3D Model Databases: The Availability of 3D Models on the World Wide Web.

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Abstract

Virtual Reality (VR) worlds or 'virtual environments (VE's)' that may be experienced must first be created using appropriate software. As in the real world, virtual environments are composed of a number of different entities or models which can be based on real or abstract concepts. Each individual model may be created by the user or imported from his/her own library or from a library provided by a third party. In this report, the initial concepts associated with object modelling will be discussed before being considered along with the requirements for the VR community. Issues that must be considered when importing a model are discussed and these include conversion between various 3D modelling standards and resolution of models in the VE. A number of sources of models on the World Wide Web are investigated and future standardisation and development trends are discussed along with the need for an AGOCG model database.

Table of Contents

1. Introduction

Virtual Reality (VR) is a revolutionary new technology that will allow users to interact with computers in entirely new ways. One of the great advantages of using VR technology is described by Leler (1995) as "...the high degree of synergy possible between the user (the occupant of or participant in the virtual environment) and the computer". When utilising a virtual environment the user has the ability to directly interact with and manipulate data in real time. Currently, there is a great deal of VR research being carried out indicating the diversity of the potential applications that this technology may have.

For the purposes of this report, applications related to VR as a tool for the facilitation of higher education will be considered. A detailed review of this area can be seen in Kalawsky (1995). In summary, Kalawsky indicates a number of areas where VR techniques may prove beneficial when compared with established methods. These include:

- Simulation of complex systems.
- Macroscopic and microscopic visualisation.
- Fast and slow time simulation.
- Allow high levels of interactivity.
- Allow a sense of immersion.
- Inherent flexibility/adaptability.

There are a number of possible uses of such environments in higher education i.e. as simulations, representations and training tools.

The virtual environment that is experienced by the user must be created using the necessary software. A number of different types of software may be used in developing the environment and this procedure can be broken down into three main areas:

i) Modelling

As in the real world, a virtual environment is composed of a number of different entities or models. Van Dam and Sklar (1990) define a model as "..a representation of some (not necessarily all) features of a concrete or abstract entity". Each may have different geometry (size and shape), surface appearance (texture and material type) and may behave in an individual manner (in terms of physics, dynamics and properties). In the virtual environment, however, the model can be based on a real physical entity or a totally abstracted concept. The initial stage of authoring involves creating the models that will be used in the environment. This is generally achieved using modelling tools, but CAD tools may also be used. As Kalawsky (1995) indicates "...the creation of virtual objects represents a significant investment in time", suggesting that any technique to reduce this time such as the ability to import/export models between systems or reuse them in different environments would be highly desirable.

ii) Creating the virtual environment

An environment may contain a number of models with various behaviours. The relationships between the objects may consequently become very complex. For example, if two moving objects meet in the environment what is the result? Will a collision occur when the boundaries of each model intersect? Will the two objects bounce off each other or will they coalesce? Will the shape of the objects be changed by the impact? Will their trajectories be modified following the impact? If one considers that this scenario may occur many times with many objects it is clear that creating the environment is extremely time-consuming and involved.

iii) Run-time environment

At run time the virtual environment software is executed by the host computer. This execution may occur on a number of levels. If the environment is simple, it may just allow the visualization of a model that has been created. On a more complex level it may combine the visualisation with some animation that has been attached or may even combine the geometry with behaviours and allow interaction between objects and also between the user and the environment.

1.1 Purpose of report

The purpose of this report is to provide information about the use of 3D model databases for members of the AGOCG user commumity and the wider community interested in utilising VR techniques in higher education. For the purpose of this report it is necessary to assume some basic understanding of VR techniques and it will concentrate on areas that are felt to be particularly relevant to the educational domain. It is not the intention of this report to concentrate on hardware issues and for a detailed review of this area please see Kalawsky (1993, 1995) and Youngblut, Johnson, Nash, Wienclaw and Will (1996).

The main objectives of this report are:

- To provide an overview of object modelling considerations for VR applications.
- To detail current formats and model composition.
- To detail the requirements that the VR community may have with respect to the definition and distribution of virtual models.
- To highlight the issues which must be considered when importing and exporting models.
- To identify a number of model databases that may be available on the internet and to relate these to specific modelling packages.
- To consider future developments in the area of model definition and distribution.

1.2 Scope of report

To achieve the purpose of the report described above, it will be necessary to examine several areas.

The report will initially concentrate on object modelling. Furthermore, a list of current file formats will be presented and the composition and structure will be discussed.

The requirements of the VR community will then be investigated. This will include a review of current object modelling packages, CAD systems and behaviour models. In addition, relevant data converters, translators and filters will be reviewed.

Issues arising from these requirements and the current formats that are available will then be reviewed. These issues include conversion between standards, resolution, performance issues, cost of support and intellectual property rights with respect to model ownership and liability issues.

In section 5, sources of model databases will be discussed with particular reference to the world wide web. A number of sites will be reviewed that represent a range of different modelling systems.

In the final section, future trends will be discussed. These will include attempts to standardise systems including STEP and VRML and also future developments in development tools and techniques such as 3D scanning and input of models. The need for an AGOCG model database will also be considered.

2 Current Object Databases

A list of file formats was downloaded from Brian Kaplan's page at Indiana University. This list has been edited to detail the most popular modelling packages currently in use. A complete list of formats can be seen in Appendix 1.

2.1 Some Popular Current Formats (including CAD)

3DMF (3D Metafile)

Extensions:	3dmf
Creator:	Apple
Viewers:	Used by the Quickdraw 3D package from Apple.
Programs:	Quickdraw 3D

3DS (3D-Studio)

Extensions:	3ds
Creator:	Autodesk
Description:	Used by the AutoDesk 3D-Studio modelling, rendering and animation package on the PC. The 3DS format consists of chunks which describe what information is to follow, its ID, and the location of the next main block. This allows filters to skip chunks they don't recognise, and allows for extensions to the format.
Programs:	AutoDesk 3D-Studio

DVS

Extensions:	viz, biz, vtx
Creator:	Division Ltd.
Description:	Used by the dVS package from Division Ltd.
Programs:	dVS

DXF

Extensions:	dxf
Creator:	AutoDesk, Inc.
Description:	Used by AutoDesk's AutoCAD and other CAD packages.
Programs:	AutoCAD
Filters:	Filters are available to convert to and from the following formats: NFF, POV-Ray, Polyray, Vivid, Rayshade, RTrace SCN, Art, QRT, REND386 PLG, Renderman RIB, AutoCad DXF, Radiance RAD, Wavefront OBJ, and RenderWare RWX.

FLT (OpenFlight Format)

Extensions:	flt
Creator:	Multigen
Description:	A 3D format from Multigen The OpenFlight format is a binary format used for input and output by the MultiGen and ModelGen database modeling tools produced by MultiGen. It is used mainly for flight simulation.

Programs:	MultiGen, ModelGen

Inventor

Extensions:	iv
Creator:	Silicon Graphics
Description:	Used by Silicon Graphics IRIS Inventor 3D graphics toolkit.
Programs:	IRIS Inventor
Filters:	Source code for a filter which reads the Inventor format comes with IRIS Inventor in the libpfdb/libpfiv source directory.
Viewers:	There is a program called ivview that is available on SGI machines and is written using Inventor libraries.
Other information:	Inventor format is a superset of the VRML networked graphics data format.
See Also:	VRML format

OBJ

Extensions:	obj (for ASCII), mod (for binary)
Creator:	Wavefront/Alias Technologies
Description:	Used by the Wavefront suite of commercial high-end animation packages.
Programs:	Wavefront
Filters:	The SPD (Standard Procedural Database) package is available and now contains filters to convert to and from the following formats: NFF, POV-Ray, Polyray, Vivid, Rayshade, RTrace SCN, Art, QRT, REND386 PLG, Renderman RIB, AutoCad DXF, Radiance RAD, Wavefront OBJ, and RenderWare RWX.
Other information:	A Postscript version of the specifications with graphics is also available.

2.2 Composition/Structure

In a geometric model, the component parts are represented by primitives such as lines, circles and polygons. However, modelling is not straight forward as many of the objects that need to be represented are very complex. For example to model a human requires a large amount of geometric detail and body parts move in an extremely complex manner. This is further complicated by the fact that different application fields will have different requirements for the body model. A body model developed for real-time VR may be of little use in a biomechanics application. 3D modelling software such as MultiGen (MultiGen Inc.) uses geometry, hierarchy and attributes to describe objects in three dimensions.
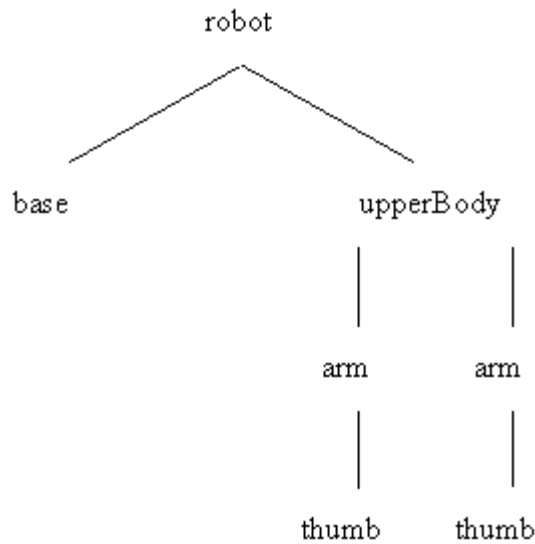
2.3 Geometry

The geometry of the model describes the data structures that represent the object shape and the computer algorithms that construct and manipulate these structures.

The geometric modelling technique can be divided up into two main areas, primitives and structure.

Structure

One of the most popular concepts that is used by many packages (such as MultiGen) is hierarchical data structuring. This method uses a tree-like structure to represent data in the object.

A good example of tree-like structure is provided by Foley, van Dam, Feiner and Hughes (1990) and can be seen in Figure 1 below.

```
                        robot
                       /     \
                  base        upperBody
                              |        |
                             arm      arm
                              |        |
                            thumb    thumb
```

Figure 1 Example of a tree hierarchy for a simple robot (From Foley et al., 1990)

Thus it can be the seen that the robot is effectively an upper body which can rotate on a base. Attached to the body are two identical arms to which are then connected to primitive "hands" with a "thumb" gripping device.

Consequently, the structure provides an intuitive way of ordering components in the model. In addition, the structure also provides an effective way of moving either the whole model or a component. For example, if a translation is applied to the root node of the model all of the sub-nodes must consequently move. If one applies a transformation to a node lower down in the structure, only it's sub-tree will be affected. For example, it can be seen from the robot structure that moving the body will cause both arms to move and consequently, both thumbs whereas, if only the left arm is moved, only the lower nodes (the left thumb) must also be moved.

Another commonly used technique is that of *instancing*. In many modelling examples there is a situation where the same model is required a number of times. For example, if one considers a model of a dining table in a room that has a number of chairs associated with it. Each chair will be identical to the others, and if one considers that there may be six or eight chairs, it is obviously inefficient to have to draw this number of chairs. In addition, there are other drawbacks. If the modeller decides to modify the chair, to change the cushion colour for example, the operation must be carried out on all the chairs. Similarly, creating a large number of models magnifies the possibility that errors will be made, resulting in differences between the geometry of the chair models themselves.

