

4. Software Development Toolkits

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- ✿ 撰寫虛擬實境的程式必需具備有即時系統、個體導向語言、網路、物理模式、多工處理、...等知識。但事實上，一位好的程式設計師不一定具備有上述等知識，而具備有此等知識者。因此如何提供一套良好的軟體發展工具供不具備有上述知識的程式設計師來完成虛擬實境的程式是探討虛擬實境軟體發展工具的主要目的。
- ✿ 虛擬實境的軟體發展工具應該具備有下列特性或功能
 - (1) 提供構建模型及環境等功能，並可接受多種常用的模型檔格式；例如，*DXF, 3DS, etc.*，
 - (2) 提供電腦圖學功能：彩繪、漸層、打光、貼圖，
 - (3) 提供模型、聲音、紋理、材質、環境等編輯功能，
 - (4) 提供物理及運動模塑功能，
 - (5) 提供動畫、瀏覽 (walk through)、編劇等功能，
 - (6) 提供網路功能，允許遠程融入虛擬環境，並可平行、分散處理，
 - (7) 具備虛擬實境週邊設備的驅動程式。

❁ 目前市面上的軟體發展工具都不具備以上所有的功能，而是只包含其中部份功能而已。

❁ 軟體發展工具產品

我們可依功能將虛擬實境相關的軟體區分成下列幾類：

- (1) 發展工具系統、
- (2) 模型/環境構建及編輯、
- (3) 編劇、
- (4) 分散處理、
- (5) 網路虛擬語言的瀏覽器等等。

(1) 發展工具系統：

- *ArtoolKit*, Univ. of Washington, Seattle, Human Interfaces Technology Laboratory (HITLab).
- *Cyberspace Developer Kit (CDK)*, Autodesk, PC.
- *EON Studio* and *EON SDK*, EON Reality, Sweden.
- *GVS*, Gemini.
- *Minimal Reality (MR) Toolkit*, Univ. of Alberta.
- *PROvision*, Division.
- *RB2 Professional*, VPL.
- *REND386 / VR386*, Univ. of Waterloo.
- *Vega*, Paradigm Simulation.
- *Virtools Dev2.1* and others, Virtools The Behavior Co., Fr.
- *Virtual Reality Distributed Environment and Construction Kit (VR-DECK)*, IBM, 1993.
- *Virtual Reality Toolkit (VRT)*, SuperScape, PC.
- *VRCreator*, VReam Inc., \$495.
- *WorldToolKit*, *WorldUp*, and *World2World*, Sense 8, PC/SGI.

(2) 模型/環境構建及編輯軟體：

- Canon Research Europe, RenderWare 2.
- Micron Green, Vr Navigator, NT\$ 45,000.
- Autodesk, AutoCAD.

(3) 編劇：

- Virtus, WalkThrough.

(4) 分散處理：

- Division, dVS operating environment, NT\$ 400K.

(5) 網路虛擬語言及其瀏覽器：

- VRML.

✿ 以下我們就部份軟體發展工具各別介紹其：名稱、出品公司、版本、執行環境(使用主機與作業系統)、產品定位、支援的週邊設備、及執行效率等。

4.1 World ToolKit (WTK)

✿ 公司名稱：Sense8 Corporation
100 Shoreline Highway Suite #282
Mill Valley, CA 94941
Tel: (415) 331.6318
Fax: (415) 331-9148
Email: info@sense8.com
web: <http://www.sense8.com>

✿ 版本：Release 8 (for Windows NT)

✿ 執行環境：PC-DOS, Windows NT, Windows 95, 98
Silicon Graphics workstations
Sun SPARCstation ZX and 20SX
DEC Alpha workstations and
HP workstations.

✿ 產品定位

WorldToolKit is a cross-platform application development system that includes virtual reality and graphic user interface (GUI) function libraries, plus powerful end-user productivity tools.

WTK 沒有設定虛擬物體屬性的功能。


✿ 執行效率 (for Windows NT)

WorldToolKit for Windows NT does not require an accelerator. It will, however, support a variety of OpenGL accelerator boards; e.g., Fujitsu's Sapphire 2SX, Evans-&-Sutherland's Freedom, and Intergraph's GLZ and Z graphics board series.

Using WorldToolKit for Windows NT accelerated with the Intergraph GLZ5 you can achieve performance up to 450,000 3D polygons, Goraud shaded and Z buffered, with a texture fill rate of 15 million, mip-mapped, tri-linear interpolated texels per second.

