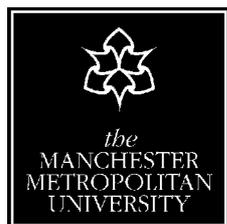


The Virtual Reality Modelling Language in Art and Design Higher Education

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1 Introduction

1.1 Adding the Third Dimension to the WWW

The World-Wide Web, which will be abbreviated to WWW or the Web throughout this document is an increasingly popular means of providing and accessing information. Its success is due to a variety of reasons, including:

- *Cross-platform portability.* WWW servers and clients (programs which retrieve the information held on the server) can work on different computer systems.
- *It uses the infrastructure of the Internet.* The Web uses the global connection of networks and communication protocols of the internet.
- *It is free.* Generally when information is published on the Web, no charge is made for viewing it. Much of the software needed for creating, serving and browsing Web documents is also freely available.
- *It is easy to use.* The WWW is a multimedia hypertext system. Documents can contain links to other Web information, which are retrieved when the user selects highlighted text or images (usually by clicking with the mouse). The other information may be image, audio and video files as well as more text documents. The rich format of hyperlinked text and graphics is created using the Hypertext Markup Language (HTML).

One of the more recent developments of the World-Wide Web, is the establishment of the Virtual Reality Modelling Language (VRML) as the standard method for describing interactive three-dimensional virtual scenes on the Web. Like HTML, these 3D worlds can be hyperlinked to other resources on the Web. In fact, VRML can be thought of as a 3D equivalent of HTML, providing a three-dimensional interface to the WWW. This report will be looking in more detail at VRML and how it can be used. Incidentally, VRML can be pronounced as 'vermal'.

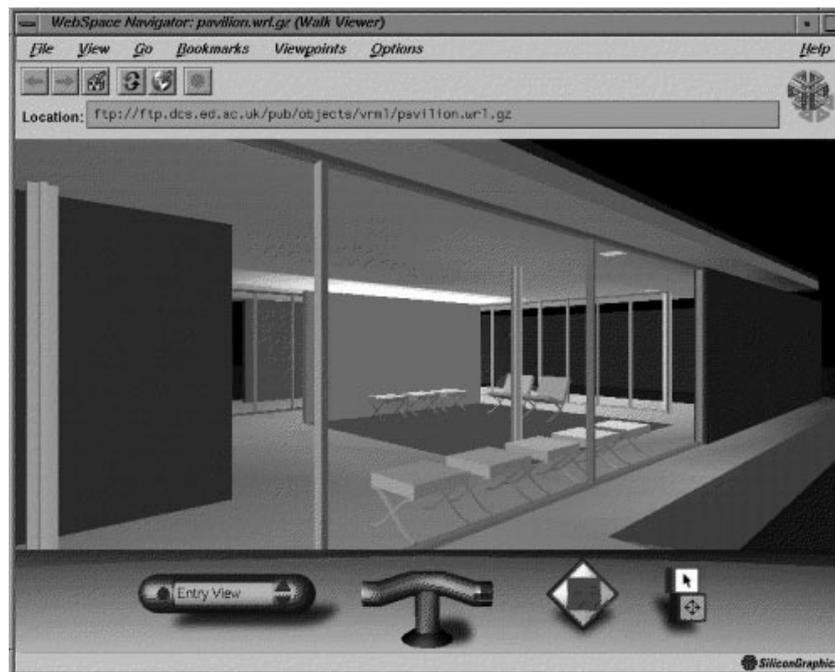


Figure 1-1 A VRML model of the Barcelona Pavilion

1.2 Use in Art and Design Higher Education

The ability to create and explore three-dimensional environments on the World-Wide Web presents many interesting opportunities for art and design higher education, especially in the disciplines of architecture, interior design, landscape and 3D design. These subjects are concerned with the communication of ideas about structures and spaces. Computer modelling is now used widely in these areas, as a tool for understanding the spatial relationships within a 3D design. The importance of VRML is that it enables the models to be viewed by more people (potentially anyone with access to the WWW), on a variety of different computer systems. Hence VRML could be used as the medium for the public exhibition of work. The additional VRML multimedia feature of allowing objects to be hyperlinked to text, sounds, images, etc, may also make it a useful tool in teaching or research.

1.3 About this Report

This report has been written primarily with the requirements of potential VRML users in art and design higher education in mind. However, it should be of interest to people outside this sector as well. It is assumed that the reader is acquainted with some of the terminology and basic concepts of the WWW and 3D computer graphics.

The aims of the report are as follows:

- To introduce the reader to VRML, describing its brief history, and outlining current and possible future development.
- Explain the main features of the VRML 1.0 language specification, through the use of an example.
- Describe some of the VRML browser software which are currently available for viewing VRML scenes.
- Provide some examples of the use of VRML on the WWW, with particular reference to art and design.
- Describe some of tools available for creating VRML models.
- Discuss issues concerned with making VRML files available on a Web server.
- Provide pointers to where more information about all the above can be found.

This report has been produced as part of the Support Initiative for Multimedia Applications project, funded under the JISC New Technologies Initiative and administered by the Advisory Group on Computer Graphics (AGOCG).

2 About VRML

2.1 History

The need for a three-dimensional equivalent of the HTML standard was first recognized at the first International Conference on the World Wide Web in Geneva, held in the spring of 1994. At this conference, Tim Berners-Lee and Dave Raggett (two of the original developers of the WWW), organized an informal 'Birds-of-a-Feather' session to discuss the creation of 3D virtual reality interfaces to the WWW. Following some presentations of current work in this field, the attendees agreed that any future progress would require a new common language for describing the 3D scenes with WWW hyperlinking features. Thus VRML (originally Virtual Reality Markup Language) was conceived.

Such was the interest expressed at the meeting that an internet mailing list (`www-vrml`), hosted by Wired Magazine, was set up to discuss the requirements for such a language (see section 7.3 for more details). Within a week over 2000 people had subscribed to the list.

The participants soon reached the consensus that the first version of VRML should be based on one of the 3D modelling languages already in existence. This would avoid 're-inventing the wheel' and so speed up development. A number of different candidates were put forward, including AutoDesk's Cyberspace Development Format (CDF), The Object Orientated Geometry Language (OOGL) from the University of Minnesota and the Manchester Scene Description Language (MSDL) from the University of Manchester. However, after some debate the members of the mailing list decided that VRML should be based upon Silicon Graphics' Open Inventor ASCII file format. The main reasons for this choice were:

- (a) Open Inventor was already being widely used in education and industry for real-time 3D visualization applications.
- (b) It not only describes the 3D polygonal geometry of a virtual scene, but also material properties, lighting and textures for added realism.
- (c) New features could easily be added.
- (d) Silicon Graphics had agreed to place the file format in the public domain.

It was also decided that the more difficult problem of implementing multi-participant interactions and behaviours should be left to later versions of VRML, VRML 1.0 would only describe static worlds. Discussion continued on the mailing list on how to extend the Open Inventor language to allow platform independence and hyperlinking to the World-Wide Web.

The first draft of the VRML 1.0 specification was presented to the second WWW Conference at Chicago in October 1994. The authors of the specification are Gavin Bell (Silicon Graphics `gavin@enr.sgi.com`), Anthony Parisi (Intervista Software `dagobert@netcom.com`) and Mark Pesce (VRML List Moderator `mpesce@hyperreal.com`).

In April 1995, Silicon Graphics and Template Graphics launched WebSpace, the first VRML compatible Web browser. Seventeen other companies and organisations also announced their support for VRML. Since then many more VRML browsers have become available, together with other software tools for creating VRML worlds. There is also an ever-increasing number of Web sites containing VRML models.