To overcome this a master version of the chair model geometry is created, and each time the object is required an instance of the master is generated. The instance basically points to the master model which means that all the versions are updated at the same time as the master. Many graphics packages will now support both these techniques, and they are commonly used in virtual environment construction.

Polygons

The most common primitive used in 3D modelling is the polygon. Green and Sun (1995) describe a polygon as "...a boundary of a 3D plane, where the boundary of this region is specified by a list of vertices." A polygon is effectively specified by a list of vertices that define the polygons region. A number of polygons can then be combined to represent the object to be modelled. The more complex and accurate the object, the more polygons that will be required to model it.
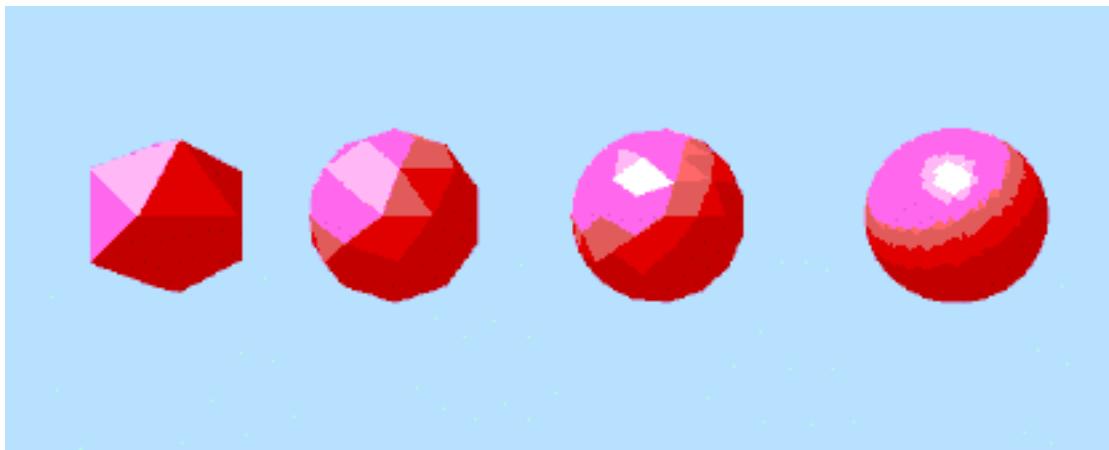
>**Figure 2** Four flat shaded spheres rendered by MultiGen. From the left, they are comprised of 20, 80, 180 and 2880 polygons respectively.

The greater the number of polygons in the model, the greater the computational effort that is used to generate the image. This is of particular relevance to virtual environments, where the display speed of the object is the highest priority.

However, compared to other primitives, polygons are relatively easy to display, have efficient display algorithms and they are easy to specify, simply by providing a list of vertices. They are also good for modelling flat faces and are well understood due to a large body of research associated with their use. Unfortunately, polygons are not particularly good for modelling curved faces and require a large number of polygons to do so. This is time consuming, and has an associated computational overhead. To overcome this problem most VR systems employ shading techniques, based on the relative position of external light sources. With careful shading, an object with a relatively coarse surface can appear smooth.

Curves and surfaces

These primitives provide a more accurate method of representing objects that have curved surfaces. Curve primitives are based on parametric polynomials and surfaces can be represented using bivariate polynomials. Many types of curves and surfaces have been developed, and the mathematics behind the concepts is far more complex than that of polygons. However, curves and surfaces, in addition to providing greater accuracy, also reduce the number of primitives required in a complex model. This means that the model can be processed more quickly and decreases the amount of storage space it requires. Unfortunately, the display algorithms for these primitives are not as efficient as those for polygons and are more complicated , making the programming and de-bugging more difficult. Furthermore, these primitives are not as widely supported as polygons, although sophisticated tools will allow them to be used to import models in to a VE system.

2.4 Level of detail

Frame rate is a pervasive concern in virtual environments. One of the most common factors which impacts on frame rate is *scene /model complexity*. Specifically, the number of polygons and complexity of textures in the draw cycle (see section 4.3) has a direct bearing on the time it takes to render the frame. Many VR systems enable the world builder to trade off model complexity and frame rate by introducing a level of detail (LOD) function. Each model may be assigned a number of LODs. Only one LOD will be displayed at any time. An LOD defines the amount of detail displayed. For example, in a driving simulator the driver may observe a car moving towards him/her on the horizon. The approaching vehicle is currently a long distance away from the driver, thus much of the detail in the car's model will be redundant. Here, a low level of detail will be employed (e.g. no textures, low polygon complexity). As the car approaches, more detail may be introduced. Finally, as the car reaches its closest point from the driver's viewpoint, the highest level of detail will be displayed (this may include environmental texturing for reflection effects and a smooth body defined by a relatively large number of polygons). Here we can see that the transition between LODs is typically defined by a combination of the size of the object and it's proximity in relation to the user's viewpoint.

LODs may be defined in many modelling packages (e.g. MultiGen) as well as most VR authoring languages (e.g. dVS, VRML 2.0). Some packages (such as MultiGen Pro) will partially automate the process of creating levels of detail by increasing/decreasing the number of polygons in the constituent primitives.

2.5 Accuracy

In an ideal world it would be desirable if models could be exact representations of their real-world counterparts. However, as Green and Sun (1995) suggest "...in reality accuracy comes with a price, usually increased display time or memory usage." Accuracy is therefore, application dependent. In a VR simulation it may be possible to represent a sphere as a limited number of polygons (see Figure 2), whereas, in a CAD application, a precise representation may be required. This suggests that models created in CAD packages may not be suitable for use in virtual environments, where the ability to display models quickly is of primary importance.

3. Requirements for the VR community

Virtual environment modelling presents a number of challenges that are not evident in traditional CAD. Firstly, a virtual environment may contain a wide range of objects. If, for example, one is generating a virtual environment of a small town, it is apparent that a great number of different objects must be created for the representation to be both interesting and believable. In CAD, one generally concentrates on a main object or a small number of objects. Another important difference in VE modelling is that objects in the environment will have their own, possibly complex, behaviours. These behaviours may also change in response to real time events such as collisions. In CAD objects are generally stationary, or will only have simple motions such as rotations. A further addition is that the objects in the environment must also be able to interact with the viewer. This can occur when the user collides with the model. For example, if one presents an object, such as a tree, that collides with the avatar model it would not be appropriate for the viewer to be able to walk through the model. Similarly, one of the great strengths of VEs is the interaction between objects and the user. The user should be able to manipulate various objects within the scene by 'picking' them and moving them at will.

All of these additional facets place extra demand on the modelling software and techniques that must be used. Of particular relevance here is the idea of reusability. This idea suggests that objects can be used in a number of environments, which means that it must be possible for the model to be easily extracted from the environment, and that standard ways of recording and transmitting the objects are used. These ideas suggest that hierarchical modelling techniques are the most appropriate for use in VEs. A further consideration is that the modeler must be aware of the behaviours that may be required when modelling the object. This is clearly an area that cannot be catered for if one is using models obtained from a database.

3.1 Solid Modelling

There are a wide variety of modelling packages available. Different flavours offer support for different applications. These are classified below.

Product design

Traditional CAD systems were developed to support the product design lifecycle. As a result, the emphasis was on model accuracy. Modelling was traditionally carried out in wire-frame, orthographic projection, with the results being explicitly rendered by the user for clarity or presentation purposes. CAD packages tend to make use of splines for modelling surfaces. As stated previously, this may not be desirable for current simulation systems, which rely on hardware rendering of polygons for performance.

AutoCAD, Pro Engineer and CATIA are typical examples of traditional CAD systems.

Presentation

A variation on the traditional CAD package has been widely used to develop virtual environments for presentation purposes (e.g. Motion pictures, television advertisements, etc.). These packages tend to include features for animation and high definition rendering (e.g. ray tracing and radiosity). Again, the models can be either polygonal or spline based. Like traditional CAD models these models are not necessarily designed to work in real-time. Animations are recorded by stop frame recording techniques, similar to those used in traditional animation. However, the emphasis is on the ascetic whereas in CAD the emphasis is on accuracy. For example presentation packages use photographic textures to enhance the realism in the scene. Alias Wavefront and 3D Studio are popular examples of such a system.

Real-Time Simulation

There are a number of packages which enable the user to develop models for real-time simulation applications. The models are polygonal and optimised for performance. The hierarchical organisation of the object database (see section 2.3.1) enables the user to optimise the model in terms of the graphics pipeline (see section 4.3). In some systems the interface enables the user to view a perspective (or parallel) view of the environment in

real-time. The models can be rendered as solid gouraud shaded, textured polygons during the modelling process. Systems may include a number of different features tailored to the simulation community. For example, smoke trains for aircraft and road building interfaces for driving simulation. The success of these features depends on the level of support offered by the conversion software included with the VR development package. MultiGen and Medit are popular examples of real-time simulation model development packages.

As the performance capacities of current hardware improve, so these three application areas will begin to merge. Already CAD packages are offering walkthrough software, where the user can develop a high definition rendered animated walkthrough featuring the product. Simulation modelling packages offer limited hierarchical animation. There are still multiple formats within each of the categories, but attempts are being made to establish standards (e.g. OpenFlight). It will certainly be some time before a standard is developed which bridges the gap between all three application areas. The main problem being the representation of the surface. Whether that is spline or polygon based is currently determined by hardware restrictions.

One of the major features of a modelling package is the interface. The ability to render shaded and textured surfaces in real-time enables the user to intuitively visualise the scene content. This will inevitably improve across the product range as hardware performance increases. Currently modelling packages are largely tied to 2D interaction devices (mouse, digitising tablet etc.). As the technology associated with 3D interaction devices matures, there will inevitably be a migration to these devices. With this, there will be a merging of modelling packages and VR development languages. This is likely to be managed by a visual programming philosophy which will enable the user to build up a world in one process. World building design methodologies will need to be established to support this.

3.2 Behaviour models

Although some of the techniques developed in computer animation are of use to designers of virtual environments, much of the VE research carried out so far has concentrated on geometrical techniques. Computer animation techniques may be applicable if one considers that objects must be able to move in a realistic way and change their physical state.

The major issue associated with these ideas is that in the VE, the creator does not have total control over events, unlike an animation, where the animator can decide exactly what will occur.

In the VE the behaviour of an object is not determined in isolation, but is the product of a complex interaction of environmental influences. These influences include the boundaries of the environment itself, static and dynamic objects within the environment, and the obstacles and unpredictable events that may occur. All of these factors will have an influence on the objects motion and must be considered when the motion is specified.

4 Issues

There are a number of issues that must be considered if one is to import a pre-designed model for use in a virtual environment.

4.1 Conversion between standards

Currently, with the distinction between development packages and modelling packages, conversion needs to occur across both standards and platforms. Currently, conversion between established modelling standards and from modelling packages to different development languages is relatively straight forward. However, there are more problems involved in converting back to the modelling package standard from the development language. This is typically due to the added functionality introduced by the development language. Furthermore, it is important to establish conversion between development languages. Due to the disparate manner in which development languages have evolved there is currently very little conversion at this level.
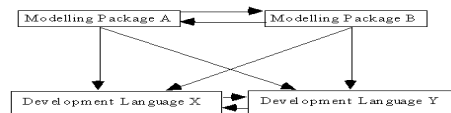
Figure 3. Conversion between standards.

