

## PUBLISHING 3D GEOLOGIC DATA AND MODELS ON THE WORLD WIDE WEB USING VRML

Edmund SIDES

International Institute for Aerospace Survey and Earth Sciences (ITC), The Netherlands  
[sides@itc.nl](mailto:sides@itc.nl)

Technical Commission Session Themes TC V-5

**KEY WORDS:** Geology, Internet, Visualisation, VR**ABSTRACT**

The development of the World Wide Web has revolutionised research and education in many scientific fields. Of particular interest to geo-scientists is the ability to link animated 3-dimensional (3D) models to Web documents, a facility that has arisen out of developments in the field of advanced computer graphics, computer animation and virtual reality. The use of the Virtual Reality Modeling Language (VRML) standard to publish 3D geological data and models on the Web is described. Initial tests with a variety of data and models, taken from mineral deposit evaluation programmes and other mineral exploration applications, reveal several limitations to the current usage of VRML browsers. Difficulties of identifying position, orientation and scale, when viewing models with a VRML browser, are identified as key problems in communicating information in this form. In order to assist viewers of such models it is necessary to add additional information, such as a set of standard viewpoints with explanatory names, which provide extra navigational information to viewers. The animation features of VRML provide a means of adding additional information to existing 3D models. Initial tests used this feature to simulate the progress of a drilling campaign during the evaluation of a mineral deposit. Models can also be displayed in rotating, or automatic fly-through, modes in order to provide the viewer with a range of pre-defined viewpoints of a given model.

**1 INTRODUCTION**

The use of interactive three-dimensional modelling programs is now a widely accepted tool for many geoscientific applications. It is easy to forget that the widespread availability of such techniques is a relatively recent development. In fact, all of the hardware and software tools used are less than 65 years old, as highlighted in Table 1 which summarises some of the key events in the development of electronic computing.

Period	Key developments
1937-1949	Turing machine, electronic computer, computer bug
1950-1959	Compiler, mass produced computer (IBM 650), silicon transistor
1960-1969	Video game, sketchpad, ASCII, BASIC, mouse, Arpanet
1970-1979	Floppy disk, daisywheel printer, microprocessor (Intel 4004), PC, laser printer, e-mail, ink jet printer, Apple, Microsoft, WordStar (word processing), Visicalc (spreadsheet)
1980-1989	IBM-PC and clones, AUTOCAD, Postscript, Lotus 1-2-3, Macintosh, CD-ROM, Windows 1.0
1990-1999	World Wide Web (URLs, HTML, HTTP), MOSAIC (and other Internet browsers using GUIs), Netscape, Java, e-commerce

Table 1 Key milestones in the development of electronic computing over the past seven decades (modified after Sides (1998), based on Bauer et al (1996))

In overall terms the trend has been for increases in the power of computing systems, accompanied by decreases in size and cost. As a result computers have become more accessible to the individual user with a consequent switch in emphasis from the use of large mainframe computers to the widespread adoption of desktop workstations and personal computers by both commercial and academic users. The methods by which users interact with computers is also

changing having evolved from the early days of punched card and tape input, through keyboard data entry with text screen displays, to current systems which allow interaction with 3D visualisations using a computer mouse. This trend is likely to continue given current developments in the areas of multimedia, speech recognition and virtual reality.

On a parallel front, these technological developments have resulted in the widespread adoption of digital technology in geoscientific applications, such that much of the information used is now stored and manipulated in digital form. Consequently geoscientists working on 3D modelling applications are becoming increasingly involved in the transfer of digital information to, and from, other users. With the spread of the World Wide Web over the past decade this has become increasingly important. Individual users now have access to a more or less unlimited "mine" of 3D information which can be accessed directly from their personal workplace. This development is having a major impact in many application areas by making data and models, which could previously only be viewed using specialist software, available to any user with an Internet browser plus appropriate plug-ins to view specific file formats. There is now an extremely large potential audience for any information which can be communicated over the Web, and many geological organisations are starting to use it as a means of publicising metadata about commercially available geological information (see for instance [[URL 1](#)], [[URL 2](#)]).

These trends suggest that during the present decade we may start communicating with computers using mainly speech and gesture, as well as becoming more and more immersed in virtual worlds representing our geologic models of the real world. Through the World Wide Web we already have access to countless such worlds created by other users, allowing us to view the 3D structure of large parts of the earth's sub-surface [[URL 3](#)]. To allow maximum benefit to be obtained from these developments more attention needs to be paid to the communication of 3D geoscientific models to a wider audience. This requires the development of new tools for visualising and interacting with such models as well for accessing such information in an efficient manner over the World Wide Web.