VRML 1.0 Specification Document

The VRML 1.0 specification document is available in the HTML format at:
<http://vrm1.wired.com/vrm1.tech/vrm110-3.html>

The latest version with clarifications can be found at:
<http://vag.vrm1.org/vrm110c.html>

2.2 Language Details

This subsection will use an example to explain some of the powerful and interesting features of the Virtual Reality Modelling Language. The VRML file which created the scene shown in Figure 2-1 is listed below.

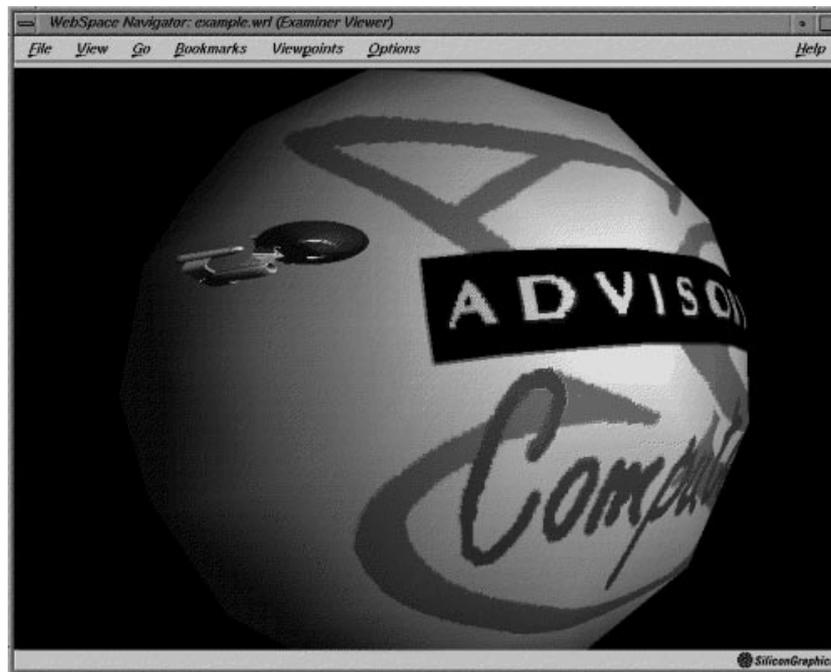


Figure 2-1 Planet AGOCC and the Starship Enterprise

Description of VRML Example Scene

Our example scene contains a light source and just two objects: a sphere texture mapped with the AGOCC logo ('Planet AGOCC') and the Starship Enterprise. Figure 2-1 shows how this VRML file appears when loaded by the WebSpace VRML browser (more about VRML browsers in the section 3). As well as describing the geometry and appearance of the 3D scene, VRML can also integrate it into the World-Wide Web. In our example, this is demonstrated in two ways. First, the sphere is hyperlinked to the AGOCC WWW home page. A user can usually follow a hyperlink by placing the mouse pointer over the appropriate object and clicking, though the exact action is dependent on the VRML browser. When a hyperlink is selected, this will tell the VRML browser to go and fetch the appropriate information from the Web. In this case it is an HTML document, if the VRML browsers cannot display HTML, the document will be displayed in the window of an HTML browser, such as Netscape or Mosaic.

The second WWW linking feature demonstrated in the example, is the use of inline objects. The geometry of the Starship Enterprise is not contained in the VRML file listed below, nor is it in any file on the same computer. The Enterprise model is actually located on a Web server at the NASA National Space Science Data Centre.

```

1  #VRML V1.0 ascii
2
3  Separator{
4
5      # Define camera position and give it a name
6      DEF Camera1 PerspectiveCamera {
7          position    -240 -30 30
8          orientation 0.15 -1.0 0.0 1.44
9      }
10
11     # Light source
12     PointLight {
13         location -270 0 220
14     }
15
16     # The textured mapped sphere hyperlinked to AGOCG Home Page
17     WWWAnchor {
18         name "http://www.agocg.ac.uk:8080/agocg/home.html"
19         description "Goto AGOCG WWW Home Page"
20         Material {
21             diffuseColor 0.6 0.7 0.9
22             specularColor 1.0 1.0 1.0
23             shininess 0.5
24         }
25         Texture2 {
26             filename "agocg.gif"
27         }
28         Sphere {
29             radius 100
30         }
31     }
32
33     # The inline Starship Enterprise
34     Separator {
35         Transform {
36             translation -150 0 0
37             rotation 1 0 0 -1.57
38         }
39         WWWInline {
40             name "http://coney.gsfc.nasa.gov/Mathews/Objects/galclass.wrl"
41         }
42     }
43 }

```

The VRML Header (line 1)

Now let's look in more detail at the VRML file. Note that the line numbers on the left hand side are included for reference only and are not part of the VRML document. The first line of a VRML file must always contain the header `#VRML V1.0 ascii`. This identifies it as VRML version 1.0 document, and so an application cannot confuse it with an Inventor file, for example.

Scene Graph and Nodes

The rest of the VRML document consists of a list of objects called nodes. These are arranged in a hierarchical structure called a scene graph, with nodes embedded within other nodes. Each node contains part of the information which is used to build up the whole scene. For example, a node may define part of the geometry of the model, or the position of a light source, or the Uniform Resource Locator (URL) of a hyperlink. Every node has the same general syntax:

```
DEF objectname objecttype { fields children }
```

Objecttype is a name which indicates what type of node it is, for example a sphere or transformation. To give an object a name the DEF objectname syntax is used. Within the curly braces are the parameters which control the characteristics of the object, for example the radius of a sphere. Group nodes can contain other nodes, the children nodes are contained within the braces. Only the objecttype and braces are required, the rest are

optional.

The order of nodes is important, because a node can affect other nodes which come after it. Group nodes, which gather other nodes together, are used to insulate sections of the scene graph from other parts and ensure that nodes within the group are treated the same way. The Separator node in line 3 is an example of a group node. Here it is collecting all the elements of the scene into one node. The end brace of the Separator node is on line 43. Indenting is used to make it easier to see the structure of the VRML file, but it is not a requirement of the language. Comments are also included to make things more readable. A comment is indicated by the # character. All characters after it until the new line will be ignored by the VRML software. An Info node can be used for important information about a VRML model, such as copyright notices.

Camera Node (lines 6 to 9)

The PerspectiveCamera node is used to indicate to the VRML browser where the initial viewpoint should be. This node has four fields to define the viewpoint and perspective projection, these are position, orientation, focalDistance and heightAngle. By default, the camera is located at (0,0,1), looking along the negative z-axis. The y-axis is up. To change to the new viewpoint at (-240,-30,30), only the position and orientation values need to be changed from their default values (as defined in the specification document), so only these fields need to be included (lines 6 and 7). The VRML browser will assume the focalDistance and heightAngle default values as read. This property is true for all nodes, and is a useful way of keeping the VRML file compact.

If no viewpoint is defined, then the VRML browser determines its own initial viewpoint. Note that in the example the DEF syntax has been used to give the camera node the name 'Camera1'.

Scene Illumination (lines 12 to 14)

The scene is illuminated from a white, omni-directional point light source at -270, 0, 220. Other lighting nodes are DirectionLight (parallel light rays) and SpotLight. Most VRML browsers have a 'headlamp' option which illuminates the scene if no light source is specified.

WWWAnchor (lines 17 to 31)

The WWWAnchor group node is used to implement the WWW hyperlinking feature of VRML. Whenever any of its children, in this case the textured sphere, are selected, the Web resource identified by the URL in the name field (line 18) will be loaded. Links can be to other VRML files, allowing the user to 'teleport' to other virtual worlds, or to HTML documents, audio files or images, in fact any file with a recognized MIME type. Non-VRML files will probably be displayed using other applications if configured correctly. The optional description field (line 19) provides additional text information about the hyperlink. How (and if) this information is presented to the user is dependent on the VRML browser.

