from <http://www.parallelgraphics.com/>.

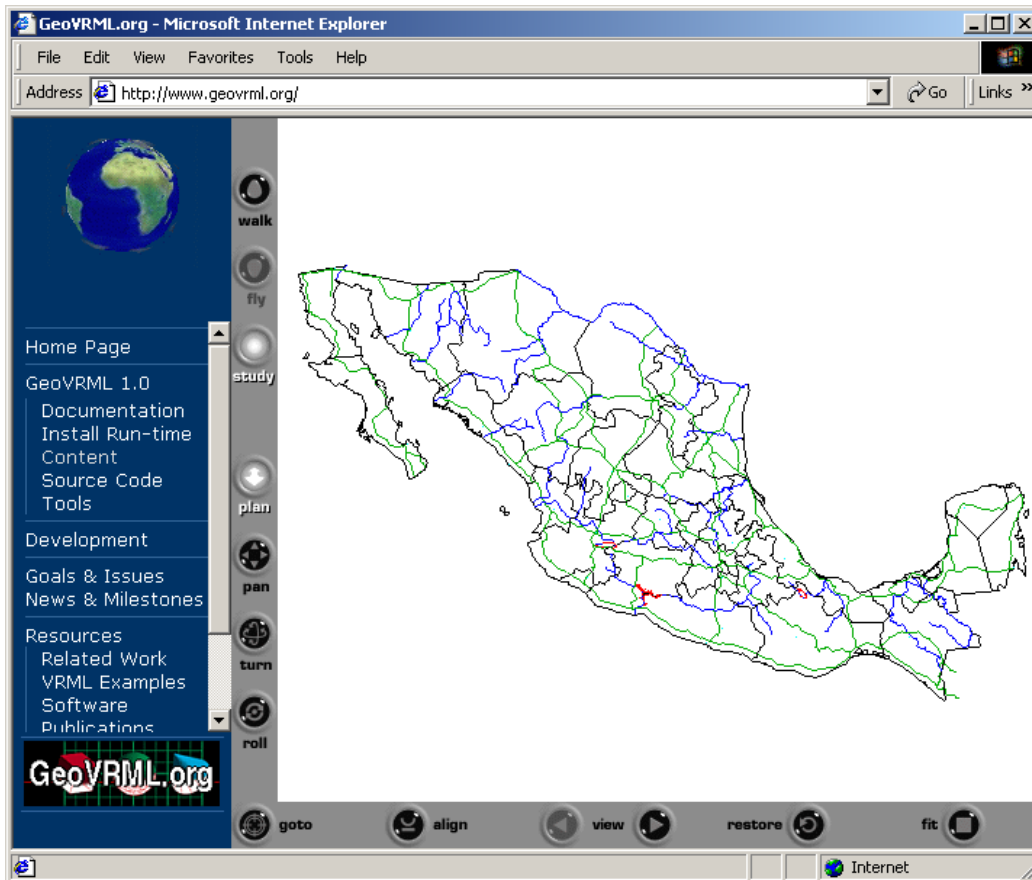


Figure 2. A GeoVRML translation of a Shape file produced by the ShapeViz utility from Bashir Research. This shows a number of layers for Mexico, including state boundaries, rivers, roads, lakes, and cities. This is being visualized in ParallelGraphics' Cortona 3.1 browser. Model provided courtesy of Bashir Research.

2.4 DEM2GeoEG

DEM2GeoEG is a program to convert USGS Digital Elevation Model (DEM) data into a VRML .wrl file that uses the GeoVRML 1.0 GeoElevationGrid (see below). The GeoElevationGrid is a version of the standard ElevationGrid but it lets you georeference the data to geographic coordinate systems such as UTM (Universal Transverse Mercator). One benefit of this is that you can inline multiple GeoElevationGrids into a single scene and they will be correctly located with respect to each other. Figure 3 illustrates a USGS DEM converted to GeoVRML using this utility. The program and source code can be found from the GeoVRML home page at <http://www.geovrml.org/>.