The development of the Virtual Reality Modeling Language (VRML) - a standard format for the definition of virtual worlds in 3D space - is very important in this context. This standard allows many of the features which are used in the construction of 3D models to be converted into a form whereby they can be automatically opened and viewed in a 3D visualisation environment on most desktop computers and workstations. The VRML standard is discussed in more detail below together with the results of investigations into its use as a means of communicating 3D geoscientific models.

## 2 VIRTUAL REALITY MODELING LANGUAGE (VRML)

The Virtual Reality Modeling Language (VRML) is a standard data description language that allows the definition of the geometry, display attributes, and motion of 3D worlds. In addition it allows for the definition of interactions between users and the stored objects, the animation of objects, and the incorporation of image textures, sounds and video clips (Ames et al, 1997). The origin of this standard is related to the interaction of developments in the fields of advanced computer graphics and virtual reality with the accompanying spread of the World Wide Web as a means of communication. Development of an agreed standard for the definition of characteristics of objects stored in virtual worlds, together with defined interactions between objects and the viewer, allows for the creation of dynamic worlds which can be interacted with on the Internet.

The initial development of VRML was prompted by discussions at the First International Conference on the World Wide Web in 1994 at which a prototype 3D interface was presented [[URL 4](#)]. Requirements for a VRML standard were defined during discussions on an electronic mailing list, and it was subsequently agreed to use the Open Inventor ASCII file format of Silicon Graphics Incorporated (SGI) as the basis for the first version of the standard, referred to as VRML 1.0. Modifications to, and enhancements of, the initial standard were co-ordinated by the VRML architecture group and a revised version, VRML 2.0, was released in August 1996. The VRML consortium, which was formed at the same time, oversaw the process by which VRML came to be accepted as an international standard, referred to as VRML97. In December 1998 the VRML consortium was reorganised and renamed as the Web3D consortium [[URL 5](#)].

The VRML standard is based on textual and numeric descriptions of virtual worlds stored in an ASCII file format. Subsequent discussion and examples are based on the VRML 2.0 specifications. The basic elements of a VRML file are as follows (after Ames et al, 1997):

- The VRML header
- Comments
- Nodes (defining the geometry, appearance and other characteristics of elements represented in the virtual world)
- Fields and field values (the parameters which control the nodes)
- Defined node names (to facilitate construction of complex objects based on replication of simple basic elements)
- Used node names

For more specific details on the VRML 2.0 standard, reference should be made to the VRML repository [URL 6] which provides information on books (e.g. Ames et al, 1997) and other Web resources on the subject.

### 3 THREE-DIMENSIONAL (3D) GEOSCIENTIFIC MODELING

A summary of the principal approaches to 3D geoscientific modelling, as applied to mineral deposit evaluation, is given by Sides (1997a). Preliminary work, aimed at investigating the potential of using VRML for representation of 3D geoscientific models, has been carried out by writing short conversion routines in order to extract drillhole data and triangulated surface models from systems used for mineral deposit modelling (Sides, 1997b, [URL 3]). For many of the features of interest fairly simple mappings from existing formats are possible, as summarised in Table 2.

Data type	VRML node
Point samples	PointSet
Drillholes	IndexedLineSet or Extrusion
Triangulated surfaces	IndexedFaceSet
Polygons (on plan or section)	IndexedLineSet
Gridded digital terrain models (DTMs)	ElevationGrid

Table 2 VRML nodes used to represent some of the main types of data used in 3D modelling of mineral deposits (after Sides, 1997b)

For instance, drillholes can be represented as either a set of vertex points joined by a series of line segments (IndexedLineSet), or by the extrusion of a circular cross section along a curvi-linear spine (Extrusion). Multiple objects can be created and stored in separate files, and then combined together using the Inline node. An example which incorporates triangulated surfaces representing surface topography and the bounding surface of an underground mineral deposit (both using the IndexedFaceSet node) and the surface drillholes (a set of Extrusion nodes) used to delineate the orebody limits, is shown in Figure 1 [URL 3].

Initial tests with a variety of data and models, from a variety of different mineral deposits, revealed several limitations to the current usage of VRML browsers. Support for the nodes defined in the VRML 2.0 standard varies between different browsers, as do the user interfaces offered. Consequently a lot of time can be wasted trying to learn how to manipulate models with different browsers. In addition, the defined nodes are not always represented as the user might expect. For instance the earth can be represented using a Sphere node, however, this is usually displayed as a polyhedral shape by the browser software, and is consequently quite angular when one zooms in to see details. Support for features such as transparency and texture mapping are also implemented to different degrees in different browsers.