Material Definition (lines 20 to 24)

We want the Planet AGOCG to have a shiny light blue appearance. So before the sphere shape (line 28) is defined it is necessary to set the diffuse, specular and shininess surface properties of the current material in the Material node. A colour is defined using the red-green-blue triplet. The ambient, emissive and transparency properties can also be defined in this node. Material properties are applied to all subsequent shapes until redefined or limited by the extent of a Group node.

Textures (lines 25 to 27)

The Texture2 node defines the texture map that is applied to all subsequent shapes. In this example, the WWWAnchor group node limits the extent of the texture mapping to the

sphere. The texture is read from the URL specified in the filename field (line 26). The texture image could be located anywhere on the WWW, but in this case the GIF image file containing the AGOCG logo is in the same directory as the VRML file.

A problem with the VRML 1.0 specification is that it does not give a standard file format for the external texture image. A number of different formats are currently being used, including Silicon Graphics' RGB format, JPEG, GIF and BMP. An alternative method of defining a texture map, is to do it in-file in the image field of the Texture2 node, in the VRML uncompressed SImage format.

Sphere and Other Shape Nodes (line 28 to 30)

To create a sphere in the scene the Sphere node is used. VRML contains a number of predefined shapes, as well as the sphere, there is the cube, cone, cylinder and ASCII text. By default the sphere is centred at (0,0,0) with a radius of one unit. In line 29 we have set the radius to 100 units.

VRML is not just limited to these simple primitive shapes. More complex forms can be created from polygons using the Coordinate3 and IndexedFaceSet combination. The Coordinate3 node defines a set of points in space, IndexedFaceSet then joins these points to form polygons.

Transformations (lines 35 to 37)

To orientate the Enterprise model correctly and place it in the right place, a rotation and translation are required. This is achieved using the Transform node. VRML uses a right-handed coordinate system. Angles are measured in radians.

WWWInline (lines 39 to 41)

The WWWInline node enables other VRML models, located anywhere on the WWW, to be included our own VRML scene. A VRML file is referenced by including its URL in the name field of WWWInline. Our example uses a model of the Starship Enterprise located at the URL:

```
http://coney.gsfc.nasa.gov/Mathews/Objects/galclass.wrl
```

Like anything on the Web, it sometimes take a while for inline objects to be retrieved. Therefore the WWWInline node also allows bounding boxes to be defined. A wireframe bounding box will occupy the space taken by the object, while it is being loaded.

Instancing

Although not included in the example, VRML allows the creation of multiple instances (or copies) of an object. If a node has been named using the DEF syntax, then an instance of it can be created later on in the file by using the USE keyword.

Multiple Viewpoints

A list of different viewpoints can be set up if more than one camera is defined in a Switch group node. Some VRML browsers then enable the user to select between these predefined viewpoints, thus creating a 'guided tour'.

Level-Of-Detail

The Level-Of-Detail or LOD feature permits alternate representations of the same object. This allows the complexity of a model to be reduced automatically as the distance between it and the viewer increases.

Tutorial

For more details about the VRML language see the specification document. Alternatively,

an interactive tutorial on creating VRML worlds can be found at the URL <http://honors.uhc.asu.edu:80/~joel/vrml/>

2.3 File Extension and MIME Type

The file extension for VRML files is `.wrl`, short for world. In order for Web servers and clients (such as browsers) to recognize the type of data they are handling a MIME type is defined. The MIME type for VRML files is `x-world/x-vrml`. Thus, if a VRML browser is installed on a UNIX system, the following line would need to be added to the user's or system-wide `mime.type` file:

```
x-world/x-vrml    wrl
```

The `x` indicates that it is experimental, but registration is in progress, so it likely that the MIME type will be changed to `world/vrml` or `model/vrml` in the near future.

3 VRML Browsers

3.1 General Information

In order to view and interact with a three-dimensional VRML scene, you need a VRML browser program. A wide range of VRML browsers are now available for a variety of different computer platforms and operating systems. Some are still under development and are released as Beta software, which may still contain bugs. This section will look at seven VRML browsers: i3D, VRScout, VRweb, WebFX, WebView, WebSpace and WorldView. All of these programs are available via the internet. Instructions for downloading and more information about each product can be found at the given Web sites. Features compared include compliance with the VRML 1.0 specification, methods of navigating through the 3D scene and whether the VRML browser is a stand-alone or helper application.

Stand-alone and Helper Applications

Some VRML browsers work as stand-alone applications, others as helper applications. Stand-alone VRML browsers are able to fetch VRML documents from the WWW using the HTTP communication protocol. Helper applications cannot do this for themselves, so rely upon HTML browsers, such as Netscape or Mosaic, to retrieve the VRML files. However, most of the VRML browsers that are currently available cannot display HTML text, the primary language of the WWW. So stand-alone VRML browsers are usually set up to work in conjunction with HTML browsers as helper applications.

Setting up a VRML browser as a helper application is not difficult, it just requires a slight alteration to the configuration files of the HTML browser, so that it knows what to do when it encounters a file of the VRML MIME type. For example, to make the VRweb VRML browser a helper application for Netscape on a UNIX system, the following line should be added to the .mailcap file in the user's home directory (or the system wide mailcap file).

```
x-world/x-vrml; vrweb -URL %u %s
```

The exact instructions for installing and configuring for a specific browser can be obtained at the site from where the product is downloaded.

Navigation and Interaction

Most VRML browsers offer the user more than one way of examining or moving through the VRML scene. Although the methods of interaction are implemented differently on each browser, there are similar themes. Usually there is an examine or flip mode, this allows the user to view an object by rotating it, or moving it up or down, left or right, closer or further away. A walk or fly mode simulates moving through the scene, with mouse or keyboard input emulating a joystick-type control. Some browsers also implement a point to and seek mode, the user points to an object in the scene using the mouse and then the viewpoint automatically moves towards it.

3.2 i3D

Centre for Advanced Studies, Research and Development in Sardinia.

Currently Supported Platforms

SGI IRIX 5.2 or later.

i3D is a free VRML browser for the SGI platform. It works by translating the VRML into its own i3D scene description file format. Version 1.0 supports WWWAnchor and WWWInline partially. SGI RGB is the only accepted file format for texture images. Gzipped files are decompressed. The software has many of the features of a high speed VR system, such as, time-critical rendering, navigation using spaceball or mouse, and stereo vision with CrystalEyes LCD shutter glasses. i3D needs to be configured as a helper application.

More Information

<http://www.crs4.it/~3diadm/i3d-announce.html>



[Figure 3-1 i3D]

3.3 VRScout

Chaco Communications, Inc.

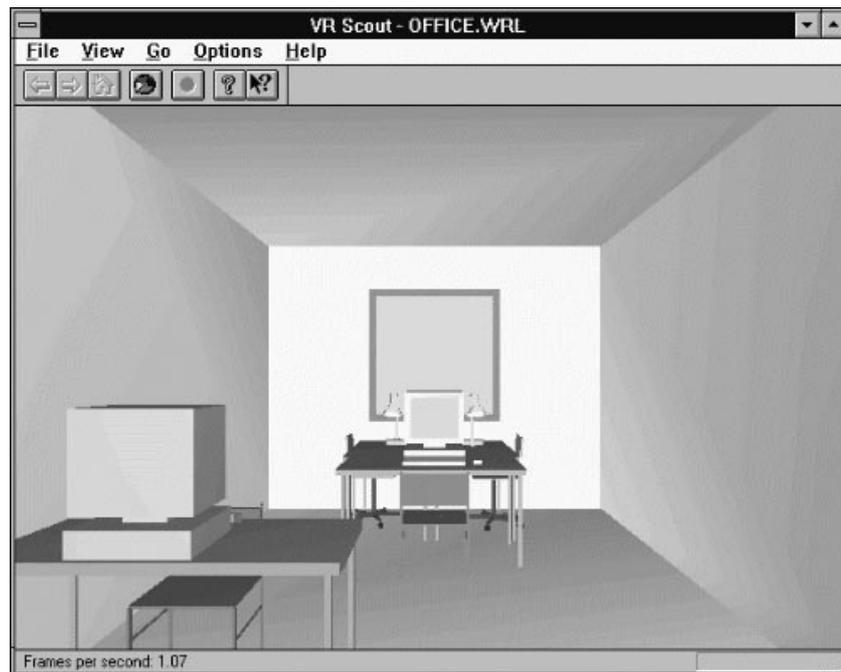
Currently Supported Platforms

Windows 3.1, NT and 95.