2.5 tsmApi

The Tile Set Manager Application Program Interface (tsmApi) from SRI International is an Open Source library of high level C functions for reading, writing, and processing the terrain data used by the TerraVision terrain visualization application. The tsmApi library can ingest a number of standard mapping products and produce GeoVRML representations of these terrain models. Specific formats that are supported include USGS DEM and DOQ, DTED level 0, GeoTIFF, TIFF, GIF, JPEG, PPM, and PGM. For further details, refer to <http://www.tsmapi.com/>.

3. Capabilities

The following list provides a high-level description of the capabilities that are specifically addressed by GeoVRML 1.0.

1. **Geographic Coordinate Systems:** Most 3D graphics systems, including VRML, use a simple Cartesian (x,y,z) coordinate system to model all data. GeoVRML provides the ability to also specify locations using geodetic or projected coordinate systems such as those commonly used in the geosciences. Specifically, GeoVRML 1.0 has support for geodetic (latitude/longitude), Universal Transverse Mercator (UTM), and geocentric coordinate systems. In addition, 21 ellipsoids and 1 geoid are supported. This support is built upon the SEDRIS Spatial Reference Model (see <http://www.sedris.org/>).
2. **Data Fusion:** GeoVRML can handle data from disparate servers across the web, generated from different sources, at different resolutions, and specified in different coordinate systems. These are all fused into a single global context for visualization. For example, you can overlay a Global Positioning System (GPS) track of latitude/longitude coordinates over a UTM-rectified terrain model.
3. **High Precision:** VRML97 provides only single-precision floating-point values. This is insufficient to represent data on a planetary scale down to around meter resolution or beyond. GeoVRML provides solutions to extending this precision to sub-millimeter by employing the specification of local coordinate systems.
4. **Dataset Scalability:** Terrain models often involve large elevation grids or image files. GeoVRML provides various scalability features to manage the streaming of large, multi-

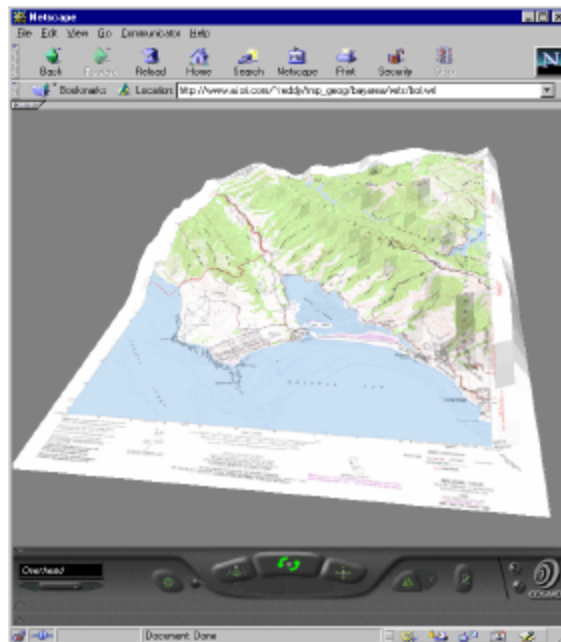


Figure 3: A USGS DEM that has been converted to a GeoElevationGrid using the dem2geoeg utility, and then draped with a DRG image for the same area.

- resolution models, thus facilitating real-time access and display of arbitrarily large terrain models.
5. **Metadata Linking:** GeoVRML provides the ability to specify a generic subset of metadata describing geographic objects, including the ability to link to a full metadata description.
 6. **Animation Support** - The ability to perform key frame animations within the supported geographic coordinate systems is provided so that animations can be defined with respect to key points on the surface of the planet.

4. Implementation

Essentially, GeoVRML 1.0 consists of ten new extensions, or nodes, that sit on top of VRML97, i.e. GeoVRML includes all of VRML97 as a subset. These nodes are defined using VRML's EXTERNPROTO extensibility features. For the purposes of the initial sample implementation, these nodes have been implemented using Java class files that are embedded within the new nodes; although we have already noted that at least one commercial VRML browser has now implemented these nodes natively. The following sections detail a small selection of the nodes that are provided by GeoVRML 1.0.

4.1 GeoCoordinate

The GeoCoordinate node enables the specification of coordinates by using geographic coordinate systems. This node can be used within standard VRML geometry nodes such as IndexedFaceSet, IndexedLineSet, or PointSet, enabling the modeler to specify coordinates in a system such as UTM. For example, a GPS will normally output location as a latitude/longitude coordinate. With the GeoCoordinate node, we can insert these coordinates directly into a VRML file and have them integrated with any other geospatial data.