4.2 Resolution

The resolution of the model can be addressed in terms of behaviour and solid model complexity. Essentially the resolution of a model is linked to the fidelity of the representation. For the solid model this may be how accurately the surfaces are modelled or how many of the components of the actual object are included in the model (e.g. is the engine included in a model of the car?). The behaviours can be similarly addressed in terms of complexity. For example, when considering the vehicle dynamics model of a car for a driving simulation the designer must consider a number of different aspects of its behaviour. Namely ride, handling, steering and braking. Models may be developed with different resolutions for each of these components. Obviously, the higher the resolution the more realistic the model. Resolution across models is tied largely to application requirements and hardware performance.

4.3 Real Time performance issues

Many of the current graphics workstations have a high performance graphics pipeline built into the hardware architecture of the system. Typically a graphics pipeline is a 3 stage process: Application, Cull, Draw. This is carried out once per frame. The Application process sets up the scene graph from the current state of the model database. The Cull process traverses the scene graph to determine which elements of the scene graph lie within the viewing frustum. Finally, the Draw process draws the scene to the current viewpoint. Many systems have multiple pipelines for multiple displays (e.g. stereo headsets, multiple projector systems). By examining the model database with respect to the graphics pipeline the designer can appreciate where performance trade offs can be made.

Some issues in terms of real-time performance are:

- Polygon Count. Evidently the more polygons the system is asked to render in a Draw cycle the slower the frame rate. Most graphics workstations render gouraud shaded polygons in hardware. It is usually possible to find a specification for this in the machine's associated documentation. Graphics cards are now available for PC platforms which will also render shaded polygons in hardware. Some systems (e.g. dVS) will run optimisation procedures on specific models, in an attempt to maintain a reasonable frame rate.

- Texture size. Textures can be stored in a separate high speed texture memory. Texture memory is limited in size (typically in the order of <100Mb), so performance limitations can occur when textures are being swapped in and out of texture memory. It is important to establish the correct size for a texture (conserve memory, but retain detail). Here the designer must trade off resolution and performance. Some systems (e.g. dVS) force the dimensions of textures to be multiples of 2, so as to make efficient use of the space available in texture memory.

- Level of Detail. Efficient use of level of detail can reduce the polygon count in any one Draw cycle.

- Model Hierarchy. A flat hierarchy will entail a long Cull process. If the hierarchy is spatially organised then there can be a significant performance payback. Some modelling systems allow the user to associate bounding volumes with groups of objects to tell the Cull process that all the objects exist spatially within this volume.

- Fog/Haze effects. Fog and haze effects can be introduced in hardware. For large models this can reduce the number of polygons to be drawn.

- Billboarding. Many development packages employ billboarding techniques to minimise polygon count. Consider the representation of a forest in a virtual environment. Even if the developer uses instancing based on a template tree, the number of polygons involved in producing a believable tree model is likely to be prohibitive. Billboarding enables the developer to represent a solid model by applying a texture (e.g. photograph of a tree) to a single polygon. The polygon, when billboarded will rotate so that it is constantly facing the user, giving the impression of a solid object. World builders have found this to be a very powerful function for representing features of the environment which make up the background.

- Partitioning (Zoning). Many development packages enable the world builder to partition the virtual environment so that the system is concerned with only part of the world at any time. Zones may be defined spatially (e.g. different rooms in a house constitute different zones) or functionally (e.g. The exterior of a car is defined in one zone, the driver's interior in another and the engine in a third). The system can switch zones on and off at appropriate times (e.g. as the user leaves room1 to walk into room2, room2 is turned on and room 1 is turned off). Zoning is a very powerful tool in maintaining an efficient virtual world.

4.4 Intellectual Property Rights with respect to model ownership

The copyright issues associated with the production of software such as 3D models is, in this sense , identical to that of producing documents. The producer of the model is, therefore, the sole owner of the copyright and can limit the distribution of the model as they wish. Several sites investigated in the course of this report place very specific limitations on the use of their models. Some indicate that models may only be used for personal work and cannot be passed on freely, sold or incorporated in other work that may be sold. The sites indicate that any other usage other than personal must be approved by the owners. What is less clear is the situation on sites where stipulations are not laid down. In these cases, it is not clear whether the authors are placing any limitations on the use of their objects, and as such, whether any copyright limitations are then present.

5. Sources of model databases

To determine the availability of model databases on the World Wide Web (WWW) a search was carried out. The search was carried out on a number of Internet search tools including Lycos, Infoseek, Altavista and HotBot using the search strings "3D Model Databases" and "3D Object Archives". Where it was possible, the search was carried out with the string used as a phrase rather than as separate words to limit the number of 'hits' that were detected. A number of links were also followed from other web sites. In particular the VR-SIG links and the Ultimate 3D Links site were used. A review of the databases found can be seen in section 5.1 below.

Sources on the WWW

The following review represents the number of model databases found on the WWW during a search carried out in November 1996. This review can not be said to be comprehensive due to the very nature of the WWW itself but represents what is believed to be a cross section of models available for a number of different platforms. Again, due to the vagaries of the WWW it can not be said that these models databases will be represented in the same format as they are at the time of writing. Many will change on a daily or weekly basis, some (especially the smaller sites maintained by an individual) will cease to exist and some may change locations. The purpose of this review is to give some indication as to the location, number, type and variety of objects that are available for download.

A Review of Model Databases on the World Wide Web

1. *The UK VR-SIG Object Archive*

   This archive is maintained by Martin Reddy for the UK VR Special Interest Group and is probably the most comprehensive object archive in the UK. Central to the archive is the object supermarket where the objects reside. Objects are held for a number of file formats including:

   - AutoCAD (.DXF)
   - VRML (.WRL)
   - Division Dvs (.BIZ)
   - Open Inventor (.IV)
   - REND386 (.PWG)
   - RenderWare (.RWX)
   - WorldToolKit (.NFF)

   There is also a link to the VR-Art Virtual Gallery.

   A wide variety of objects are available for all the file types including vehicles, shapes, room interiors and molecular models. There is also great variation in the size of the object. For example, Division DVS models range from 1K to 8749k in size.

   One of the major advantages of this site is that in most cases the user can choose to view the object as a 2D bitmap (.BMP). This means that the correct object can be selected before the downloading commitment is made.

   The site also contains a number of converters to allow the user to change from one file format to another (for example Autocad (.DXF) to Open Inventor (.IV)). Furthermore, there is information on file formats, a search tool, a list of other useful web sites and archives, software information and a facility for the user to upload their own models so that they can be placed in the archive.

2. *The 3D Studio Object Archive*

   This title is used as there appears to be little in the way of information on the site. It appears that the archive is maintained at the University of Dusseldorf although no names or contact numbers are provided.

The actual archive itself consists of 605 models for the 3D Studio file format arranged in alphabetical order which range from objects such as ants to anvils to star trek vehicles. No thumbnail images are viewable so it is not possible to view the object without first downloading it. Objects in the archive range from less than 1Kbytes to 570Kbytes in size.

3. *Viewpoint Data Labs*

Viewpoint Data Labs of Utah maintain a large commercial web site that offers a number of facilities. The basis of the site is a large reference library of over 5000 3D objects that can be viewed and purchased by the site user. Viewpoint indicate that the objects are available in over 75 formats and in varying resolutions. The "Gold" collection contains objects of medium resolution which are generally comprised of less than 10,000 polygons and the "platinum" collection comprises objects of high detail and resolution. The objects are grouped by category rather than format and the categories include US cars and trucks, military and space, internal and external anatomy and geography. In addition there is also a "limited edition" set of collections grouped under the headings air power, real time graphic games, NURBS, earth imaging, 3D USA and Magellan geographix.

Viewpoint also offer a vis/sim database of models optimised for real time work. These models can be obtained in ascending order of cost as geometry only, geometry and textures or geometry, textures and two levels of detail.

There is also the facility at Viewpoint to acquire a number of free objects, including 105 VRML models, by registering with them and obtaining a password.

4. *The Avalon Archive*

Viewpoint, since June 22nd 1996, also now maintain the Avalon Object Archive. In comparison to the Viewpoint site, however, all the objects available here are free to download. From the home page the user is invited to enter the site by clicking on one of four portals. These portals reflect the main site at Viewpoint and three mirror sites located at Washington University (FTP Site), Prague and Italy. While reviewing these sites for this report, access was found to be slow to all sites.

Again, the main area of interest at Avalon is an archive of 3D objects which can be downloaded freely by the site user. The objects are, in a similar way to the Viewpoint site, grouped by category rather than by file type. There are fourteen categories of objects including aircraft, anatomy, plants, space and water craft. To review a list of these objects it is necessary to click on the category and a text description of the models under that category will appear. Some objects can also be viewed as 2D images (if a "th" appears beside the text description) whereas many can not. Clicking on the text description will bring up the file type, size, a thumbnail image (if available, see Figure 4 below) and the author of the object.
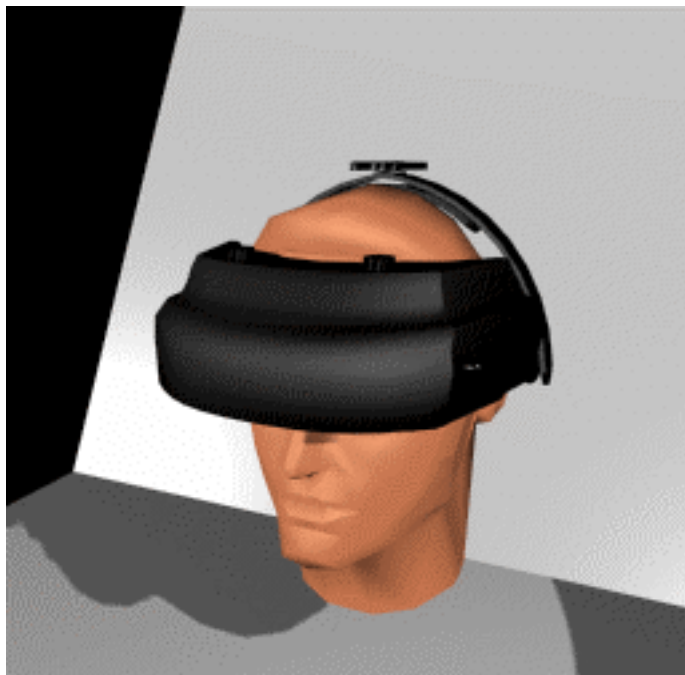
Figure 4. A typical thumbnail image from the Avalon site. This is the 2D image for the VR Head Mounted Display Model.

It would appear that most of the objects in this archive are in 3D Studio file format although some Wavefront files are also available.

In addition to the sites collection of objects there are also a number of other useful facilities. The site also makes available forty six data translators that allow conversion between various file types. Examples include translators to convert from AutoCAD (.DXF) format to 3D Studio (.3DS) or Inventor (.IV). A list of format specifications for a number of packages is available for download as are various compression utilities (such as WinZip and PKZip) and a number of useful 3D Studio utilities. An upload facility, to allow authors to include their own models in the archive, is also provided on a very comprehensive collection of useful information.