VRScout is a stand-alone VRML browser for Microsoft Windows from Chaco Communications. Version 1.1 runs on Windows 3.1, NT and 95, using Intel's 3DR rendering software. VRScout supports the entire VRML 1.0 specification, including WWWAnchor, WWWInline objects and textures. Textures can be in GIF, JPEG and BMP formats. The user can navigate through the scene in Walk, Fly or Examiner viewing modes. Gzipped and zipped files are decompressed automatically.

More Information

<http://www.chaco.com/vrscout/>



[Figure 3-2 VRScout]

3.4 VRweb

IICM, NCSA and the University of Minnesota.

Currently Supported Platforms

Windows 3.x, NT and 95; SGI; Sun OS and Solaris; DEC Alpha and ULTRIX; HP-UX; IBM AIX; LINUX.

As can be seen from the list above, VRweb is supported on Microsoft Windows and a wide range on UNIX platforms. Ports are currently under way for the Macintosh 68000 and Power PC. All are implemented using the Mesa graphics library, which does not utilize or require any special graphics hardware, and so can be quite slow. However, an OpenGL version, which does take advantage of any graphics hardware, is available for the SGI, DEC Alpha and Windows NT and 95 platforms. The source code has also been made available.

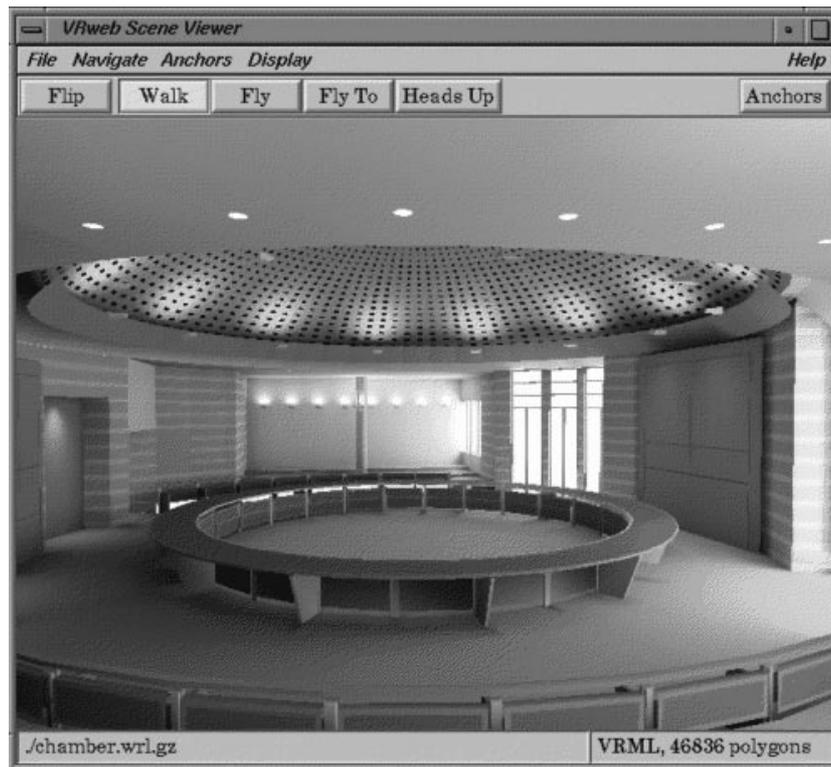
The latest UNIX version of VRweb supports most VRML features, including WWWAnchor, texturing (in-file texture images only) and Level-Of-Detail. VRweb 1.1 does not yet implement WWWInline objects. The user has a choice of five different navigation modes (Flip, Walk, Fly, Fly-To and Heads-Up) and can select the type of rendering required, from wireframe to full textured smooth shading. VRweb needs to be set up as a helper application.

More Information

<http://www.iicm.tu-graz.ac.at/Cvrweb/>

VRweb can be downloaded from:

<ftp://unix.hensa.ac.uk/mirrors/Hyper-G/VRweb>



[Figure 3-3 VRweb (for SGI)]

3.5 WebFX

Paper Software, Inc.

Currently Supported Platforms

Windows 3.1, NT and 95.

The WebFX Plugin is a popular VRML browser for the PC platform. Unlike the other browsers described in this section, it is an embedded viewer, with the 3D scene displayed within the window of the HTML web browser application. WebFX will only work correctly with one HTML browser, and that is Netscape Navigator version 2.0. It is fully compliant with VRML 1.0, including WWWAnchor, nested WWWInlines, Level-Of-Detail and textures. Textures can be in GIF, JPEG, and BMP formats. WebFX also supports GZIP decompression and some Open Inventor nodes.

There are three navigation modes: Walking, Flying and Pointing, using a mixture of mouse and keyboard input. Exploration of the 3D scene is aided by collision detection and selection between predefined viewpoints. It is also one of the fastest Windows based VRML browsers.

More Information

<http://www.paperinc.com/>



[Figure 3-4 WebFX Plugin for Netscape]

3.6 WebView

San Diego Supercomputer Centre.

Currently Supported Platforms

SGI / UNIX.

WebView is a free standalone VRML browser for SGI systems. SDSC have released it with full source code, as a public platform for the development of the VRML specification. The source code needs to be compiled after downloading.

WebView supports both VRML 1.0 and Open Inventor 2.0, the latter to allow the testing of experimental extensions to VRML. The most recent release is still Beta, so there are still some bugs and missing features.

There are four viewing modes: Examiner, Fly, Plane and Walk. A useful feature is a dialog box which gives the coordinates of the current viewpoint, such information can be helpful when building VRML worlds. WebView supports WWWInline and WWWAnchor nodes but cannot load gzipped files. External texture image files must be in the SGI RGB format and in the same directory as the VRML file.

More Information

<http://www.sdsc.edu/EnablingTech/Visualization/vrml/webview.html>



[Figure 3-5 WebView]

3.7 WebSpace

Silicon Graphics Inc. and Template Graphics Software.

Currently Supported Platforms

SGI (IRIX 5.3); Windows NT and 95; Sun Solaris; IBM AIX;

WebSpace was one of the first VRML browsers to become available, and remains the favoured choice for the Silicon Graphics' workstations. It supports its own HTTP communication so can work standalone as well as an external viewer to an HTML web browser. WebSpace is 100% VRML 1.0 compliant. Features supported include WWWAnchor, WWWInline, Level-Of-Detail, textures (JPEG, GIF and Silicon Graphics RGB formats), GZIP decompression and also Open Inventor nodes. The user can begin to view and move around the scene while WWWInline objects are being loaded. A 'Smoothest Motion' option enables quicker and smoother movement through the scene by rendering with less detail, utilizing the VRML Level-Of-Detail where possible.

WebSpace has two navigation modes: Walk and Examiner. Both have an on-screen simulated dashboard, Walk mode has a joystick (see Figure 3-6), Examiner has a simulated trackball. Movement is enabled by interacting with these controls using the mouse, alternatively the keyboard can be used. There is also point and seek navigation option. If multiple viewpoints are defined in the original VRML file, WebSpace gives the user the option of moving automatically between the viewpoints, thus simulating a 'guided tour'.