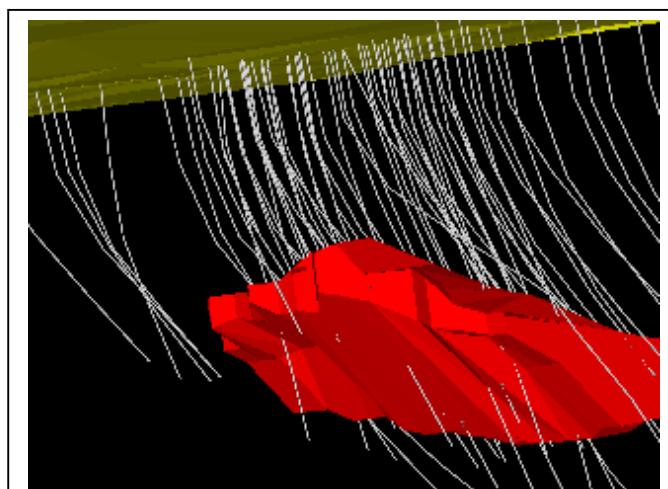


Figure 1 Three-dimensional visualisation of a mineral deposit model, showing topographic surface (yellow), a set of inclined drillholes (grey), and the limits of the mineralised body (red).

The results of these initial tests, and examination of VRML files published on the Web by other users, proved that it is relatively easy to convert information stored in existing 3D models into VRML format. Nevertheless this does not immediately solve the problem of communicating such information to a broader audience, since it is usually very difficult for the casual user to navigate around such virtual worlds unless they already have a fairly detailed knowledge of the information. This is a general feature of virtual reality applications which relates to the fact that it is much easier for us to comprehend objects which we are familiar with in our everyday environment (e.g. buildings, cars, trees, etc), where we have an inherent understanding of the shape and dimensions involved. In the case of sub-surface shapes,

which are never actually seen in a physical sense, the user needs further information in order to help them understand what they represent. In this context it was decided to investigate the potential of using other features of the VRML standard as a means of providing additional information when communicating virtual geologic worlds to the general user. These tests were mainly aimed at investigating the use of animation (position and orientation interpolation), and the ability to link 3D models with other models or with text and image files (anchor node).

#### 4 ANIMATION OF 3D GEO-SCIENTIFIC DATA

Two demonstrations were developed in order to test the use of the animation features of VRML:

##### 4.1 Spinning globe with linked maps and 3D models

A spinning globe showing points on the earth's surface which are linked to maps, or other 3D models, was created (Figure 2). Using known latitude and longitude values, points can be displayed on the globe in their correct geographic location, and can then be linked to related files using the VRML Anchor node. This approach has been tested by linking several points to existing VRML files, and also to images of geological maps that are in turn linked to 3D models stored in VRML format. Several of the files created are stored on the author's home page [URL 3], and it is recommended that these should be viewed whilst reading this section.

The results of this test suggests that 3D models, that are to be accessed over the Internet, could be indexed using either an interactive globe or a digital terrain model of the country or region of interest. The user could then navigate around the index model in order to select a specific area of interest, and then obtain details of available models, or other data, by clicking on reference points which are linked to the individual models or more detailed summaries. Given that a large number of users will be already familiar with desktop globes, and physical terrain models, this approach should allow them to target the information that they require by starting their navigation from a familiar perspective. VRML also provides for the display of 3D models at different levels of detail (LOD node) which would allow a global model to be combined with detailed terrain models of specific countries or regions in such a file.

##### 4.2 Animated drillhole advance

In this example, a simple animation of two drillholes was developed in order to illustrate how changes of data with time can be represented using VRML (Figure 3). The initiation and completion of the display of the drillholes are taken to correspond with the start and end of the physical sampling process, respectively. Where data for an entire project are stored in this manner a user would be able to view the progress of sampling with time. This would allow more detailed analysis of sampling efficiency and help in the optimisation of sampling grids.