✿ 支援的週邊設備：

Stereographics CrystalEyes and CrystalEyes VR
Virtual I/O PDS i-glasses (including head tracker)
Virtual Reality Inc, high-resolution HMD
General Reality HMD (including head-tracker)
Virtual Research EyeGen3, VR4 and VR5
SpaceTec Spaceball 2003
Logitech Magellan 3D Mouse
Ascension Bird and Flock of Birds
Polhemus Position Trackers
Precision Navigation Trackers
3D Studio, Wavefront, AutoCAD (DXF), and
ProEngineer

 產品特性：

(1) Complete, Open and Portable

WTK is a portable, cross-platform development system for visual simulation and virtual reality applications. Current platforms include Windows NT, Windows 95, Windows 95, Sun ZX and 20SX, Evans & Sutherland Freedom Series, Silicon Graphics, Hewlett-Packard, DEC, Intel, and Power PC.

Whatever system you work on, WTK has the function library and end-user productivity tools you need to create, manage and commercialize your applications. Because of WorldToolKit high-level API (application programmer interface), you can prototype applications quickly and reconfigure them as required.

WTK also supports network-based distributed simulations and the largest array of interface devices, such as head mounted displays, trackers and navigation controllers.

(2) Optimized to leverage the power of Windows NT

Based on OpenGL, WTK for Windows NT is the fastest high-quality, texture-mapped, real-time simulation and virtual reality system available in the Windows NT environment -- Microsoft recommended environment for high performance 3D graphic applications. Similarly, major hardware manufacturers such as Intergraph and Evans & Sutherland are following this lead with the release of OpenGL/Windows compatible graphics accelerators, offering breakthrough price/performance capabilities.

4.2 WorldUp

✿ 公司名稱：Sense8 Corporation

✿ 版本：Version 1 (for Windows NT)

✿ 執行環境：PC-DOS, Windows NT, Windows 95

✿ 產品定位：

WorldToolKit (WTK) 是一套程式庫 (library)，使用者必需寫程式來呼叫。sense 8 公司於 1995 年底將 WTK 加上一個使用者介面，做成 WorldUp，號稱不需要程式也可以用 WTK。

4.3 dVISE/dVS

✿ dVS 是英國 Division 公司的產品，目前已出到第 3 版。dVS 中的 VCToolkit 是一套函式庫。dVS 沒有設定虛擬物體屬性的功能。dVS 有 SGI, Windows NT 等版本。

4.4 Superscape VRT

✿ 公司名稱：Superscape, Inc.

✿ 版本：Release 7

✿ 執行環境：Inter based PC; don't support any graphics accelerator.

✿ 產品定位：

The VRT is Superscape's complete graphical environment for the creation of virtual worlds. Through the VRT's editors the user can create and manipulate the virtual world in real time to give it whatever appearance and interactions they want.

✿ 支援的週邊設備：

Spacemouse, Space Ball 2003, Virtual I/O Headset, Polhemus fastrack, Ascension flock of birds, Logitech 3D Mouse, Aeropoint device, CrystalEyes.

✿ 執行效率：

125,000 polygons per second

(Pentium 100, 640×480 resolution, polygons average 10 pixels)

✿ 主要功能及特性：

Superscape VRT 包含一個瀏覽器 (Visualiser)、五個編輯器 (World, Shape, Sound, Image, and Layout editors)、及網路 (VRML)、檔案轉換等其他功能。Superscape VRT 是目前功能最齊全一套發展工具；且使用者可以不要寫程式。另外亦提供 Behaviours - Superscape Control Language (SCL)

🌸 Visualiser (Virtual world viewer)

Resolutions 1280×1024 to 320×200 (5 options)

Real time resolution switching

World size = 4.29 billion units cubed

40 different world navigation styles

Real time lighting and moving light sources

Dynamics; Movement, Gravity, Friction

Collision detection

3D animation, bending

Over 50 autonomous objects

Texture Mapping

Screen capture to disc or printer

Plus file security, distancing, detail level override, object behaviors

🌸 World editor

Real Time editing whilst world navigating

Instant object selection and manipulation

Object functions: move, resize, scale, drag, duplicate, distance, color, light, texture, velocities, behaviors, rotate, rotational velocities, gravity, friction, vertical and horizontal restitution, pushable, sound, bend, collision detection, animate