More Information

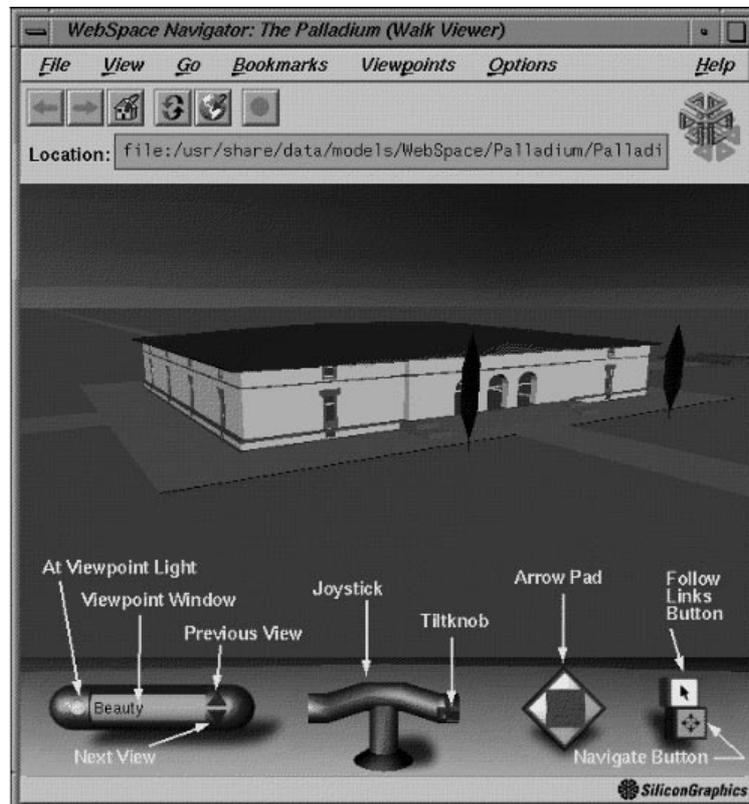
<http://webpace.sgi.com/>

European download area for SGI WebSpace Navigator 1.1

<http://www-europe.sgi.com/Products/Evaluation/webpace1.1/>

WebSpace 1.0 for non-SGI platforms

<http://www.sd.tgs.com/~template>



[Figure 3-6 WebSpace (annotated)]

3.8 WorldView

Intervista Software, Inc.

Currently Supported Platforms

Windows 3.1, NT and 95.

WorldView was the first VRML browser for Windows. It is able to work in standalone mode, or as a helper application for a HTML browser. Version 0.9g supports WWWAnchor, nested WWWInline, Level-Of-Detail, GZIP decompression and textures in GIF, JPEG and BMP formats. There are two navigation modes: Fly and Inspect. On-screen buttons are used to move around the 3D scene.

More Information

<http://www.webmaster.com/vrml/>

3.9 Other VRML Browsers

Other VRML browsers are also available, including AmberGL (Windows NT/95), Fountain (Windows), GLView (Windows NT/95), NAVFlyer (Windows), Virtus Voyager (Macintosh), VRealm (Windows NT/95), WebOOGL (SGI, Sun), and Whirlwind (Macintosh). The SDSC maintains an upto date list of all VRML browsers at their VRML Repository. This can be found at the URL:

<http://www.sdsc.edu/SDSC/Partners/vrml/software/browsers.html>

Reviews of the different VRML browsers, mostly for the PC platform, can be found at the following URLs:

<http://cedar.cic.net/~rtilmann/mm/vrml.htm> (Richard Tilmann)

<http://www.construct.net/tools/vrml/browsers.html> (Construct, Inc)

<http://cwsapps.texas.net/vrml.html> (Consummate Winsock Apps List)

4 Examples of VRML on the WWW

The aim of this section is to provide examples of how VRML is currently being used, principally in art and design. More examples can be found by following the links at the Web sites listed in section 4.3. Note that PC-based VRML browsers may have difficulty in displaying some of the larger, more complex worlds.

VRML models can be of real places and objects, or can be totally imaginary or abstract. Already, VRML is being used in a variety of ways, including scientific visualization (such as molecular models), entertainment, and home spaces. A home space is the 3D equivalent of the HTML home page, with hyperlinks indicated by objects rather than text or images. Home spaces can belong to individuals or organizations.

4.1 Art and Design Examples

Architecture

UCLA Department of Architecture & Urban Design

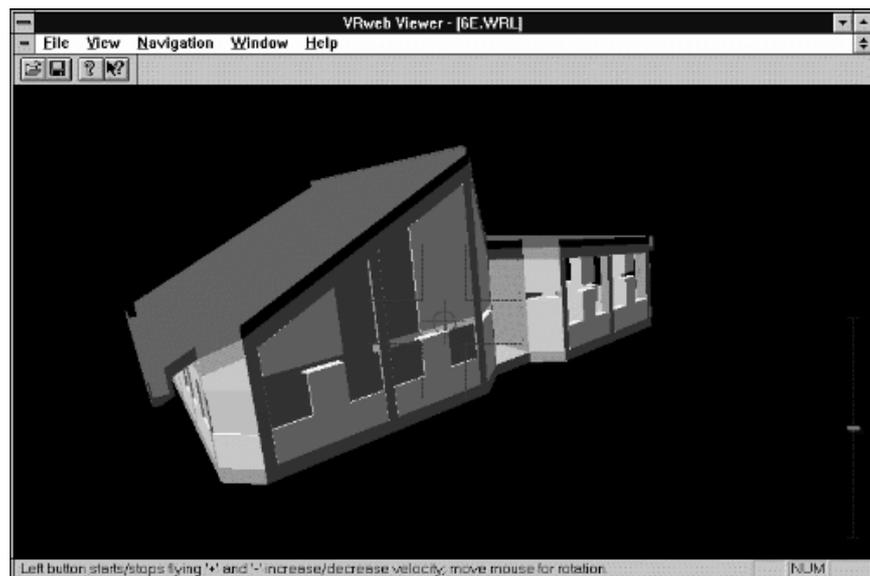
<http://www.gsaup.ucla.edu:80/vrml/>

This site contains many architectural models, converted from a variety of different formats, including Autocad DXF, 3DStudio and Lightscape. Most files are quite large, over a Mbyte in size, so may take a while to download. Figure 3-5 shows their model of the Equitable Building in Los Angeles, texture mapping is used for the detailing of windows, etc. The texture image is defined in-file.

University of Bath

<http://fos.bath.ac.uk/VRML/vrml.html>

The University of Bath has more models of buildings and urban areas, including a volumetric model of the City of Bath. The chair model in Figure 3-1 is from this site, as is the building in figure 4-1.



[Figure 4-1 A model from the University of Bath viewed with VRweb (for windows)]

Interior Design

Lightscape Technologies, Inc.

<http://www.lightscape.com/models.html>

This Web site contains a number a very realistic models of interior spaces. The scenes have been generated using the lightscape visualization software (which uses radiosity techniques) and then converted into VRML. Figure 3-3 shows their Jerusalem City Hall model. The VRML files are large, for example the Jerusalem model contains over 40000 polygons, and is 1.1 Mbyte in size when compressed.

Industrial Design

Grundig Corporation

<http://www.asia-online.com/corporate/grundig/>

Grundig uses VRML to advertise some of their electronic products. Figure 4-2 shows a model of their PA1 (MAX) hi-fi system. (199kbytes compressed).



[Figure 4-2 Grundig's PA1 (MAX) System]

Ceramics

Virtual Ceramics Gallery

http://www.bekkoame.or.jp/~inoue_k/VCM3.html

This Web site contains VRML models of several ceramic works created by Katsuhiko Inoue in Japan. Figure 4-3 shows a piece called the Gyokkoshun Vase (170 kbytes).