5. *Mesh Mart*

This site is maintained by Richard Tilmann and it would appear that it has not been updated since 1995.

The site basically mirrors the objects that can be found at Avalon, although all of those here have a thumbnail image that can be viewed prior to download.

Has a limited tools and utilities page and a good library page.

6. *3D Cafe*

The 3D Cafe can be found located within the Platinum Pictures Productions commercial web site. The 3D Cafe markets itself as the " ultimate resource for computer graphic artists" and appears to be a mix between a commercial site and a free object archive. To enter the free archive one must first agree to a usage licence agreement. The free object archive contains objects in the following file formats:

3DS, PRJ, MAX, WRL, LW, LWO, LHA, COB, DEM and DXF.

Again, the archive is subdivided in categories rather than by file type, the nineteen categories including anatomy, computing, military and a rather novel horror section!

The objects for each category are displayed when the user clicks on the category name. It is difficult to determine the exact number of objects but the claim is made on the site that the 3D Cafe is the largest model library in the world. The user is also given the option of loading thumbnail images for the majority of the objects at this stage. A typical thumbnail can be seen below.

Figure 5. A thumbnail obtained from the anatomy section of the 3D Cafe archive. The object is entitled "Dominique riding a unicorn!".

7. *Model Masters*

Model masters maintain a small, mainly commercial site. The commercial libraries are divided into two main areas, an interiors library and a transportation library. The interiors library contains the type of objects one would expect to find in a house or office including various types of chair, tables, dressers and home sports equipment. The transportation library contains models of various automobiles (see thumbnail below), aircraft, trains and trucks.

Figure 6. A thumbnail of the VW Golf GTI model (8061 polygons) in the model masters commercial library.

These models are available in for purchase in 3DS, DXF, and LW file formats but are not available for free download.

There are a limited number (5) of models available for free download from this site. These models are essentially a subset of the interior models and are comprised of a sofa, a globe, a coffee maker, a light fitting and an exercise stepper. All of these models can be downloaded in any one of five formats (3DS, DXF, IOB, LW, OBJ, and HRC).

The site text also suggests that a further library will be available soon.

8. *World ToolKit Users Group Archive*

This FTP site is maintained by Terry Fong of NASA's Intelligent Mechanisms Group. As the name suggests, this site contains approximately 200 models, the majority of which are downloadable in Sense8 neutral file format (.NFF) readable by World Tool Kit but some files are also available in AutoCAD (.DXF) and Amiga Videoscape (.VID) formats.

The collection consists of objects such as simples shapes (various cubes etc.) through to more complex models such as cars, household objects and animals. The objects range in file size from 1K to over 600K but there are no thumbnail images that can be viewed so the user must download the model to view it properly. The text on the pages would also indicate that this archive has not been updated since 1993. Martin Reddy indicates that many of these objects are mirrored at the UK VR-SIG site.

9. *3D Eye Inc.*

3D Eye of Georgia, USA maintain a commercial web site.

Only three free models available in four formats. However, they do sell models and there are several thousand with thumbnail images that can be viewed on this site.

10. *Anders Viscontis*

Only four objects in COB format.

11. *Byte by Byte Soft FX Pages*

Limited number of models (11) for this format only.

12. *NewTek Lightwave Object Archive*

An FTP site containing a number of models for the lightwave format. There are approximately 60 objects available here, but no 2D images are available to view the models before download. A text index is provided, however, a section of which can be seen below.

FILE:	snubfigh.lzh	SIZE:	18810 bytes
DESCRIPTION:	This is a small space fighter I made in Modeler 3.0. It contains a scene file with the limited hierarchy intact.		

FILE:	geosat.lzh	SIZE:	54702 bytes
DESCRIPTION:	A detailed-multi object of a ComSat. LW3D format. Much of the surfacing already done.		

FILE:	vorlon2.lzh	SIZE:	55251 bytes
DESCRIPTION:	Vorlon Fighter, not to be confused with other Vorlon ships. Great object and scene file.		

Figure 7. A section of the index from the NewTek Lightwave Object Archive

13. *Flash Fire Designs*

A number of models for sale for the following file formats:

- Alias/Wavefront Alias/Wavefront OBJ
- Autodesk 3D Studio 3DS
- Kinetix 3D Studio Max MAX
- Impulse Imagine OBJ,IOB
- Caligari True Space SCN,COB
- New Tek Light Wave LWO,LW

No free objects though!

14. *Lava*

The Lava site contains fourteen downloadable architectural models. Some models are replications of existing buildings such as Lloyds of London and the Kitakyushu City Museum of Art, whereas others are the modeller's own designs. Each model can be downloaded in one or more of the following file formats:

DXF, DWG, 3DS, AVI, and WRL.

15. *3D-Active*

This commercial site contains 5 free downloadable objects in Apple QuickDraw format (.3DMF) with thumbnail images. The objects are a tricycle, microscope, key ring, lamp and spider.

16. *Acuris 3D-Models*

The Acuris site is a commercial site with a number of models that can be purchased by the user. There are also four models and some textures that can be obtained free. The current objects are a chair, an F-16 fighter aircraft, a Porsche car and a vase of flowers although these models may change on a monthly basis. These models can be obtained in the following file formats:

3DS, 3DMF(mac), DXF, DXFp(mac), and OBJ

In addition, it is also possible to purchase a number of data translators which can convert, for example, Autodesk 3ds to Wavefront OBJ, Open Inventor iv to Apple 3dmf and Wavefront OBJ to Autodesk 3ds. It must be stressed again, however, that these translators can not be downloaded freely.

17. *Aminet*

Aminet is advertised as the "the world's largest Amiga software archive" and is divided into a number of sections such as games, development software and hardware. The object archive is contained within the Graphics section of the web site and contains approximately 300 models. All of the objects are downloadable in the .LHA file format for Imagine. No thumbnail images are supplied for the models.

18. *Animotion*

Animotion provide the "Prop Shop" for users wishing to download 3D objects. Although the company offer a number of models for sale in the following categories:

Civil, People, Technology, Nautical and Miscellaneous

they also provide ten free objects that can be downloaded. This group contains objects such as a reception desk, a wall clock, a street light and a video wall. These objects can all be viewed as 2D images before download. Animotion stress, however, that these objects can be utilised in the users work but cannot be redistributed or resold in any form. All of the objects available, both free and for sale, are available in either .3DS, .DXF or both file formats.

19. *Bit Garden*

This is a small Japanese site of models created by Tatsuo-M. There are five free downloadable models, which can be viewed as 2D images, of a piece of cake, a plate, a fork, a fossilised rock and a pencil and vary in size from 54K (plate) to 720K (rock). These objects are available for the STRATA format.

20. *Caltech's RenderMan Repository*

The site will be of interest to anyone who uses the RenderMan interface. There are 10 free downloadable models on this site along with a link to a further repository of Star Trek objects. The objects include a light bulb, a mechanical gear animation and a teapot, all with viewable 2D images. The objects can only be downloaded in RenderMan file format (.RIB).

Also available on the site are shaders, texture maps and various other goodies that will be useful to those using this package.

21. *Cyberware*

The objects available from this site can be found on an FTP link from the Headus (metamorphosis) pages. Headus is a 3D scanning and digitising bureau based in Australia and appears to specialise in scans of human heads. There are six downloadable objects available from this site and they are called a hip, dino, fist, horse, isis and jasonhead. It is not possible to view 2D images of these objects so the user is committed to downloading before they can be viewed. File formats available include .3DS, .PLY and .OBJ although not all of the objects are available in all formats.

22. *Electric Streetcar*

This site is entirely devoted to establishing a collection of models of electric mass transit vehicles. Currently, it is possible to download 6 models of various tramcars used in the United States. These models can be downloaded in Lightwave, 3DS, Wavefront, Form Z and 3DMF file formats. The type 5 car is also available in VRML format.

Figure 8. A 2D image of the type 8 tramcar available at the Electric Streetcar model site.

23. *The Furniture Exchange*

As the name suggests the exchange is a repository for models of interior furniture. It is maintained at Ball State University by J. Bieszke of the College of Architecture and Planning. There are six models by different authors that can be downloaded at this site including three chair designs , a bookcase, a desk and a display stand. The models are available in .DGN and .DXF file formats.

A facility is also provided for users to submit their own designs in .DWG and the other formats previously mentioned.

24. *Foss Colour*

Foss Colour of Denmark provide a small site with six objects for free download. The objects are a paper sheet, a bike, a garden bench, a guitar and a divers knife. The objects are .DXF meshes and 2D images are provided to view the objects before download.

25. *Harry H. Chang's Web Pages*

Harry's web site contains a number objects to download created by various authors. There are a number grouped into laboratory equipment, industrial models, military models and architectural categories that must be purchased. However, there are also a number that can be downloaded freely. The vast majority of these are Star Wars objects including vehicles weapons and characters. There are approximately 70 in all, and all are available in the 3DS format. There are a small number of additional objects but these are mirrored at the Avalon site and will not be discussed here.

The site also has a mirror site in Germany and the pages are available in a number of different languages.

26. *Lawrence Berkeley Laboratory*

This FTP site is maintained at the LBL and contains over 100 downloadable .DXF models. There is little information here as to the nature of these models and no 2D images are provided.

27. *The MECN Tree Factory*

Tree Factory is a 3D modelling tool, designed for swift generation of "realistic" polygon-based tree models. On this site there is one free tree model available for download with a 2D viewable image included. This file is available in DXF format (124K) or in Lightwave Object format (LWO, 227K). There are also some GIF images of various tree types that have been modelled using this package for viewing purposes only.

28. *Caligari Corporation*

This site is maintained by Caligari, producers of the TrueSpace 3D modelling package. This site contains an art gallery which is divided into several categories including VRML, still images, animation, textures and objects. From the objects page it is possible to view 6 TrueSpace mesh models by various authors as 2D images. These models, including a body, a Star Wars Tie Fighter and a fountain pen, can be downloaded freely. There is also a link on this page to an FTP site where a further 5 objects including a dolphin and a Christmas tree light can be obtained. No 2D images of these models can be viewed before download however.

Free VRML models can also be obtained at this site.

29. *Paradigm Productions*

This commercial site contains 69 objects that can be downloaded. They are grouped into architecture (3 models), furniture (31), entourage (8), space (11), sports (4), vehicles (2) and miscellaneous (10). No 2D images are available to view the objects and Paradigm stress that objects must be utilised in the users own work only. All of the objects are available in Lightwave 3D format.

The site also contains a very useful links page.

30. *RatScabby*

This site provides possibly the most effective method of displaying the objects that are available for download. There are 12 models displayed on a single image (see Figure 9 below).

Figure 9. The single image "showcase" provided for Rat Scabby models.

The user can then download any of the objects by simply clicking in the appropriate area on the image. A more conventional listing is also provided on the web page. All the models are available in Caligari TrueSpace format (.COB) and some are also available in .DXF and 3D Studio ASCII format on request.

There are also a number of textures (14) that can be obtained from this site.

31. *Specular*

Specular produce their own 3D modelling package for Windows (Infini-D) and provide 5 sample models from their Replicas CD-ROM in this format. The sample models are a chair, a girl, a space vehicle, a bicycle and a WW2 fighter plane produced by various authors. Thumbnail images are provided to view each object, which can also be obtained in 3DMF format.