Plan, elevation, plus 100 user definable viewpoints

Multiple palette editing

Virtual Clip Art - load and save facility

Over 100 other functions

✿ Shape editor

Real time editing

Shape functions include: create, duplicate, extrude and spin, animate, mesh, reflect and rotate, lighting, texture

Load backdrop - to use 2D images as templates

Two function for automatic generation of 3D animation cells

Parametric shape creation

Shape primitives, 32767 maximum

Orthogonal subviews

Undo

✿ Sound editor

Direct recording

Stereo sound output

Low, high and band pass filters

Pitch adjustment

Fade in and out effects

Input 8 and 16 bit .WAV files

Cut and paste

Create, duplicate, rescale, crop

Sound progress marker

20 samples supplied

✿ Image editor

Import and export *PCX*, *JPG*, *BMP*, *GIF*, *TIF*, and *TGA*

Features - paint, fill, spray, circle, cut and paste, crop, resize, rotate, flip, line, rectangle, *etc.*

Magnify

Remap palette

Samples supplied

✿ **Layout editor**

- Multiple windows onto virtual world
- Bitmap controls and backdrop
- Instrumentation - numeric or graphical
- Fully configurable user interface

✿ **VRML export**

- VRT* to *VRML* world file export
- Texture support
- DXF* Transfer
- DXF* to *VRT* import
- VRT* to *DXF* export
- Nine entities supported
- Lighting and scaling options
- Cookie cutter
- Supports layers

✿ **Behaviours - Superscape Control Language (SCL)**

600 plus commands. Categories include programming, logical, mathematics, bitwise assignment, color, sorting, collisions, markers, counters, windows, flags, movement, rotations, bending size, position, textures, file handling, animations, viewpoints, lighting, string handling, objects, shape creation and miscellaneous.

Instant compile and decompile on object by object basis.

Debugger and code monitor.

✿ **User extendable with SDK**

- Editor functions - search and replace, cut and paste, etc.
- Virtual clip art
- Over 200 ready to use Virtual clip art objects including:
 - Virtual Humans - Adam and Eve
 - Many include sound, textures, dynamics and behaviors
 - Optimised and distanced
 - Illustrated catalogue included

🌸 Virtual worlds

Over 20 applications and example including:

New office

Air sea rescue

Cromwell house

Shopping mall by Lava *VR*

🌸 Office block by real time design

Kitchen

3D game

Talking head

Helicopters by westland

Excavation by MW Barber

Video walkman

Petrol station

🌸 World file output

VRT file

Component files

Open scripts

DXF

VRML

4.5 Cyberspace Development Kit (CDK)

- ✿ Cyberspace Development Kit (CDK) 是 Autodesk 的產品，目前是 2.0 版。CDK 是一套包含 140 個 C++ Class 的 Class library，使用者可以繼承已有的 Class 發展出新的 Class 來使用。CDK 只能在 PC 上使用，且不支援任何加速卡。CDK 具有設定虛擬物體屬性的功能。

4.6 Minimal Reality (MR) Toolkit

- ✿ 公司名稱：
University of Alberta. The MR Toolkit is available at no cost to licenced academic and research institutions. You can either ftp the PostScript copy of the licence from ([ftp.cs.ualberta.ca](ftp://ftp.cs.ualberta.ca)) cd pub/graphics and get the file "licence.ps".
- ✿ 版本：MR Toolkit Version 1.4
- ✿ 執行環境：
The current version of the MR Toolkit is callable from C, C++ and FORTRAN programs on HP, SGI, DEC, and IBM RS6000 workstations.
- ✿ 產品定位：
MR (Minimal Reality) Toolkit consists of a set of subroutine libraries, device drivers, support programs and a language for describing geometry and behavior. MR provides a device independent and portable platform for the development of VR applications.

✿ 支援的週邊設備：

The Flock of Birds, Fakespace Boom, Liquid Image HMD, Polhemus Isotrak/Fastrak. CyberEye, ADL1 (head tracker), Spaceball, CrystalEyes, iGlass, Flight Helmet, EyeGen 3, CyberGlove, Dataglove, EyePhone 1, 3D-MAX, Cybermaxx,...

✿ 產品功能及特性：

The *MR* toolkit has the following significant advantages over other *VR* software.

(1) Portability:

The *MR* toolkit is designed for the production of *VR* applications that run at more than one site using different hardware configurations. Applications developed using *MR* will run at most *MR* sites with little or no modification to the source code. This allows for the amortization of development costs and the possibility of commercial applications.