[Figure 4-3 Gyokkoshun Vase]

Fine Arts

Abulafia Gallery

<http://www.cgrg.ohio-state.edu/~mlewis/Gallery/vrml.html>

This is a virtual art gallery containing five recent oil paintings by Mathew Lewis. High, medium and low resolution models are provided to accommodate a wide range of computer systems. The medium resolution model is displayed in Figure 4-4. Each painting is hyperlinked to a HTML document containing a high resolution image.



[Figure 4-4 The Abulafia Virtual Art Gallery]

4.2 VRML Object Libraries

The VRML Object Supermarket

<http://www.dcs.ed.ac.uk/generated/package-links/objects/vrml.html>

This site contains an assortment of gzipped VRML models, ranging from bananas to buildings (the Barcelona Pavilion model shown in Figure 1-1 can be found here). All models are freely available and can be used within your own VRML scene. This resource is provided by the UK Virtual Reality Special Interest Group as part of its 3D Object Archive.

4.3 Lists of Links

VRML Repository (SDSC)

<http://www.sdsc.edu/SDSC/Partners/vrml/examples.html>

The VRML Repository has a long list of VRML examples, categorised under various headings. A good place to start looking for more models.

Virtual UK (A. L. Digital Ltd.)

<http://www.algroup.co.uk/main/vruk>

VRUK is a virtual map of the United Kingdom, containing links to VRML models that represent real sites.

5 Creating VRML Worlds

5.1 VRML Modellers

The example in section 2 shows that it's quite possible to create a VRML world just using a text editor. However, to build more complex scenes, modelling software will be required. There are currently about a dozen or so different software packages that can create VRML worlds. This number is likely to increase as VRML becomes more popular.

There are basically two types of VRML modellers, object builders and scene assemblers. An object builder enables the user to create arbitrary shapes interactively and then export the geometry in the VRML format. These packages usually support other 3D file formats as well. ClayWorks (Tim Lewis, Lancaster University) and Ez3d (Radiance Software International) are examples of object builders. A scene assembler allows the user to assemble 3D objects into VRML scene, and include hyperlinks, inlines and Level-Of-Detail. WebSpace Author (Silicon Graphics), Fountain (Caligari Corporation) and Virtual Home Space Builder (ParaGraph International) are examples of this type of software.

A hyperlinked list of VRML modellers can be found at the SDSC VRML Repository.
<http://www.sdsc.edu/SDSC/Partners/vrml/software/modelers.html>

5.2 Geometry Translators

There are a number of different tools available for converting models from other commonly used 3D file formats (such as Autodesk's DXF, 3DStudio and Wavefront) into VRML. This section describes six such tools, four are programs which are freely available via the internet, and the other two are Web sites which provide a public conversion service.

obj2wrl (John Moreland, SDSC)

Obj2wrl is a PERL (Practical Expression and Report Language) script which reads a Wavefront OBJ file and outputs the geometry in the VRML format. The program is available at the following URL:

<http://www.sdsc.edu/EnablingTech/Visualization/vrml/tools/obj2wrl/help/obj2wrl.html>

3DStudio R4 to VRML Converter (Autodesk, Inc)

Autodesk have produced an IPAS module which converts 3DStudio models into VRML. The module allows the user to attach WWWAnchor links to objects and include WWWInlines. The IPAS routine will only run under 3DStudio Release 4.

<http://www.autodesk.com/prod/mm/vrmlconv.htm>

ivToVRML (Silicon Graphics, Inc)

This is a command-line program for the SGI platform which converts Inventor files into VRML. Silicon Graphics also provide translators which convert DXF, stereolithography (SLA), OBJ, Alias, Softimage, IGES and 3DS files into the Open Inventor format. So to convert, let's say, DXF into VRML, one could use DxfToIv and then ivToVRML. More details about SG's translators can be found at:

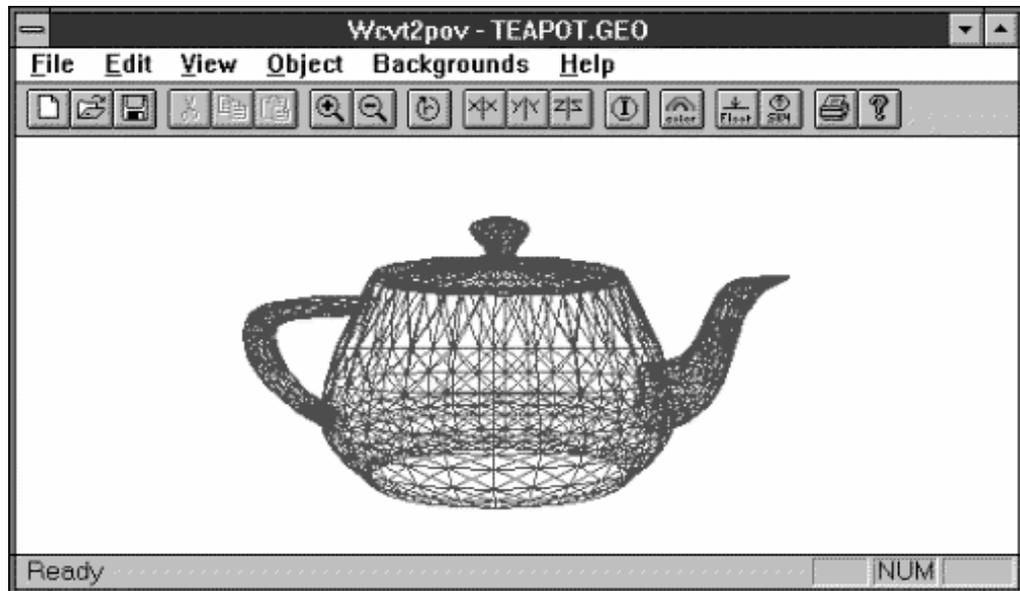
<http://webpace.sgi.com/Tools/index.html>

WCVT2POV v2.6 (Keith Rule)

WCVT2POV is a Windows application that converts between many different 3D file

formats. VRML is just one of the formats it can export. Formats that it can import include DXF, 3DS, Neutral File Format, OBJ, RAW triangles and TrueType Fonts. It also displays the loaded geometry.

<http://www.europa.com/~keithr/>



[Figure 5-1 WCVT2POV]

Organic Online: DXF to VRML

Organic Online provide a public DXF to VRML conversion service. It requires uploading the DXF file to <ftp.organic.com>, waiting two hours, then retrieving the translated file using HTTP. Full instructions can be found at the URL:

<http://www.organic.com/vrml>

ORC Inc: 3D formats to VRML

The ORC public translator works in a similar way. But it can translate from Alias, 3DS, IGES, Inventor, SoftImage, SLA and Wavefront, as well as DXF. Full instructions are located at:

<http://www.ocnus.com/translate.html>

The VRML Repository has a complete list of geometry translators, it can be found at:

http://www.sdsc.edu/SDSC/Partners/vrml/software/geom_trans.html

5.3 Testing the Validity of the VRML

If you intend to put your VRML model on a Web server, it's a good idea to check that it conforms correctly to the VRML specification. A VRML browser may not be able to display the scene correctly if the file contains invalid VRML. There are currently two tools available for checking the validity of VRML documents.

vrmlint (Silicon Graphics, Inc)

Vrmlint is a program for SGI systems which checks files for invalid VRML. Any problems are reported. The software is available from the URL:

<http://webpace.sgi.com/Tools/index.html>

VRML Authenticator (Daeron Meyer, Geometry Centre)

This Web site contains a VRML authentication script. Enter the URL of the VRML model to be checked in the form, press the submit button, then any errors will be reported. The VRML Authenticator can be found at:

<http://www.geom.umn.edu/~daeron/docs/vrml.html>



[Figure 5-2 The VRML Authenticator]

6 Serving VRML Worlds

6.1 Configuring the Web Server

VRML files are made available on the WWW in the same way as HTML documents, using httpd server software. An updating of the server's configuration files to include the VRML MIME type, is the only change necessary. For example, for a CERN httpd server, the following line would need to be added to the httpd.conf file:

```
AddType .wrl x-world/x-vrml      8bit  1.0
```

Other types of server software will require different changes. Refer to the server documentation for more details.