32. *RenderMan Star Trek: The Next Generation models.*

This collection contains 2 RenderMan (RIB) files of ships from Star Trek. The files are converted from publicly-available 3D models available in other formats. The two available models are the Enterprise -D and a Romulan Warbird. Each file has a preview image, the RIB source code, and the README file distributed with the original 3D model.

33. *Strata Media Tools*

Strata provide a number of downloadable objects on their commercial site. In the Gallery section there are 11 objects with preview images that can be obtained. The objects include a pair of sunglasses, a horseshoe and a beach ball and can be downloaded in 3DMF or VRML formats.

Strata also provide an "Object of the Week" promotion. On this page is an image of a 3D object selected for that week that may be downloaded. The image at the time of writing is a motorcycle. A useful feature here is the Object of the Week archive where it is possible to view and download a number of objects by various authors from this promotion. Currently there are 22 models in the archive which can be

downloaded in one or all of the following formats: StrataClip, 3DMF and VRML. The objects include such items as plants, CD-ROM drivers and even a case of beer. It is worth noting that these objects are changed weekly suggesting that the archive will expand steadily.

34. *The New Graphics BBS*

This is a large site which contains a link to an FTP site. The FTP site contains a large number of models for the following file formats:

Lightwave 3D Objects, Imagine 3D Objects, 3D Studio Meshes, DXF Objects, TrueSpace Objects and Infini-D Objects.

There are no preview images although many of the files do have a text description of the object that can be viewed.

Also available on the comprehensive site are images and animation, movies, a gallery, relevant application information and a list of further links.

35. *POV-Ray*

The POV-Ray sites contains objects in 3DS, DXF, MDL, MISC and RAW formats. The site has a number of each and also a number that have been converted from various formats into POV-Ray INC files. Most of the files do not have individual preview images although some have a JPG index which can be viewed before downloading.

The site also contains many images which can be downloaded freely.

36. *Stanford*

This site contains a number of Space Shuttle models collected by Apostolos Lerios. This list was compiled during April, 1992 (even though the Web page is fairly recent), for a NASA project.

There are six models produced by different groups which may be obtained by FTP from the page. A detailed description of the format of each model is included although no preview images of any of the models are available.

37. *Watermarks Technical Creations*

The Watermark site has a page containing 49 downloadable objects in 3DS format. The objects are categorised as follows:

- Custom Meshes (4 objects)
- Humans (22)
- Furniture (7)
- Computers (2)
- Plants (6)
- Automobiles (2)
- Miscellaneous (6)

Also available are 5 DXF meshes of a computer, a monitor, a keyboard, a chair and an office phone.

38. *Washington State University*

The WSU 3D Object Model Database contains several sets of 3D object models collected over several years to use in object recognition research. The sets are collected from a number of sites:

- Michigan State University's PRIP Lab (20 models)
- The University of South Florida's vision research group (81 models)

- The NETLIB scientific repository (119 models)
- WSU (7 models)

The models are in the main primitive shapes and industrial type objects such as taperolls, cubes and various polyhedra. An example of a preview image can be seen in Figure 10 below.
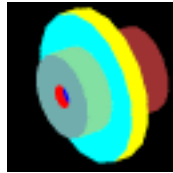
Figure 10. A thumbnail image of an object from the Michigan State Collection

39. *Wonka's Free Objects*

This site contains 12 free objects in Lightwave 3D format. The objects include a satellite, a washing machine and an American football. The objects are displayed as 2D preview images, and downloading is achieved by simply clicking on the appropriate image. The text suggests that 2 new pages of models will be added soon, but there is no indication as to when the site was last updated.

6. Future Trends

6.1 Standardisation Trends

Virtual Reality Modeling Language (VRML)

One area that can be exploited in higher education is the extensive access that these establishments have to the WWW. The Virtual Reality Modelling Language (VRML) enables world builders to create and explore three-dimensional worlds on the WWW. VRML is a platform-independent language for virtual reality scene design based on the OpenInventor format. Various viewers or "plug-in" VRML browsers can be used to explore a virtual environment (e.g. CosmoPlayer, Liquid Reality, Community Place browsers).

Currently, the latest version of VRML (VRML 97) is in the process of being submitted as an ISO standard.

The first point of call for anyone interested in VRML models on the WWW should be the VRML Repository. The repository is maintained at the San Diego Supercomputer Center (SDSC) and provides a comprehensive source of information. Categories of information include hardware and software which includes a comprehensive list of browsers, a documentation section, a worlds section, sounds and textures section and a miscellaneous section. The worlds, sounds and textures category contains links to a number of sites where VRML models and worlds can be freely downloaded. These include:

1. *3RD Dimension Technologies Inc.*

   A commercial site which contains a number of VRML models that can be viewed. There are also a large number of models that can be purchased from this commercial site.

2. *Ocnus' Rope Company VRML Models*

   This site contains almost 400 VRML models grouped into 32 categories including toys, vehicles, military and music. Each model has a small thumbnail image that can be viewed, the name of the file and the file size. Also provided is a 3D Mall, a 3D version of the object catalogue and the facility for the user to upload their own models if they wish.

The repository also provides a link to the UK VR-SIG Object Archive which contains a number of VRML models. It should also be noted that many of the model databases mentioned in section 5.1 also contain downloadable VRML models and information pertaining to this file format.

Standards for the Exchange of Product Data (STEP)

STEP is based on an initiative started in the mid-1980s by the US PRO IGES/PDES Organization (IPO). The basis of STEP was developed from the Product Data Exchange Specification (PDES), the specification being forwarded to the international community in 1988. STEP was approved as an international standard (IS) in 1994.

The goal of STEP is to provide a representation of product information, mechanisms and definitions that will allow product data to be exchanged between different computer systems and environments. In this way, the information can be updated and transferred throughout the entire product lifecycle which will include design, manufacture, utilisation, maintenance and disposal.

STEP is organised into a series of separately published parts. In order to specify the product information, STEP uses the specification language EXPRESS to enable consistency and precision of representations.

The overall objective is to provide a mechanism for describing product data that is platform independent and can be used throughout the entire lifecycle of the product. Therefore, STEP is suitable for neutral file exchange and also as a basis for implementing and sharing product databases and archiving.

The use of STEP has been approved by more than 20 countries world-wide.

6.2 Development tools

Development tools for VR systems have moved on from the early data driven, and ultimately deterministic systems to a more intuitive event driven architecture. Furthermore, there is a migration to visual programming techniques both in terms of the model definition and world definition (e.g. Steed 1996). This may signal a future amalgamation of modelling and world builder languages.

With the web comes possibilities for model sharing, already being exploited by various systems (Division's Universal Product and VRML 97). However, with these developments comes an ever increasing need for standardisation. Certainly, multi-party interaction will drive the need for a standard. Presently there are few systems which cater adequately for this. Although there is a trend toward standardisation within the hardware domain (e.g. PC graphics cards, sound cards, etc.), ultimately world design methodologies are still, in many ways, product dependent.

6.3 The need for an AGOCG database

Section 5.1 of this report indicates that there are a vast number of 3D models contained in databases on the world wide web that are relatively easy to access. This suggests that it is not necessary to consider the formation of an AGOCG model database. This is due to several factors:

- It is difficult to determine the type of models that members of the AGOCG user commmunity would require given that the members are active in many different research fields. A molecular model that is useful for a chemist will be of little use to an historian interested in the visualisation of an historical artefact.
- The UK VR-SIG already maintains a large collection of models on its web site. Similarly, the VRML repository also has a large collection of VRML models.
- The formation and maintenance of a repository site would require a considerable amount of man-hours and computational facilities. It is difficult to see what, if any, added-value would be offered to members of the AGOCG user commmunity by the formation of such a repository.

A possible alternative may be to provide a model database links web site for the membership. This would essentially take the form of section 5.1 of this document. Using this method links to, and a review of, appropriate databases can be provided. If the information is correctly structured, members can then identify sites and collections of models that are appropriate for their own discipline.

The set-up time and maintenance of such a site is considerably reduced, as is the demand for computational resources, providing a very cost-effective solution for AGOCG.

7 Acknowledgement

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Appendix

3D2

Extensions: 3d, 3d2, 3d4

Creator: Antic Software

Description: Used by the Stereo CAD-3D 2.0 package for the Atari ST. Each format can store up to 40 objects and contains all information about the objects, including the lighting and colour palette.

Programs: Stereo CAD-3D 2.0

Another form of the 3D2 specifications can be found at http://www.mediatel.lu/mmedia/render/h_3d2.html.

3DMF (3D Metafile)

Extensions: 3dmf

Creator: Apple

Description: Used by the Quickdraw 3D package from Apple.

Programs: Quickdraw 3D

Additional documentation of the 3DMF format can be found at http://www.info.apple.com/qd3d/3DMFspec.HTML.

3DS (3D-Studio)

Extensions: 3ds

Creator: Autodesk

Description: Used by the AutoDesk 3D-Studio modelling, rendering and animation package on the PC. The 3DS format consists of chunks which describe what information is to follow, its ID, and the location of the next main block.

Programs: AutoDesk 3D-Studio

An "unofficial" 1.0 specification is also available. A more recent format specification may be available from http://www.mediatel.lu/mmedia/render/h_3ds.html and http://www.mediatel.lu/mmedia/render/h_3DS_details.html. Additional information may be found on the comp.graphics.packages.3dstudio newsgroup. Other information may be found at the Autodesk Web site.

3DX

Extensions: 3dx

Creator:

Description: The purpose of this new object format is to provide an optimised object, for the different displaying modes, with expansion possibilities, and information for 3D clipping, animation, and so on.

ART (Another Ray Tracer)

Extensions: art

Creator: Tom Wilson <twilson@sunny5.dab.ge.com >

Description: Used by the ART ray tracer which comes with the public domain VORT package for Unix.

Programs: ART ray tracer

Filters:	The SPD (Standard Procedural Database) package is available at http://www.eye.com/triwrld/Free/freebies.htm and now contains filters to convert to and from the following formats: NFF, POV-Ray, Polyray, Vivid, Rayshade, RTrace SCN, Art, QRT, REND386 PLG, Renderman RIB, AutoCad DXF, Radiance RAD, Wavefront OBJ, and RenderWare RWX.

AVS (Application Visualization System)

Extensions:	geom, prop, scr
Creator:	Advanced Visual Systems, Inc.
Description:	Used by the AVS commercial high-end visualization environment by Advanced Visual Systems, Inc.
Programs:	Application Visualization System (AVS)

BIFF

Extensions:	biff
Description:	The BIFF format defines an image to be a sequence of 2D bands. Every band may have its own size and pixel type (even allowing the pyramid representation to be used). There are also separate parameters for positioning and magnification of each band. Any amount of ASCII text may also be stored in the file.

BIN

Extensions:	bin
Creator:	Silicon Graphics
Description:	The Silicon Graphics BIN format is supported by both Showcase (TM) and the powerflip demonstration program. BIN files are in a simple format that specifies only independent quadrilaterals.
Programs:	Showcase, powerflip

BRL (Ballistic Research Laboratory)

Extensions:	brl
Creator:	BRL-CAD
Description:	
Programs:	BRL-CAD
Filters:	A filter is available to convert IGES into BRL-CAD format.