4.2 GeoElevationGrid

The GeoElevationGrid node provides the capability to define a grid of height values offset from the ellipsoid or geoid used to model the planet. It supports the specification of height fields in latitude/longitude or UTM coordinate systems. VRML97 already provides an ElevationGrid node; however, in this node all values are offset from a single flat plane. This is acceptable if the area being modeled is small in extent, for example, less than 1 km², but for larger areas the curvature of the earth becomes significant. Figure 3 illustrates an example showing a GeoElevationGrid.

4.3 GeoLocation

The GeoLocation node lets the user georeference an arbitrary VRML model, that is, locate it at a specific point on the earth. It also orients the model correctly, depending upon its position on the earth, so that +Y is aligned with gravitational up, +Z points true north, and +X points east. This ensures that a model built using the standard VRML right-handed coordinate system will be placed on the earth so that its base is aligned with the surface of the planet. Figure 4 illustrates the capabilities of the GeoLocation node by georeferencing models of individual buildings of the SRI International main campus to an underlying terrain model of Menlo Park, CA.

4.4 GeoLOD

The GeoLOD node provides the capability to browse multi-resolution, tiled terrain data that are streamed over the web. It automatically manages the progressive loading of higher-resolution data as the user approaches the terrain, and also unloads terrain data that the user has flown past. These are essential memory management and scalability operations for browsing massive terrain datasets. For example, Figure 5 illustrates a large multi-resolution dataset that is built using the GeoLOD node. We illustrate the capability to fly down through several levels of detail while higher-resolution data are streamed over the Internet to the user's display.

4.5 GeoPositionInterpolator

One of the many strengths of VRML is its ability to model dynamic systems. We therefore incorporate the capability to animate models using geographic coordinates. This is implemented through the GeoPositionInterpolator node, which functions in much the same way as the standard VRML97 PositionInterpolator node, except that the key frame values can be specified using geographic coordinates. For example, if a GeoPositionInterpolator is created and given two geodetic coordinates, (122.413 W, 37.7483 N, 10000) and (116.388 E, 39.906 N, 10000), and the output is routed to a VRML model of a Boeing 777, then this aircraft would fly over the surface of the planet, from San Francisco to Beijing, at a constant altitude of 10,000 m. Using this capability, a vehicle could be animated based upon the list of latitude/longitude coordinates from



Figure 4. A texture-mapped site model of the SRI International campus that has been georeferenced onto an underlying terrain model. Note the accurate alignment of the latitude/longitude-specified buildings with the underlying 1 m resolution USGS DOQ satellite imagery in UTM coordinates.

a prerecorded GPS track, or from a live feed of Distributed Interactive Simulation (DIS) Protocol Data Units (PDUs).