6.2 VRML Optimization and File Compression

File size is an issue which needs to be considered when creating VRML worlds. When a VRML file is large, of more than a Mbyte let's say, many people will be deterred from viewing it. This could be because network transmission rates are slow, so downloading such a large file would take too long, or because the VRML browser and computer system cannot handle complicated models. There are a number of ways in which the size of a VRML file can be reduced and so made more acceptable for browsing on computers with different capabilities.

Use of WWWInline and Level-Of-Detail

Using inline objects can reduce the size of a VRML file quite significantly. For example, the Planet AGOCG scene in section 2 is described in only 43 lines, if however, the geometry of the Starship Enterprise was defined in-file instead of being a WWWInline object, then the file would be over 10,000 lines long.

When WWWInline is used in conjunction with the Level-Of-Detail feature, it allows VRML browsers to optimize their performance. Some VRML browsers, like WebSpace, implement on-demand loading, enabling the user to start viewing and exploring the scene before all the inline data been retrieved. When WWWInline is used with LOD, the least complex representation of the inline object will be loaded and displayed first. More detailed versions of the object will only be loaded if closer views are required. The browser can also use LOD as a hint, allowing it to automatically reduce scene complexity in order to match its rendering capabilities and make movement smoother.

The DATAFAT MUNGER!

The Datafat Munger is a PERL script by James Waldrop that reduces the size of a VRML file by removing excess precision from floating point numbers. It does this by taking all numbers down to 2 digits of precision, making very small numbers equal to zero, and also deleting unnecessary white space such as indents. The reduction in file size can be significant, especially for VRML files created using geometry translators. Polygon normals can also be removed, since the browser will determine them for itself. The Datafat Munger is available from:

<http://www.construct.net/vrmltools/datafat.html>

GZIP File Compression

Most VRML files on the WWW have been compressed using GZIP. GZIP is one of the GNU tools from the Free Software Foundation. It is widely used because it is freely available for most computer platforms, and can reduce the size of a VRML file by as much as 80 percent. The file extension for a gzipped VRML document is `.wrl.gz`. Most VRML browsers can now automatically decompress gzipped files.

6.3 Server-Side Scripting

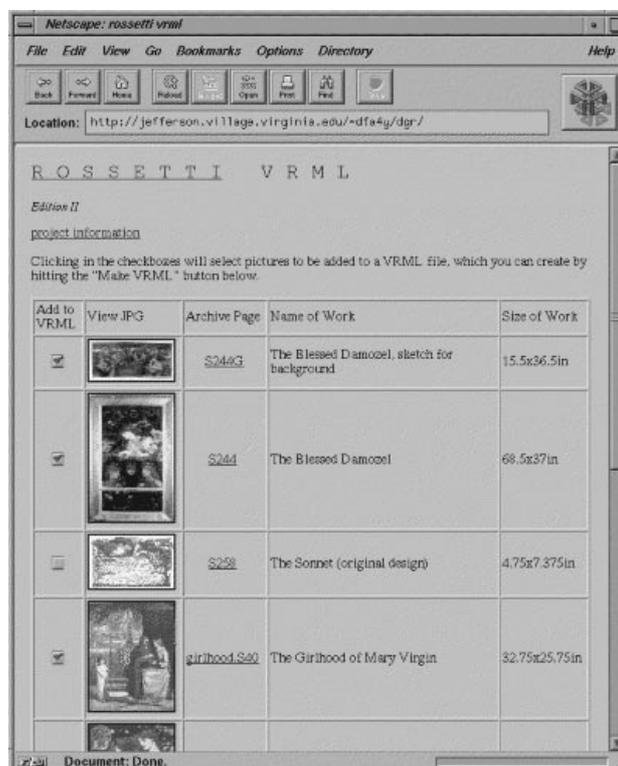
Like HTML documents, VRML files can be created on demand by programs running on the Web server, a process known as server-side scripting. The program or script is executed on the server when a Web client makes a request. The output from the program is then sent to the client.

An example of server-side scripting is the Rossetti Room which can be found at the URL <http://jefferson.village.virginia.edu/~dfa4y/dgr/>

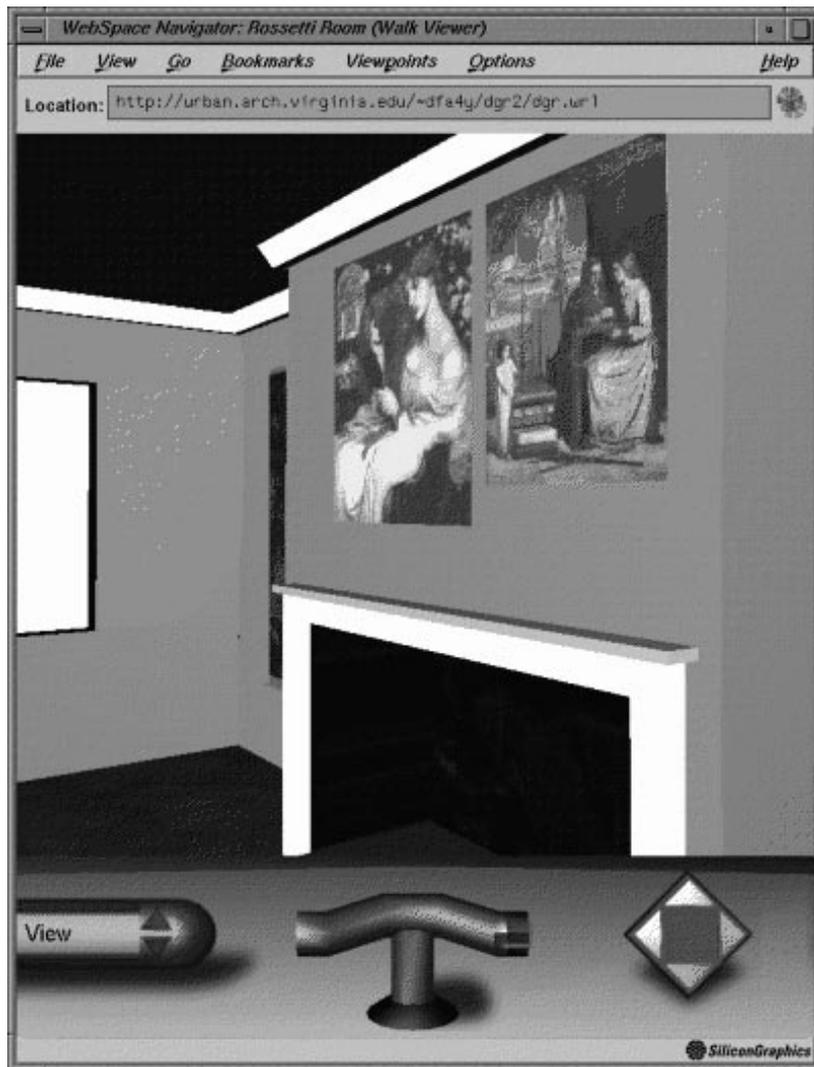
The Rossetti Room is a VRML model of the studio of the pre-Raphaelite painter and poet Dante Gabriel Rossetti. Users can select which paintings should be placed in the room, using the checkboxes on the HTML page, see Figure 6-1(a). The model is generated by clicking on the 'Make VRML' button. Figure 6-1(b) shows how the studio model appears when viewed with WebSpace. Each picture in the scene is also hyperlinked to a HTML page containing more information about the picture.