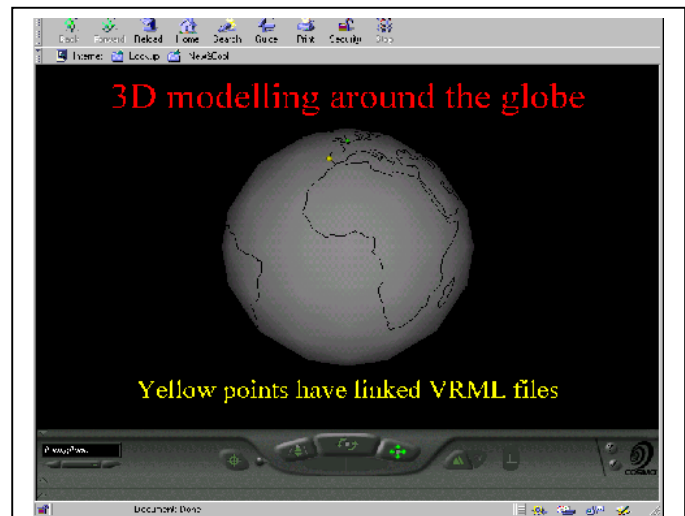


Figure 2 Model of a globe (rotating in the source file) which is used to provide a visual index of maps and 3D models which can be opened in the same browser by clicking on the reference (This figure was generated using Netscape 4.0.3 and Cosmo Player 2.0 beta)

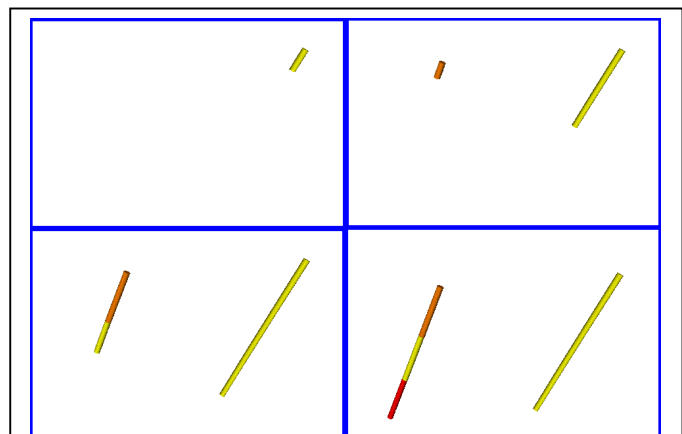


Figure 3 Use of the animation features of VRML to represent the advance of two closely spaced drillholes (time interval increases from left to right and from top to bottom)

## 5 DISCUSSION

The examples presented above illustrate the ease with which information concerning 3D geological models can be converted into VRML format. This immediately allows such information to be published on the World Wide Web where a wide range of users can obtain, and interact with, impressive 3D visualisations of the stored information. With respect to the work presented here, some of the main advantages and disadvantages concerning the use of VRML for this purpose are presented in Table 3.

Although it is relatively easy to convert geoscientific information into VRML format, much of the information represented by such models may still be relatively inaccessible to the general user. This is due to the fact that it is generally difficult to identify position, orientation and scale, when viewing such models with a VRML browser. These problems can be alleviated by incorporating extra information such as standard sets of viewpoints with explanatory names.

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>• conversion easy for data &amp; surfaces</li> <li>• low cost 3D visualisation</li> <li>• wide accessibility</li> <li>• closer user interaction</li> <li>• ability to store time/animation</li> <li>• ASCII format facilitates editing</li> </ul>	<ul style="list-style-type: none"> <li>• difficult to navigate</li> <li>• difficult to distinguish 3d structure</li> <li>• construction may be time consuming</li> <li>• volumetric data cannot be handled</li> <li>• variable browser support</li> <li>• file format somewhat cumbersome</li> </ul>

Table 3 Summary of some of the main advantages and disadvantages of using VRML to represent 3D geoscientific models

Limitations to the use of VRML for storing geo-referenced data have led to the formation of the geo-VRML working group (Rhyne, 1999, [URL 7](#)). Initial work by this group has led to the development of tools to facilitate several geographic coordinate transformations, and also for improved visualisation of large terrain models. The recommendations, and current activities, of this group are likely to lead to the implementation of changes, or additions, to the VRML standard that will make it easier to communicate georeferenced 3D data over the Web.

One of the major limitations of VRML is the lack of facilities for handling volumetric data such as those commonly used to represent variations in physical and chemical properties within sub-surface geologic domains. It is likely that many of the techniques currently being developed in the fields of medical imaging and volume rendering will, with time, become more widely available on standard desktop computers. There is therefore a need to ensure that procedures for handling this type of data are incorporated into the VRML standard.