Other information: The BRL-CAD home page is at http://web.arl.mil/software/brlcad/index.html.

BYU (Brigham Young University Format)

Extensions:	byu
Creator:	Brigham Young University
Description:	Used by the Brigham Young University Movie BYU program.
Programs:	Movie BYU

COB (Calgari Object)

Extensions:	cob (objects), scn (scenes)

Creator:	Calgari
Description:	File format used by the Calgari trueSpace2 program.
Programs:	trueSpace2

Other information: Specifications are available from http://www.mediatel.lu/mmedia/render/files/calgari.pdf in Acrobat format.

Cyberware

Extensions:	cy, tmesh
Creator:	Cyberware
Description:	"Range map" files used by Cyberware 3D digitizers and the Cyberware Echo scanning software.
Programs:	Echo
Filters:	Filters are available from ftp://ftp.cyberware.com/. These include: • byutodxf - Used to convert a Cymage MOVIE.BYU file to a .dxf polygon mesh. • byutotmesh - Used to convert a Cymage MOVIE.BYU file to Echo format. • cy2iv - Converts Echo files to OpenInventor format. • cyconvert - Used to convert Echo files to MOVIE.BYU, Wavefront, or Digital Arts format file. • cyges - Used to convert Echo files to IGES, entities 106, 110, or 112. • cytomesh - Used to convert Echo files to an AutoCAD mesh script. • cytoslice - Used to convert Echo files to an AutoCAD slice script. • echoascii - Used to convert Echo files to ASCII.
Viewers:	plyview

Other information: More information may be available from the Cyberware Web site at http://www.cyberware.com/.

DEM (Digital Elevation Model)

Extensions:	dem
Creator:	U.S. Geological Survey (USGS)
Description:	A Digital Elevation Model (DEM), consists of a sampled array of elevations for ground positions that are normally at regularly spaced intervals.

Other information: Specifications can be found at http://edcwww.cr.usgs.gov/glis/hyper/guide/1_dgr_dem.

DKB

Extensions:	dkb
Creator:	DKB-Trace ray tracer
Description:	Used by the public domain DKB-Trace ray tracer. The POV-Ray ray tracer (see below) is an extension of DKB-Trace, however they use somewhat different object file formats.
Programs:	DKB-Trace ray tracer
See Also:	POV format

DVS

Extensions:	viz, biz, vtx

Creator:	Division Ltd.
Description:	Used by the dVS package from Division Ltd.
Programs:	dVS

DWB (Designer's Workbench)

Extensions:	dwb (binary), dwba (ASCII)
Creator:	Coryphaeus Software
Description:	The binary DWB format is used for input and output by the Designer's Workbench, EasyT, and EasyScene database modeling tools produced by Coryphaeus Software.
Programs:	Designer's Workbench, EasyT, EasyScene

Filters are available from ftp://www.coryphaeus.com/pub/:

Filters:	• asctodwb - converts DWBA (ASCII) to DWB (binary) format. • dwbtoasc - converts DWB (binary) to DWBA (ASCII) format. • dwb2oflt - converts DWB files to OpenFlight format. • oflt2dwb - converts OpenFlight files to DWB format. • pstovfn - converts Postscript Type 1 fonts to VFN outline format.

Other information: Additional information may be available from the Corphaeus Web site at http://www.coryphaeus.com/.

DXF (Drawing Interchange File)

Extensions:	dxf
Creator:	AutoDesk, Inc.
Description:	Used by AutoDesk's AutoCAD and other CAD packages.
Programs:	AutoCAD
Filters:	The SPD (Standard Procedural Database) package is available at http://www.eye.com/triwrld/Free/freebies.htm and now contains filters to convert to and from the following formats: NFF, POV-Ray, Polyray, Vivid, Rayshade, RTrace SCN, Art, QRT, REND386 PLG, Renderman RIB, AutoCad DXF, Radiance RAD, Wavefront OBJ, and RenderWare RWX.

Other information: Version 10.0 of the DXF format is also available. There is also a minimal format specification at

http://www.mhri.edu.au/~pdb/interchange/min3d.html to help you create DXF 3D object files. Further information may be available from AutoDesk

FHS

Extensions:	fhs
Creator:	Fraunhofer Gesellschaft
Description:	Used by in-house VR software by the Fraunhofer Gesellschaft.
Viewers:	fhsview

Other information: More information, filters, and viewers may be available at http://www.igd.fhg.de/www/igd-a4/projects/fhs/.

FLT (OpenFlight Format)

Extensions:	flt
Creator:	Multigen
Description:	A 3D format from Multigen The OpenFlight format is a binary format used for input and output by the MultiGen and ModelGen database modeling tools produced by MultiGen. It is used mainly for flight simulation.
Programs:	MultiGen, ModelGen

Other information: The original format may be found at http://www.multigen.com/openflig.txt.

GDS

Extensions:	gds
Creator:	McDonnell-Douglas
Description:	McDonnell-Douglas GDS Format. The GDS format (also known as the "Things" format) is used in at least one CAD system.

GFO

Extensions:	gfo
Creator:	Silicon Graphics
Description:	The Silicon Graphics GFO format is the simple ASCII format of the barcelona database that is provided in the IRIS Performer sample database directory.
Programs:	barcelona demo, IRIS Performer
Filters:	A filter `/usr/share/Performer/src/lib/libpfdb/libpfgfo/pfbin.c` for Silicon Graphics IRIS Performer is available with the Performer distribution.

GKS (Graphics Kernel System)

Extensions:	gks, cgm
Description:	GKS is a standard specifying the input and output primitives for displaying 2D and 3D graphical data. Although GKS has no native file format, the CGM (Computer Graphics Metafile) format is often closely associated with its use.

GLC

Extensions:	glc
Description:	GLC object file format.

IGES (Initial Graphics Exchange Specification)

Extensions:	iges
Creator:	IGES/PDES Organization (IPO)
Description:	IGES - Initial Graphics Exchange Specification - is an American National Standard that defines a neutral data format for the digital exchange of information among computer-aided design (CAD) systems and other applications of graphic (vector) presentation nature. The standard is developed and maintained by the IGES/PDES
Organization (IPO);	a program area of the U.S. Product Data Association.
Programs:	AutoCAD, Alias

Other information: More information may be available at http://elib.cme.nist.gov/nipde/stds/wh-iges.html.

IM

Extensions:	im
Creator:	Silicon Graphics
Description:	The IM format is a simple format developed for test purposes by the Silicon Graphics IRIS Performer engineering team. As new features are added to IRIS Performer, the IM loader is extended to allow experimentation and testing.
Programs:	IRIS Performer

Infini-D

Extensions:	
Creator:	Infini-D
Description:	Used by the Infini-D package on the Macintosh.
Programs:	Infini-D

Inventor

Extensions:	iv
Creator:	Silicon Graphics
Description:	Used by Silicon Graphics IRIS Inventor 3D graphics toolkit.
Programs:	IRIS Inventor
Filters:	Source code for a filter which reads the Inventor format comes with IRIS Inventor in the libpfdb/libpfiv source directory.
Viewers:	There is a program called ivview that is available on SGI machines and is written using Inventor libraries.
See Also:	VRML format

Other information: Inventor format is a superset of the VRML networked graphics data format.

IRTP (Interactive Real-Time PHIGS)

Extensions:	irtp
Creator:	AAI/Graphicon
Description:	The AAI/Graphicon IRTP format is used by the TopGen database modeling system and by the Graphicon-2000 image generator.
Programs:	TopGen, Graphicon-2000, IRIS Performer
Filters:	The Silicon Graphics IRIS Performer is distributed with a loader in the /usr/share/Performer/src/lib/libpfdb/libpfirtp directory.

LSA, LSB (Lightscape A and B Formats)

Extensions:	ls, lsa (ASCII), lsb (binary)
Creator:	Lightscape Technologies
Description:	Lightscape Technologies LSA and LSB Formats. The Lightscape Visualization System is a product of Lightscape Technologies, Inc., and is designed to compute accurate simulations of global illumination within complex 3D environments.
Programs:	Lightscape Visualization System, IRIS Inventor

Filters:	Programs pflsa.c and pflsb.c are available with Silicon Graphics IRIS Inventor in `/usr/share/Performer/src/lib/libpfdb/libpflsa` and libpflsb directories.

LWOB (Lightwave Object Format)

Extensions:	iff, lwob
Creator:	LightWave
Description:	Used by the LightWave animation software. LightWave 3D objects are stored as IFF files with a FORM type of LWOB. Other chunks stored in a FORM LWOB file are PNTS, SRFS, SURF, CRVS, and POLS chunk.
Programs:	LightWave

Other information: Another source for the LWOB format is
http://www.mediatel.lu/mmedia/render/h_lightwave.html. There is also a
comp.graphics.apps.lightwave newsgroup.

MAZ

Extensions:	maz
Creator:	Division Ltd.
Description:	The MAZ format is used by the dVise package by Division Ltd.
Programs:	dVise

MEDIT

Extensions:	medit
Creator:	Medit Productions
Description:	The MEDIT format is used by the Medit database modeling system produced by Medit Productions.
Programs:	Medit, IRIS Performer
Filters:	A loader is available for Silicon Graphics IRIS Performer in the `/usr/share/Performer/src/lib/libpfdb/libpfmedit` directory.

MEME (MEME Shape file)

Extensions:	rwx
Creator:	Immersive Systems
Description:	Used by the Meme commerical virtual reality system for the IBM PC by Immersive Systems.
Programs:	Meme, IRIS Performer
Viewers:	A Meme viewer demo is available for the PC at http://www.immersive.com/memedemo.htm
See Also:	RWX format

MGF (Materials and Geometry Format)

Extensions:	mgf
Creators:	Greg Ward < GJWard@lbl.gov> of LBL, in association with Rob Shakespeare of Indiana University, Ian Ashdown of Ledalite Corp. and Holly Rushmeier of NIST
Description:	A simple ASCII representation of surface geometry and materials for the purpose of visible-light simulation andrendering. Similar to Wavefront's .OBJ file format.

Filters:	Translators from 3D Studio and Radiance rendering formats, and to Inventor, VRML and Radiance as well as a parser for the MGF format is available at ftp://hobbes.lbl.gov/www/mgf.
See Also:	OBJ format

Other information: MGF documentation and examples are available at http://radsite.lbl.gov/mgf/HOME.html.

MDL (MoDeL)

Extensions:	mdl
Creator:	Moray
Description:	Moray modeler file format.
Programs:	Moray

MSDL (Manchester Scene Description Language)

Extensions:	msdl
Creator:	University of Manchester
Description:	Used by the Computer Graphics Unit at the University of Manchester in graphics packages developed there.
Filters:	Libraries and filters are also available via ftp at ftp://ftp.mcc.ac.uk/pub/cgu/MSDL.

Other information: An intro to MSDL is available from the Computer Graphics Unit at the University of Manchester. MSDL specifications, scenes, and parser may be available at ftp://ftp.mcc.ac.uk/pub/cgu/MSDL/.

