GeoVRML 1.0 is an extension to the ISO standard Virtual Reality Modeling Language (VRML) that provides support for geographic applications. It offers the unique capability of an open file format that lets geoscientists integrate their geographic data directly into a three-dimensional (3D) computer graphics scene graph and allows remote users to view the result interactively over the web using freely-available standards-based software. The GeoVRML 1.0 release includes a document specifying a rich suite of extensions to VRML97, as well as an open source sample implementation of these extensions. A number of tools are provided as well as sample content that can be browsed with a standard VRML97 browser plug-in for Netscape Communicator or Internet Explorer. GeoVRML 1.0 was publicly announced as an official recommended practice of the Web3D Consortium in June of 2000. It is the product of work performed within the GeoVRML working group (http://www.geovrml.org/). This article is intended to provide our readers with an overview of the capabilities offered by GeoVRML 1.0 and an appreciation of the status and future direction of the ongoing work.

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GeoVRML features and 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 geographic coordinate systems. In addition, 2D ellipsoids and spheroids 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. It is insufficient to represent data on a planetary scale. For example, 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-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, thus facilitating content sharing across the web.

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.

7. Content Tools: As part of the GeoVRML package, we recommend a small number of tools to aid the creation of VRML files that use GeoVRML nodes. These include an open source utility to convert US Geological Survey (USGS) DEM files into GeoVRML (see Figure 2), and Chris Thorne’s Rez multi-resolution tiling utilities.

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Description of Extensions

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 EXTENSION PROTOTYPE extensibility features. For the purposes of the initial implementation, these nodes have been implemented using Java class files that are embedded within the new nodes; although it would be possible for these to be implemented natively by a VRML browser. The following sections detail each of the ten nodes that are provided by GeoVRML 1.0.

• 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.

• GeoElevationGrid

This 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 km, but for larger areas the curvature of the earth becomes significant. Figure 3 illustrates an example where we have created a GeoElevationGrid that spans the entire earth with all data specified in terms of a latitude/longitude grid. The grid of latitude/longitude heights is transparently converted into a Cartesian frame by the GeoElevationGrid node and accurately displayed with the correct degree of curvature for the earth. We have exaggerated the vertical heights by a factor of 200 to accentuate areas of high elevation. As a result, large mountain ranges such as the Himalayas are clearly distinguishable.

• GeoLine

The GeoLine node is a grouping node that reads its children data from a location in the web. The point at which its children are read and displayed is defined by the value of a field called load. If the load field is set to TRUE (the default field value), then the VRML file specified by the url field is loaded immediately. If the load field is set to FALSE, then no action is taken, but a subsequent TRUE event sent to the field will cause the file to be loaded. Such an event can be caused, for example, by a ProximitySensor event (e.g., load a scene as the user approaches it) or a VisibilitySensor (e.g., unload the scene when it is not visible). This node provides improved scalability over the standard VRML97 Inline node because the VRML97 specification does not define when the scene for an inline node should be loaded.

• 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 if X is aligned with gravitational up, ±2 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.

• 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 uploads 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.

• GeoMetadata

The GeoMetadata node aims to specify metadata describing any number of GeoVRML nodes. This can be thought of as similar to a VRML97 WorldInfo node, but specifically for describing geographic information. There is a number of organizations already working on standards and representations for geographic metadata, such as the ISO TC211, FGDC, CEN TC171, OpenGIS Consortium, and others. Rather than adopt any particular standard, the purpose of the GeoMetadata node is to provide links to any of these complete metadata descriptions, with the option to also supply a short, human-readable summary.
Both images show a model of a virtual temple structure where each column and slab has been georeferenced to meter accuracy ... the center of the model. All objects are now faithfully located and no camera jitter is evident during navigation.

An illustration of the rounding errors that can occur in geographic models due to single-precision inaccuracies.

GeoVRML 1.0 provides geoscientists with a rich suite of enabling capabilities that cannot be found elsewhere as a standard VRML extension. It is a rich environment for modeling geographic objects with great scalability, animation, accuracy, and preservation of the original geographic data. The implementation is released as an 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/

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