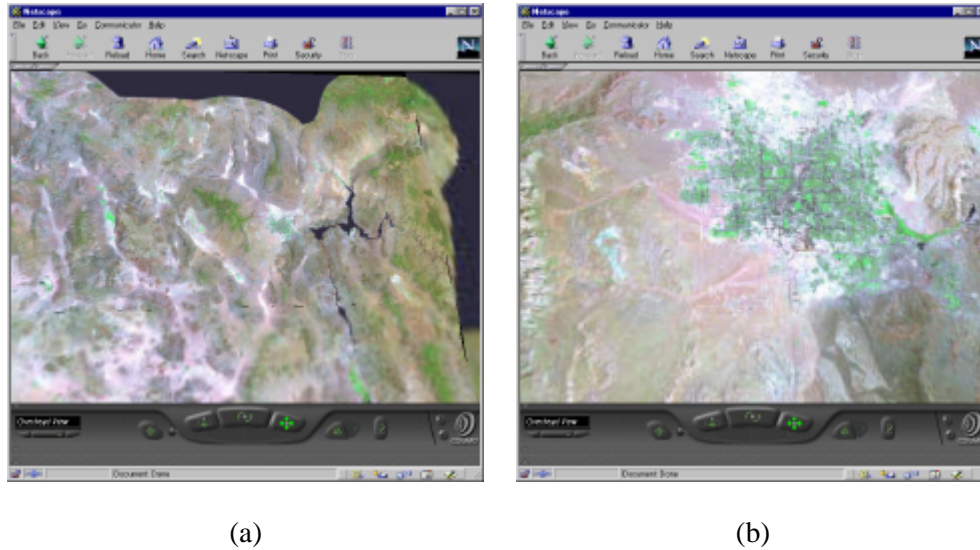


Figure 5: An example showing the scalability features provided by the GeoLOD node. The two images show a user's descent into a terrain model of the Mojave desert in southern California. The source imagery and elevation data for this terrain model total 1.3 GB.

5. Discussion

GeoVRML 1.0 is currently an accepted recommended practice of the Web3D Consortium. In addition to this, the GeoVRML nodes have been submitted to ISO as part of an amendment to the VRML97 specification. The intention is that these capabilities will eventually become an optionally-implemented part of the current VRML ISO specification, and also an additional profile in any future revisions of the specification.

The GeoVRML work is of major relevance to several exciting initiatives that are currently evolving. For example, we note that this work provides the technical foundation to build the vision of a highly accurate and large-scale model of the earth into which we can embed massive quantities of georeferenced data: a vision that is sometimes referred to as the Digital Earth. (<http://www.ai.sri.com/digital-earth/>, <http://www.digitalearth.gov/>).

On a related topic, the OpenGIS Consortium (OGC) is evolving its Web Mapping Testbed (WMT) technology as a means to revolutionize the use of geospatial data on the web. Its efforts to date have focused largely on two-dimensional (2D) presentations and also on the cataloging of geographic data. As such, the GeoVRML work is well positioned to integrate with the OGC

efforts and add web-based 3D visualization capabilities to this initiative; for example, as an XSLT translation of the OGC's GML (Geographic Markup Language) format.

Additionally, the GeoVRML working group is tracking the evolving X3D development and hopes to provide extensions to enable the support for geographic applications in X3D. For example, that group has already produced a document type definition (DTD) for GeoVRML within X3D. This is available from the X3D web page at <http://www.web3d.org/x3d.html>.

Finally, the GeoVRML group is currently compiling issues for a future version of GeoVRML, including support for more coordinate systems, ellipsoid definitions for all other planets in the solar system, new GeoVRML nodes, and additions to various current nodes.

6. Conclusions

GeoVRML provides the geosciences field with a rich suite of enabling capabilities that cannot be found elsewhere as a web browser plug-in. That is, the ability to model dynamic 3D geographic data that can be distributed over the web and interactively visualized using a standard browser configuration. With the presence of this standard, and the recent emergence of many low-cost 3D accelerator cards for common desktop computers, the scene is now set to allow researchers, educators, and businesses to publish their rich, 3D geospatial products to a wide audience over the Web. For example, GeoVRML enables such diverse applications as 3D terrain modeling, weather simulation, line-of-sight determinations, urban planning, bathymetric visualizations, disaster relief assessment and planning, GPS data visualizations, virtual real-estate, and virtual tourism. The Java implementation is released as open source and includes various tools for generating GeoVRML data. All these facilities provide geoscientists with an excellent medium to present complex 3D geographic data in a dynamic, interactive, and web-accessible format. For further details, see <http://www.geovrml.org/>.

Acknowledgements

Many people have contributed to the development of GeoVRML 1.0. In particular, the authors would like to thank Salvador Bayarri of ESRI for his work to support GeoVRML in ESRI's ArcInfo and ArcView products; Matt Fadoul of Bashir Research for adding GeoVRML support to the ShapeViz tool; Farid Mamaghani and the SEDRIS project for algorithms to support geographic transformations in GeoVRML; Dan Toms for producing a Java package based upon these algorithms; Jay Feuquay and Brian Davis of the USGS for providing terrain data; and Nat Bletter, Aaron Heller, and Doug Gordin for providing resources for the various application examples. The work performed by SRI International was funded in part by the Defense Advanced Research Projects Agency (DARPA) under contracts MDA972-97C-0037, subcontract 12165SRI of contract no. F19628-95-C-0215), and MDA972-99-C-0011. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the Defense Advanced Research Projects Agency, the United States Government, or SRI International.