MTV

Extensions:	nff, mtv
Creator:	MTV ray tracer
Description:	Scene description used by the MTV ray tracer. For all intents and purposes, the format is the same as the NFF format, with the exception that polygonal patches must be triangles.
Programs:	MTV ray tracer
See Also:	NFF format

NFF and ENFF (Neutral File Format)

Extensions:	nff, enff
Creator:	Eric Haines <erich@eye.com>
Description:	The NFF format is a minimal scene description language written by Eric Haines and was designed in order to test various rendering algorithms and efficiency schemes. It is used by a variety of programs including several public domain raytracers. ENFF is the Extended Neutral File Format.
Programs:	Standard Procedural Database
Filters:	The SPD (Standard Procedural Database) package is available at http://www.eye.com/triwrld/Free/freebies.htm and now contains filters to convert to and from the following formats: NFF, POV-Ray, Polyray, Vivid, Rayshade, RTrace SCN, Art, QRT, REND386 PLG, Renderman RIB, AutoCad DXF, Radiance RAD, Wavefront OBJ, and RenderWare RWX.
Viewers:	There is at least one NFF previewer program written using the VOGLE graphics library, but it doesn't allow you to rotate or move the object, and only displays the scene as a wireframe.
See Also:	WTK format

Other information: NFF specifications can be found at http://www.mediatel.lu/mmedia/render/h_nff.html.

NURBS (Nonlinear Uniform Rational B-Splines)

Extensions:	txt, nurbs
Creator:	Computer Science Department, University of Utah
Description:	Spline surface format. These models were created using the Alpha_1 geometric modeling system at the Computer Science Department, University of Utah.
Programs:	Alpha_1

OBJ

Extensions:	obj (for ASCII), mod (for binary)
Creator:	Wavefront/Alias Technologies
Description:	Used by the Wavefront suite of commercial high-end animation packages.
Programs:	Wavefront
Filters:	The SPD (Standard Procedural Database) package is available at http://www.eye.com/triwrld/Free/freebies.htm and now contains filters to convert to and from the following formats: NFF, POV-Ray, Polyray, Vivid, Rayshade, RTrace SCN, Art, QRT, REND386 PLG, Renderman RIB, AutoCad DXF, Radiance RAD, Wavefront OBJ, and RenderWare RWX.

Other information: A Postscript version of the specifications with graphics is also available.

ODL (Object Description Language)

Extensions: odl

OFF (Object File Format)

Extensions:	off
Creator:	Digital Equipment Corporation
Description:	OFF was developed in 1986 at Digital Equipment Corporation's Workstation Systems Engineering for the and archiving of 3D objects. OFF is an ASCII-based format and is independent of languages, devices, and operating systems.
See Also:	OOGL format

Other information: The OFF archive is available at ftp://gatekeeper.dec.com/pub/DEC/. This archive contains the format specification, tools, and objects. It is not currently supported and is copyrighted.

OOGL (Object Oriented Graphics Library)

Extensions:	oogl, off, list, tlist, grp, quad, mesh, inst, bez, vect
Creator:	Geometry Center, University of Minnesota
Description:	These files can be displayed using the public domain Geomview program for SGI, X, and other platforms, written by written by staff members of the Geometry Center at the University of Minnesota. OOGL uses the OFF format for its polygonal files. An extension of the MESH and OFF files are used by the Meshview program developed at Indiana University.
Programs:	Geomview, Meshview
See Also:	OFF format

Other information: A tutorial of the OOGL format is also available.

PHD (PolyHedra Database)

Extensions:	phd
Creator:	Silicon Graphics
Description:	The PHD format was created to describe the geometric polyhedron definitions derived mathematically by Andrew Hume and by the Kaleido program of Zvi Har'El. This format describes only the geometric shape of polyhedra; it provides no specification for color, texture, or appearance attributes such as specularity.
Programs:	Kaleido, IRIS Inventor
Filters:	Source code for this format is distributed with Silicon Graphics IRIS Inventor in `/usr/share/Performer/src/lib/libpfdb/libpfpoly/pfphd.c`

PLY

Extensions:	ply
Creator:	Stanford University
Description:	Used by the ZipPack polygon mesh "zippering" package on the Silicon Graphics platform written at Stanford University.
Programs:	ZipPack
Filters:	The zipper program and code for reading and writing the PLY format can be found at ftp://graphics.stanford.edu/pub/zippack.

Other information: More information about ZipPack can be found at http://www-graphics.stanford.edu/software/zippack.

POL

Extensions:	pol
Creator:	InnovMetric Software Inc.
Description:	The POL 3D file format was created and is maintained by InnovMetric Software Inc. The POL format was created to fill the need of storing data representing multi-contour, simple, planular, polygons using a binary file format.
Filters:	IMCompress, IMFilter (polygon reduction software)

Other information: Questions regarding this format should be directed to Marc Soucy at msoucy@imetric.qc.ca.

Polyray

Creator:	Polyray ray tracer
Description:	Scene description used by the Polyray ray tracer.
Programs:	Polyray ray tracer
Filters:	The SPD (Standard Procedural Database) package is available at http://www.eye.com/triwrld/Free/freebies.htm and now contains filters to convert to and from the following formats: NFF, POV-Ray, Polyray, Vivid, Rayshade, RTrace SCN, Art, QRT, REND386 PLG, Renderman RIB, AutoCad DXF, Radiance RAD, Wavefront OBJ, and RenderWare RWX.

POLY

Extensions:	poly (ASCII), bpoly (binary)

Creator:	Side Effects Software
Description:	Side Effects POLY format. The Side Effects Software PRISMS database modeler format supports both ASCII and binary forms of the POLY format.
Programs:	PRISMS

POV (Persistence of Vision)

Extensions:	pov
Creator:	POV-Ray ray tracer
Description:	Used by the POV-Ray ray tracer for the Mac, PC, Amiga, and Unix.
Programs:	POV-Ray ray tracer
Filters:	The SPD (Standard Procedural Database) package is available at http://www.eye.com/triwrld/Free/freebies.htm and now contains filters to convert to and from the following formats: NFF, POV-Ray, Polyray, Vivid, Rayshade, RTrace SCN, Art, QRT, REND386 PLG, Renderman RIB, AutoCad DXF, Radiance RAD, Wavefront OBJ, and RenderWare RWX.

Other information: The original specs should be available at http://www.povray.org/ Additional information can be found on the comp.graphics.rendering.raytracing newsgroup.

PTU (Performer Terrain Utilities)

Extensions:	ptu
Creator:	Silicon Graphics
Description:	Silicon Graphics PTU Format used by IRIS Performer.
Programs:	IRIS Performer

QTVR (QuickTime Virtual Reality)

Extensions:	qtvr
Creator:	Apple
Description:	QuickTime VR is a virtual reality delivery platform for the Web and CD-ROM and is used to deliver both photographic and computer-generated virtual reality objects and scenes. Scenes are typically texture-mapped cylinders which are viewed from within. Objects are 3D models which can be rotated and manipulated inside of a scene.

Other information: Additional information is available from http://qtvr.quicktime.apple.com/. You can find the QuickTime VR FAQ at http://dev.info.apple.com/techqa/qtvr/qtvr.html.

QRT

Extensions:	qrt
Creator:	QRT ray tracer
Description:	Scene description used by the QRT ray tracer.
Programs:	QRT ray tracer
Filters:	The SPD (Standard Procedural Database) package is available at http://www.eye.com/triwrld/Free/freebies.htm and now contains filters to convert to and from the following formats: NFF, POV-Ray, Polyray, Vivid, Rayshade, RTrace SCN, Art, QRT, REND386 PLG, Renderman RIB, AutoCad DXF, Radiance RAD, Wavefront OBJ, and RenderWare RWX.

Other information: A context free grammar for the QRT scene files is also available.

Radiance

Extensions: rad (ASCII), oct (binary octree)

Creator: Greg Ward

Description: Used by the Radiance public domain radiosity renderer for Unix. The ASCII files are converted into an octree format for rendering.

Programs: Radiance renderer

Filters: Information on Radiance translators can be found at http://radsite.lbl.gov/radiance/man_html/Notes/translators.html. The SPD (Standard Procedural Database) package is available at http://www.eye.com/triwrld/Free/freebies.htm and now contains filters to convert to and from the following formats: NFF, POV-Ray, Polyray, Vivid, Rayshade, RTrace SCN, Art, QRT, REND386 PLG, Renderman RIB, AutoCad DXF, Radiance RAD, Wavefront OBJ, and RenderWare RWX.

Other information: Documentation of the scene description files and the Randiance package are available at http://radsite.lbl.gov/radiance/HOME.html.

RayDream

Extensions: ray, shade

Creator: Ray Dream, Inc.

Description: Used by the RayDream commercial animation package by Ray Dream, Inc. The specs for this format are not available.

Programs: RayDream

Other information: More information can be found at the RayDream site.

RAY (Rayshade)

Extensions: ray, shade

Creator: Craig Kolb

Description: Used by the Rayshade public domain ray tracer for Unix.

Programs: Rayshade ray tracer

Filters: The SPD (Standard Procedural Database) package is available at http://www.eye.com/triwrld/Free/freebies.htm and now contains filters to convert to and from the following formats: NFF, POV-Ray, Polyray, Vivid, Rayshade, RTrace SCN, Art, QRT, REND386 PLG, Renderman RIB, AutoCad DXF, Radiance RAD, Wavefront OBJ, and RenderWare RWX.

RIB (RenderMan Interface Bytestream)

Extensions: rib

Creator: Pixar

Description: Used by the Renderman commerical renderer by Pixar.

Programs: Renderman

Filters: The SPD (Standard Procedural Database) package is available at http://www.eye.com/triwrld/Free/freebies.htm and now contains filters to convert to and from the following formats: NFF, POV-Ray, Polyray, Vivid, Rayshade, RTrace SCN, Art, QRT, REND386 PLG, Renderman RIB, AutoCad DXF, Radiance RAD, Wavefront OBJ, and RenderWare RWX.

RWX (RenderWare Script File)

Extensions:	rwx
Creator:	Criterion Software Ltd.
Description:	The RWX script file format is used by the RenderWare graphics package from Criterion Software Ltd.
Programs:	RenderWare
Filters:	The SPD (Standard Procedural Database) package is available at http://www.eye.com/triwrld/Free/freebies.htm and now contains filters to convert to and from the following formats: NFF, POV-Ray, Polyray, Vivid, Rayshade, RTrace SCN, Art, QRT, REND386 PLG, Renderman RIB, AutoCad DXF, Radiance RAD, Wavefront OBJ, and RenderWare RWX.
See Also:	MEME format

S1000

Extensions:	s1k
Creator:	United States ARMY
Description:	The S1000 format is used by the United States ARMY SIMNET distributed simulation system for armored vehicle training.
Programs:	SIMNET

SCENE

Extensions:	scene
Description:	The SCENE format is for the storage and interchange of 3D geometric information. The format is under construction.

Other information: Comments are being called for from interested parties, these can be emaied to pdbourke@ccu1.auckland.ac.nz. The draft document is avialable via the Web from http://www.mhri.edu.au/~pdb/interchange/scene.html and is located in the "Computer Graphics" directory.