(2) User community:

There are over 400 *MR* sites in 39 countries. This opens up the possibility of joint development efforts and sharing the work of developing common tools.

(3) Extensibility:

The *MR* toolkit was designed to be easy to extend. Frameworks are provided for adding new device drivers, interaction techniques and tools built on top of *MR*'s functionality.

(4) Source code:

Complete source code is provided with the *MR* distribution. This makes it easy to extend the package by modifying existing facilities or adding new ones. With complete source code you don't depend on anyone else for software maintenance and development.

(5) Vendor independent:

MR is independent of any hardware or software vendor, therefore, we are not profit or sales motivated. Our main motivation is to provide good software to the *VR* community.

4.7 VRCreator

✿ 公司名稱：VREAM, Inc.

2568 North Clark Street, Suite 250, Chicago,
Illinois 60614

Tel: 312-477-0425

Fax: 312-477-9702

Email: info@vream.com

✿ 版本：The latest version：1.0

✿ 執行環境：PC with Microsoft Windows 3.x, Windows NT or Windows 95，沒有支援加速卡。

✿ 產品定位：

VREAM's VRCreator virtual reality creation software lets non-programmers quickly and easily create powerful virtual reality applications or virtual worlds running under Microsoft Windows 3.x, Windows NT or Windows 95 on a standalone PC, a local or wide area network, or the Internet.

✿ 執行效率：

100,000 polygons/sec on 90 MHz Pentium
(standard SVGA graphics card)

✿ 產品功能及特性：

Support for sophisticated VR-based interactivity, gravity, elasticity, throwability and more...

Full VRML compatibility (read / write)

Networked, multi-participant virtual reality worlds and applications

100,000 polygons/sec on 90 MHz Pentium (standard SVGA graphics card)

Real-time Gouraud and Phong shading

Real-time Z-buffering

Real-time, perspective corrected texture wrapping

Multiple light sources and lighting models

Built-in support for graphics acceleration cards

Support for immersive VR (HMD, trackers, gloves).

4.8 Virtus WalkThrough Pro

✿ 公司名稱：Virtus Corporation

✿ 版本：V2.5.1

✿ 執行環境：

Macintosh System Requirements

Any color Apple PC, Mac II, PowerBook, Quadra or Centris
Recommended Configuration:

Macintosh PowerBook 170 or 180c, Quadra or Centris
8MB+ RAM and System 7.1 or later

PC/Windows System Requirements

80386-based (or later) personal computer

8MB RAM - Microsoft Windows 3.1+

VGA or SVGA display adapter

Recommended Configuration:

80486-based personal computer or Pentium

8MB+ RAM - Microsoft Windows 3.1+

VGA or Super VGA display adapter

✿ 功能及特性：

Discover Virtus WalkThrough Pro, a powerful and intuitive 3-D visualization program that features robust modeling and editing tools, perspective-correct texture mapping, and the most effective and affordable combination of real-time 3-D rendering and "walk through" navigation available. With our award-winning program, you can envision, create and explore any idea without leaving your desktop. Build in our 2-D Design window and watch as your work is rendered instantly in a companion 3-D Walk window. Use texture mapping to add realistic surface details such as doors and windows, bricks and tile, landscapes, even corporate logos. Bring in a QuickTime movie (Macintosh) to enliven 3-D multimedia presentations. At any time, use your mouse or keyboard to quickly navigate in, around and through your models.

4.9 Virtus VR

✿ 公司名稱：Virtus Corporation

✿ 版本：？

✿ 執行環境：

Macintosh System Requirements

Any color Apple Macintosh LC, Mac II, PowerBook, Quadra or Centris

8MB RAM and System 6.0.5 or later

PC/Windows System Requirements

80386-based (or later) personal computer

8MB RAM - Microsoft Windows 3.1+

VGA or SVGA display adapter

Recommended Configuration:

80486-based personal computer or Pentium

8MB+ RAM - Microsoft Windows 3.1+

VGA or Super VGA display adapter

✿ 功能及特性：

New to virtual reality software ? Looking for a program to help you get started ? Virtus VR is the first product to offer "drag-and-drop" tools that you can use to create 3-D worlds, making it easy and fun to build your own environments. Into the program's 2-D window, drag basic 3-D shapes from numerous galleries supplied with the program and combine these to build complex objects, structures and models. For even more realism, add 2-D surface features and textures that we've provided. You'll see your designs instantly rendered in a companion 3-D window, where you can also use your mouse to quickly and fluidly navigate through and explore your world from any perspective.