The PERL script which assembles the room can be examined at:

<http://jefferson.village.virginia.edu/~dfa4y/dgr/dgrvml.pl>



[Figure 6-1(a) Rossetti Room HTML Page]



[Figure 6-1(b) Rossetti Room VRML model]

7 Future Development of VRML

7.1 VRML 2.0

The Virtual Reality Modelling Language is still being developed and refined. The first version of VRML describes static worlds, you can move around them, but other than following the hyperlinks, nothing happens. However, there is a demand for fully interactive, multi-participant 3D environments. It is intended that with the next version of VRML it will be possible to create and view such worlds.

Features of VRML 2.0 will include:

- *Improved or new ways of describing the static 3D scene.* For example, to include nodes for defining terrain or backdrops and enable the use of URNs (Uniform Resource Names) as well as URLs for locating Web resources. Identifying inline objects by a unique name rather than via a location on a particular server, will allow local mirroring of commonly used objects and so speed up the loading of the scenes. At one time it was intended that these refinements were to be included in a VRML 1.1 specification, but it now looks as though this version will not be released, and the VRML 1.1 features incorporated into VRML 2.0.
- *Scalability.* In the future VRML browsers will need to be able to handle very large worlds composed of many VRML models. Currently all the VRML objects on the Web exist within their own discrete space, it would be better if they could be part of one continuous world, allowing the user to move between them spatially rather than via their URL reference. For this to be practical the VRML browser will need to implement on-demand loading and culling, which is already carried out to some extent by a few applications. The VRML 2.0 specification should be able to help the browser with this process.
- *Behaviours and Interactions.* In VRML 2.0 objects will be able to move and react when things happen to them. This implies a concept of time. In computer graphics objects are animated by scripts or programs, using iterative loops and 'if something happens do something else' statements. Different scenarios will require different programs or scripts. Therefore, VRML 2.0 will allow world builders to create their own interaction and behaviour scripts. These could be written in C, PERL or more probably Sun Microsystem's Java programming language. VRML will provide the Application Program Interface (API), the basic library of commands through which the interactivity takes place.
- *Multi-user Environments.* The scripting feature of VRML 2.0 will need to be able to support network operations, connecting various computers and users, in order to create interactive multi-participant worlds.
- *Extensibility.* Individuals or companies will be able to define their own prototype VRML objects or nodes.

The process of drawing up the VRML 2.0 specification is now under way. Interested parties, which now includes most of the major computer companies like Microsoft, Apple, Sun, as well as SGI, have been invited to submit their proposals for the standard. The relative merits of each of the proposals will be discussed on www-vrml mailing list. After a set period one of the candidates will be chosen as the basis of the specification through reaching a

consensus or by taking a vote. The first draft of the VRML 2.0 specification should be published by the spring of 1996. The VRML Architecture Group (VAG) will act as the focus during the debate. The home page of VAG is at <http://vag.vrml.org>. The role of the VAG as the standards body, may soon be replaced by the establishment of a more formal VRML Consortium.

7.2 Participating in the Development Process

If you are interested in the development of VRML then the main forum for debate and information is the **www-vrml** mailing list. To subscribe, email majordomo@wired.com. In the message body write:

```
subscribe www-vrml your-email-address
```

This is a heavily used mailing list, with sometimes many hundreds of messages a week, so the digest version may be more suitable. Instructions on how to receive the digest version and to unsubscribe from the list are sent when you join.

For more information about www-vrml go to <http://vrml.wired.com/>

Hyper-archives of the mailing list can be found at the following locations:

<http://www.eit.com/www.lists/www.lists.2.html>

<http://www.blacksun.de/contents.html>

7.3 More Worlds Needed

Whatever the outcome of the VRML 2.0 specification process, VRML 1.0 provides a solid foundation for creating and viewing three-dimensional worlds on the WWW. Although the number of VRML sites is increasing rapidly, people have only just started to discover what is possible. The infrastructure and tools are in place, now it's really up to the world builders to use their imagination and create. This report has provided a few examples of how VRML can be used in art and design higher education, but VRML has many more potential applications: as a method for the public exhibition of work, or in teaching and research, or as an art-media in itself. There are numerous possibilities.

Of course there are problems, such as the slowness of downloading some models, particularly from across the Atlantic, or the difficulties some VRML browsers have in viewing complex worlds and the fact that not all are fully compliant with the VRML 1.0 specification. But it does work, three-dimensional cyberspace is becoming a reality.

8 Further Information Sources

8.1 World-Wide Web

The **VRML Repository** at the San Diego Supercomputer Centre maintains a comprehensive range of information about all aspects of VRML. References to this site have been made throughout this document. The URL of its home page is: <http://www.sdsc.edu/vrml>

The **VRML Frequently Asked Questions (FAQ)** is a good starting point for learning about VRML. It can be found at the URL:

http://www.oki.com/vrml/VRML_FAQ.html

The **Yahoo Index** on VRML is at:

http://www.yahoo.com/Entertainment/Virtual_Reality/Virtual_Reality_Modeling_Language_VRML/

Wired's **VRML Forum** is available at <http://vrml.wired.com>

VRML World is a online magazine about VRML and other related topics from Mecklermedia. Go to <http://www.mecklerweb.com/netday/vrml.html>

Mark Pesce is the moderator of the `www-vrml` mailing list, his Web page contains a number of papers on the future development of VRML.

<http://hyperreal.com/~mpesce>

New College of California **vrmlLab**

<http://infopark.newcollege.edu:80/vrmlab/>

VRML at NCSA

<http://www.ncsa.uiuc.edu/General/VRML/VRMLHome.html>

VRML-O-Rama by Spidaman contains many VRML links.

<http://www.well.com/user/spidaman/vrml.html>

8.2 Mailing Lists

`www-vrml` is the main forum for all topics concerning VRML, see section 7.2 for more details on joining.

`vrml-modeling` mailing list discusses issues concerning the creation of VRML worlds. To subscribe to the list, send email to `vrml-modeling@sdsc.edu` containing the message `add vrml-modeling`.

`vrml-behaviours` discusses technical issues regarding implementing interaction and animation behaviours in VRML. To join this list, send email to `vrml-behaviours@sdsc.edu`, containing `add vrml-behaviours` in the message body.

Black Sun Interactive maintains an hyper-archive of all three of these mailing lists, it can be found at <http://www.blacksun.de/contents.html>

The Usenet news group **alt.lang.vrml** also discusses VRML.

8.3 Publications

The following two books on VRML are now available:

VRML Browsing and Building Cyberspace

Mark Pesce

New Riders Publishing, Indianapolis, USA, 1995

ISBN 1-56205-498-8

The VRML Sourcebook

Andrea L. Ames, David R. Nadeau, John L. Moreland

John Wiley & Sons, 1995

ISBN 0-471-14159-3

Since VRML 1.0 is based upon the Open Inventor format, the following book may be useful for reference.

Inventor Mentor

Josie Wernecke

Addison-Wesley Publishing Company, 1994

ISBN 0-201-62495-8

The standard reference book for 3D computer graphics is Foley et al. Glassner's book provides an alternative less mathematical introduction to the main concepts of 3D modelling.

Computer Graphics: Principles and Practice (2nd edition)

James D. Foley, Andries van Dam, Steven K. Feiner and John F. Hughes

Addison-Wesley Publishing Company, 1990

ISBN 0-201-12110-7

3D Computer Graphics: A Users's Guide for Artists and Designers

Andrew S. Glassner

The Herbert Press, London, 1989.

ISBN 1-871569-37-0

Books on the World-Wide Web and the Internet are filling up the shelves of book shops. However, the following SIMA report is an excellent introduction:

Running a World-Wide Web Service

Brian Kelly

SIMA Report Series, 1994

ISSN 1356-5370

An online version of this handbook is available at:

<http://info.mcc.ac.uk/CGU/SIMA/handbook/handbook.html>