SCN

Extensions:	scn, rtrace
Creator:	RTrace ray tracer
Description:	This format was designed to replace a very simple format called SFF used by the RTrace ray tracer. There is a filter that converts SFF to SCN.
Programs:	RTrace ray tracer
Filters:	The SPD (Standard Procedural Database) package is available at http://www.eye.com/triwrld/Free/freebies.htm and now contains filters to convert to and from the following formats: NFF, POV-Ray, Polyray, Vivid, Rayshade, RTrace SCN, Art, QRT, REND386 PLG, Renderman RIB, AutoCad DXF, Radiance RAD, Wavefront OBJ, and RenderWare RWX.
See Also:	SFF format

Other information: Many other converters are available to convert to and from this format available via anonymous ftp from ftp://asterix.inescn.pt/pub/RTrace. For more information about the RTrace package and information about its author, see http://diana.inescn.pt/acc/acc.html.

Sculpt

Extensions:	scene
Creator:	Sculpt3D

Description: Used by Sculpt3D on the Amiga.

Programs: Sculpt3D

SDL (Scene Description Language)

Extensions: sdl

Creator: Wavefront/Alias Inc.

Description: Used by the Alias suite of commercial high-end animation packages. SDL is actually a language, and as such is very tricky to convert to other formats. However, Alias can import and export a variety of formats.

Programs: Alias

Other information: The Alias Web site is http://www.alias.com/. More information may be found on the comp.graphics.apps.alias newsgroup.

SDML (Spacial Data Modeling Language)

Extensions: sdml

Creator: University of Toronto

Description: SDML is a spatial description language used for storing CAD and GIS data, such as found in Landscape Planning, Design, and Architectural databases. SDML currently exists in two versions: the old SDML format and the new (Version 1.0) format. The old format is derived from the ASCII-based format used in the CLRview and PolyTRIM software environments. The new format, released in 05Feb95, is a more detailed, capable, and size-optimized revision of the old SDML and supports all the features of the CLRMosaic software.

Programs: CLRView, PolyTRIM, CLRMosaic

Other information: The updated version of the SDML format can be obtained from http://www.clr.toronto.edu:1080/CLRMOSAIC/SDML.html. More information about CLRMosaic can be found at http://www.clr.toronto.edu:1080/CLRMOSAIC/SDML.html.

SDTS (Spatial Data Transfer Standard)

Extensions: sdts, tvp

Creator: US Geological Survey

Description: The SDTS is a language for communicating spatial information. It was developed to allow U.S. Federal agencies to share spatial data among applications which use different hardware, software, and operating systems. It was adopted in 1992 as Federal Information Processing Standard (FIPS) 173 and is the standard for spatial data exchange for U.S. Federal Government agencies.

Other information: More information can be found at ftp://sdts.er.usgs.gov/pub/sdts/www/html/sdts.html.

SFF (Simple File Format)

Extensions: sff

Description: Scene description used by the RTrace ray tracer. This format has been replaced by the SCN format. Filters are available for converting SFF to SCN.

See Also: SCN format

SGF (Standard Graphics Format)

Extensions:	sgf
Creator:	United States Naval Academy
Description:	The SGF format is used at the United States Naval Academy as a standard graphics format for geometric data. The description of the standard graphics format is described by David F. Rogers and J. Alan Adams in the book Mathematical Elements for Computer Graphics.
See Also:	SPF format

SGO and Flip File (Silicon Graphics Object)

Extensions:	sgo
Creator:	Silicon Graphics
Description:	Used by the IRIS Showcase package for Silicon Graphics workstations. The Flip File format is a very simple format which supports only quadrilaterals (four-sided polygons).
Programs:	IRIS Showcase

Other information: A more complete SGO specification is also available.

Softimage

Extensions:	soft
Creator:	Softimage (Microsoft)
Description:	The Softimage format is used in the Softimage|3D modeling, animation, and rendering package and related programs.
Programs:	Softimage|3D

Other information: The Softimage Web site is at http://www.softimage.com/. The Softimage users Web site is at http://vizlab.beckman.uiuc.edu/softimage/. Additional information may be found on the comp.graphics.apps.softimage newsgroup.

SOL

Extensions:	sol
Creator:	Enabling Technologies, Inc.
Description:	SOL format was used primarily by Enabling Technologies Clip3D package for Windows.
Programs:	Clip3D
Filters:	Clip3D
Viewers:	Clip3D

SPF (Simple Polygon Format)

Extensions:	spf
Description:	The SPF format is used at the United States Naval Academy as a standard graphics format for geometric data. The description of the standard graphics format is described by David F. Rogers and J. Alan Adams in the book Mathematical Elements for Computer Graphics.
See Also:	SGF format

STEP (Standard for the Exchange of Product Mode Data)

Extensions:	stp, step

Description:	STEP (ISO 10303) is a set of standards which provide for the exchange of engineering product data. It was created specifically for exchanging models and is most mportant in Europe as one of the few solid model exchange formats.
Programs:	Trispectives, UniGraphics
Filters:	Trispectives - to and from, UniGraphics - from

Other information: A Web site with a wealth of information about the STEP format is http://www.igd.fhg.de/www/igd-a2/hyperstep/.

STEP format specifications can be found at http://www.igd.fhg.de/www/igd-a2/hyperstep/iso-10303/gen.html. A short description is available at http://www.steptools.com. A lengthy description of the whole ISO 10303, now referred to as STEP is avaiable at http://rpksun1.mach.uni-karlsruhe.de/public/Mitarbeiter/Polly/ISO10303/StatusList.html.

STL, STLA (Stereolithography Interface Format)

Extensions:	stl (binary), stla (ASCII)
Creator:	3D Systems
Description:	The STL format is used to define 3D solids to be imaged by 3D lithography systems. The ASCII version of this format is known as STLA and has a very simple structure. STL files are the native file format of the SLA CAD software created by 3D Systems of Valencia, CA, USA. STL files may be ASCII or binary in form, although binary is far more common due to the very large resulting size of the CAD data when saved to the ASCII format.
Programs:	SLA CAD

Strata

Extensions:	???
Creator:	StrataVision
Description:	Used by the StrataVision package on the Macintosh.
Programs:	StrataVision

SV (SuperViewer)

Extensions:	sv
Creator:	John Kichury of Silicon Graphics
Description:	The SuperViewer (SV) format is one of the several database formats that the I3DM database modeling tool can read and write. The I3DM modeler was developed by John Kichury of Silicon Graphics and is provided with IRIS Performer.
Programs:	I3DM, IRIS Performer
Filters:	The source code for the SV format importer is in the file pfsv.c of the IRIS Inventor distribution.

TDDD (3D Data Description)

Extensions:	t3d, tddd, iff
Creator:	Impulse

Description: Used by the Impulse's Imagine and Turbo Silver 3.0 raytracers for the Amiga. TDDD files contain 3D object definitions and can be extended to describe different types of object information. TDDD data is stored as FORM TDDD chunks using the Amiga and Electronic Arts Interchange File Format (IFF). Imagine 3.0 also supports a Texture File Format stored as a FORM TFORM chunk in an IFF file.

Programs: Imagine, Turbo Silver 3.0

Other information: There is also a specification for the texture file available. The TDDD specifications can also be found at http://www.mediatel.lu/mmedia/render/h_imagine1.html. The specifications for the texture file format can be found at http://www.mediatel.lu/mmedia/render/h_imagine2.html.

TPoly (Triangulated Polygon)

Extensions: tpoly, tnpoly

Description: Triangulated polygon files.

UNC (University of North Carolina Walkthrough Format)

Extensions: unc

Creator: University of North Carolina

Description: The UNC format was once used at the University of North Carolina as a format for geometric data in an architectural walkthrough application.

VID

Extensions: vid

Creator: VideoScape

Description: Amiga VideoScape format.

Programs: VideoScape

Vivid

Extensions: ???

Creator: Vivid

Description: File format for the Vivid ray tracer.

Programs: Vivid

Filters: The SPD (Standard Procedural Database) package is available at http://www.eye.com/triwrld/Free/freebies.htm and now contains filters to convert to and from the following formats: NFF, POV-Ray, Polyray, Vivid, Rayshade, RTrace SCN, Art, QRT, REND386 PLG, Renderman RIB, AutoCad DXF, Radiance RAD, Wavefront OBJ, and RenderWare RWX.

VRT, VCA

Extensions: vca (objects), vrt (worlds)

Creator: SuperScape

Description: Used by the SuperScape VRT package.

Programs: VRT ray tracer

VRML (Virtual Reality Modeling Language)

Extensions: wrl, vrml

Description:	VRML is a subset of the Silicon Graphics OpenInventor file format for use in Internet applications. This particular format has become the standard Internet Modeling Language format for the World Wide Web.
See Also:	Inventor format

Other information: Specifications for this format (v1.0) can be found at http://vrml.wired.com/vrml.tech/vrml10-3.html. The

Moving Worlds proposal which was officially accepted as the standard for VRML 2.0 can be found at http://vrml.sgi.com/moving-worlds/index.html.

WLD (WorLD Format), PLG (PoLyGon Format), FIG (FIGure Format)

Extensions:	plg, wld, fig
	Creators: REND386, VR386, AVRIL, Gossamer
Description:	Used by the REND386, VR386, AVRIL and Gossamer graphics libraries for the PC.
Programs:	REND386, VR386, AVRIL, Gossamer
Filters:	The SPD (Standard Procedural Database) package is available at http://www.eye.com/triwrld/Free/freebies.htm and now contains filters to convert to and from the following formats: NFF, POV-Ray, Polyray, Vivid, Rayshade, RTrace SCN, Art, QRT, REND386 PLG, Renderman RIB, AutoCad DXF, Radiance RAD, Wavefront OBJ, and RenderWare RWX.

WTK (World Toolkit Format)

Extensions:	nff (ASCII), bff (binary)
Creator:	Sense8
Description:	The WorldToolKit Neutral File Format which has both binary and ASCII representations. This format is used by package. Sense8's NFF format was loosely adapted from the Videoscape (.geo) format, with the addition of 12-bit color, per-polygon texture application, and portals. It was later extended to support vertex normals, 24-bit color, and vertex uv coordinates. The binary BFF format layout and order is identical to the ASCII version, with the exception that only 24-bit, and not 12-bit, colors are not supported. Note that this format is totally different than the NFF format by Eric Haines.
Programs:	WorldToolKit
See Also:	NFF format

Other information: More information can be obtained on the Sense8 Web site.

X3D

Extensions:	x3d, obj
	Creators: x3d 2.0, xdart
Description:	Used by x3d 2.0 and the xdart renderers.
Programs:	x3d 2.0, xdart

Other information: Both renderers are available via ftp from ftp://dpls.dacc.wisc.edu/graphics.

XOF

Extensions: xof

Creator: RenderMorphics (Microsoft)

Description: XOF is used by the RealityLab 3D renderer by RenderMorphics, which was aquired by Microsoft in February 1995. RealityLab is now a core component of Windows95.

Programs: RealityLab

XOR (External Object Representation)

Extensions: xor, tri (triangles)

Creator: Royal Institute of Technology

Description: External Object Representation (XOR) allows objects in an object-oriented programming environment to exist outside the memory address space in which they were created, e.g. in external files, communication channels and databases.

Other information: Documentation can be found at http://www.bion.kth.se/tests/xor/report/report.html. E-mail harald@bion.kth.se for more information.

YAODL (Yet Another Object Description Language)

Extensions: ydl, yaodl

Creator: Silicon Graphics

Description: Used by Silicon Graphics Powerflip program.

Programs: Powerflip