With objects that we've provided, you can build worlds with specific applications, including home and office design, landscaping, military, modern architecture, outer space and more. Or create your own objects. Then take a break from building your worlds and take a trip through one of ours. Virtus VR includes prebuilt scenes for you to explore, including an undersea kingdom, a futuristic space scene and the Kennedy motorcade in Dallas. Virtus Galleries, additional collections (sold separately) of commonly used items that can save you many hours of modeling time, are also available for use with Virtus VR.

Topics include Alphabet Rooms, Archaeology, Home Remodeling, Interior Design, Office Design and Science Fiction.

4.10 Virtual Reality Modeling Language

- ✿ The Virtual Reality Modeling Language (*VRML*) is a developing standard for describing interactive three-dimensional scenes delivered across the Internet. Basically, it is a combination of virtual reality and Internet resource.
- ✿ Users can have immersion experience in *VR* and take advantage of multi-user interaction, so *VRML* is widely used in business and scientific researches.
- ✿ *VRML* is a language for describing multi-user interactive simulations -- virtual worlds transmitted via the global Internet and hyperlinked with the WWW (World Wide Web). All aspects of virtual-world display, interactions and internetworking can be specified using *VRML*. That is why *VRML* is becoming the standard language for interactive simulation within the WWW.



- ❁ The worlds constructed in *VRML* can contain objects that have hyperlinks to other worlds, HyperText Markup Language (*HTML*) documents or other valid Multipurpose Internet Mail Extensions (*MIME*) types. When a user selects an object with a hyperlink, the appropriate *MIME* viewer is launched. So far, many well-known viewers have been announced in application and plug-in forms. The latest version of *VRML* is version 2.0, which has basic interactive and networking features; the future versions of *VRML* will allow for richer behaviors, including animation, motions and real-time multi-user interaction.



4.10.1 History

- ❁ *VRML* is totally a non-official product rather than a general agreement of Internet users. It was conceived in 1994 at the first annual World Wide Web Conference in Geneva, Switzerland. After five months, the first draft was published and now the third draft was published at May 26, 1995. The future version (version 2.0) is still under construction and testing.

4.10.2 Features and requirements

- ✿ *VRML* 1.0 is designed to meet the following requirements:
 - (i) Platform independence,
 - (ii) Extendibility, and
 - (iii) Ability to work well over low-bandwidth connections.
- ✿ *VRML* is just a text description, and no special hardware requirement; thus *VRML* is born with platform independence. To obtain the extendibility, *VRML* is based on the syntax of the model language of Open Inventor (*SGI*), which is widely accepted by many 3D applications.
- ✿ Before the high-bandwidth network is publicly used, the Internet users decided to disable the interactive in the first version of *VRML* to avoid network traffic jammed.
- ✿ Because the interaction on the Internet will need more efforts on describing interactive behaviors of objects communicating on a network, hence the huge data streams will occupy all available time on the network.

4.10.3 How to build a virtual world using VRML

- ✿ According to the complicity of the *VRML*, mainly due to the coordinates of objects, lights, separators, etc., we often use authoring tools to build a world with *VRML*. That is, we use some 3D modeling tools, often called world builders, rather than text editors to construct worlds and attach hyperlinks to appropriate objects in a intuitive way, then these world builders will translate these 3D worlds to *VRML* forms. For example (in the way we use),
 - (1) Use *TrueSpace* (Caligari Corporation) to build 3D worlds with lights, viewpoints, color and materials specified. Besides, we can also see the rendering result in advance.
 - (2) Use *Fountain* (Caligari Corporation) to attach hyperlinks to objects, then translate them to *VRML* form. If you want to know the detail of the *VRML* version 1.0, you may visit:
<http://vrml.wired.com/vrml.tech/vrml10-3.html>,
or if you want to know more about the proposal for *VRML* version 2.0, you may visit:
<http://webspacesgi.com/moving-worlds/spec/spec.main.html>.

4.10.4 Softwares to construct and view VRML

(Copyright 1995-1996, San Diego Supercomputer Center, Inc.)

A. Authoring Softwares

- Fountain (AKA Caligari worldSpace), Caligari Corporation.
Currently Supported Platforms: Windows 3.1, Windows 95.