Another requirement is illustrated by the features available in several volume visualisation software packages which allow viewers to cut sections through solid objects in order to obtain a better understanding of their internal structures. The current state of the art with respect to VRML browsers could be compared with the problem of deciding how good a particular cake or pie is without being allowed to cut it open or to bite into it. In the future standard operators need to be defined which will allow the general user to cut open or slice into objects in a virtual world, in addition to the current facilities for rotation, and translation, which allow the user to view such objects from all angles.

## 6 CONCLUSIONS

It has been demonstrated that the animation and user interaction features of VRML provide a valuable means of adding additional information to existing 3D geoscientific models which have been converted to VRML format for web publication. In the context of 3D data mining such features may facilitate display and query of metadata relating to 3D information. In addition the animation features of VRML offer the capability of representing temporal information related to 3D data, or models, to the user. Work is continuing on this front in order to try to develop ways of displaying changes in the shape and location of a model as additional information is obtained.

In the broader context of current and future developments in hardware and software technology, the following factors are important in guiding future research and development in 3D geoscientific modelling:

- ◆ New opportunities offered by the ever increasing spread of the Internet
- ◆ The need to present results of specialist 3D geoscientific modelling to a wider audience
- ◆ The need for new tools to cope with the current data explosion
- ◆ The VRML standard which provides a format for the definition of 3D data, plus time, which is likely to be around for a long time



Although there may be doubts about the exact impact of these developments on the field of 3D geoscientific modelling, the Internet and VRML are undoubtedly here to stay. Future developments are likely to make it increasingly easy for relatively untrained users to access 3D geo-scientific models, and this will require careful thought by model builders as to exactly what information they wish to convey in a given model, as well as how best to do so. Enhancements to the VRML standard are currently being developed, and in this regard it is recommended that representative earth science organisations should submit lists of requirements for their own particular applications in order to ensure that future Internet tools meet their needs.

## ACKNOWLEDGEMENTS

This contribution is based on presentations made at two conferences (Sides, 1997b, 1998). These conference contributions have previously only been published in abstract form.

## REFERENCES

Ames, A.L., Nadeau, D.R., and Moreland, J.L. (1997) VRML 2.0 Sourcebook. John Wiley & Sons, Second Edition, 654 pp.

Bauer, L., Carlson, B., Burgess A., and Miller, C. (1996) Timeline tracing evolution of computing and computer technology (Special issue on 50 years of computing). Computer, IEE Computer Society, 29 (10), October 1996, pp. 25-110.

Rhyne, M.-T. (1999) A commentary on GeoVRML: a tool for 3D representation of georeferenced data on the web. Int. J. Geographical Information Science, vol.13, No. 4, pp. 439-443.

Sides, E.J. (1997a) Geological modelling of mineral deposits for prediction in mining. Geol. Rundsch., vol. 86, pp. 342-353.

Sides E.J. (1997b) Using VRML tools for visualisation of geologic data and models. Abstracts of papers presented at the European Science Foundation conference "Space-time modelling of bounded natural domains: Virtual environments for the geosciences", 9-14th December 1997, Kerkrade, The Netherlands.

Sides E.J. (1998) Using VRML for communicating the results of geoscientific modelling over the Internet. Abstracts of papers presented at the conference "3D Modeling of Natural Objects: A challenge for the 2000's", 3-5th June 1998, ENSG, Nancy, France.

## WEB REFERENCES

- [URL 1] <http://edcwww.cr.usgs.gov/webglis>  
The United States Geological Survey's (USGS) Global Land Information System (GLIS)
- [URL 2] <http://geixs.eurogeosurveys.org/en/geodata.html>  
Geological Electronic Information eXchange System (GEIXS)
- [URL 3] <http://www.itc.nl/~edsides/vrmlgeo.htm>  
Section of the author's home page devoted to work related to the use of VRML for geoscience applications. (includes links to most of the models and examples mentioned in this paper)
- [URL 4] <http://www.vrml.org/about/history.html>  
A brief history of the development of the VRML Specification
- [URL 5] <http://www.web3d.org/>  
Home page of the Web3D consortium; a good source for information about the latest developments with respect to 3D applications on the Web. This organisation, which replaced the VRML organisation, is responsible for developing and promoting 3D on the Web.

- [URL 6] <http://www.web3d.org/vrml/vrml.htm>  
The Virtual Reality Modeling Language (VRML) repository, hosted by the Web3D consortium, which contains extensive resources about VRML standards, software and examples (formerly hosted by the San Diego Super Computer Centre)
- [URL 7] <http://www.ai.sri.com/geovrml/>  
Home page of the geoVRML Working Group which is seeking to improve the capabilities of communicating georeferenced data, on the Web, using 3D visualisation tools.