B. Browsing Software

A browser is required in order to view a VRML file. The browser is the program which reads and renders the VRML file. Instructions for installing and configuring a specific browser can be obtained at the site from which it is downloaded.

- Dive - A multi-user VR with a VRML interface, Olof Hagsand, SICS. Currently supported platforms: SGI, Sun, HP/UX.
- Microsoft VRML Add-In Beta 1.1, Microsoft, Inc. Currently supported platforms: Windows 95.
- Virtus Voyager, Virtus Corporation. Currently supported platforms: Macintosh, Power Macintosh, Windows 95.

- VR Scout 1.1, Chaco Communications, Inc. Currently supported platforms: Windows 3.1, Windows NT, Windows 95.
- VRealm, Integrated Data Systems & Portable Graphics Inc. Currently supported platforms: Windows 95, Windows NT version 3.5 (Intel).
- VRweb, IICM, NCSA, and the Gopher team. Currently supported platforms: Windows 95, Windows NT (Intel), Windows 3.x (Win32S), HP-UX, SUN OS, SUN Solaris, SGI IRIX, DEC Alpha, DEC ULTRIX, LINUX, IBM AIX.
- WebFX, Paper Software, Inc. Currently supported platforms: Windows 3.1, Windows NT (Intel), Windows 95.
- WebSpace, Silicon Graphics Computer Systems and Template Graphics Software. Currently supported platforms: SGI, Windows NT (Intel), Windows NT (MIPS)/ 95, SUN Solaris, IBM AIX.
- WebView, San Diego Supercomputer Center. Currently supported platforms: SGI/UNIX.
- WIRL, VREAM. Currently supported platforms: Windows 95.
- WorldView, InterVista Software, Inc. Currently supported platforms: Windows 3.1, Windows 95, Windows NT (Intel).

4.10.5 VRML mailing lists

✿ *vrml-behaviors@sdsc.edu*

To subscribe, email to listserv@sdsc.edu.

In the message body type: add vrml-behaviors

✿ *vrml-modeling@sdsc.edu*

To subscribe, email to listserv@sdsc.edu.

In the message body type: add vrml-modeling

✿ *Worldbuilders@caligari.com*

The latest about Caligari's upcoming VRML tools, including specific features, release schedule, and how to become a beta tester.

To subscribe, email to worldbuilders-request@caligari.com.

In the message body type: subscribe

✿ *www-vrml@wired.com*

General discussion on VRML. Unmoderated.

To subscribe, email to majordomo@wired.com.

In the message body type: subscribe www-vrml your-email-address

✿ *www-vrml-digest@wired.com*

The DIGEST-ONLY Version of the Virtual Reality Markup Language (VRML) Mailing List.

To subscribe, email to majordomo@wired.com.

In the message body type: subscribe www-vrml-digest

4.10.6 VRML publications

(Copyright 1995-1996, San Diego Supercomputer Center, Inc.)

[Leonard 1995] A. Leonard, "VR for the people," *Web Review*, Sep.29-Oct.12, 1995.

[Jacobson 1995] L. Jacobson, "Cyberspace: it's a place," *c/net central*, July 1, 1995.

[Karpinski 1995] R. Karpinski, "3-D technology hits the Web - navigating virtual worlds on the Internet," *Interactive Age*, Issue 12, 1995.

[Meyer 1995] M. Meyer, "Surfing the Internet in 3-D," *Newsweek*, May 15, 1995, pp.68-69.

[Vacca 1995] J. R. Vacca, "The outer limits - virtual reality on the Internet," *Internet World*, Vol.6, No.3, Mar. 1995.

4.10.7 VRML-related publications

(Copyright 1995-1996, San Diego Supercomputer Center, Inc.)

[Glidden 1995] R. Glidden, "Microsoft network to support VRML," *The Tessellation Times*, Issue 522.01, 1995.

[Glidden 1995] R. Glidden, "TriSpectives," *The Tessellation Times*, Issue 516, 1995.

[Herbst 1994] K. Herbst, "Web-Posium," *Internet World*, Vol.5, No.7, Oct. 1994.

[Herbst 1995] K. Herbst, "Webstock '94 - four days of lines and tech talk," *Internet World*, Vol.6, No.2, Feb. 1995.

[Kochevar 1995] P. Kochevar and L. Wanger, "The tecate data space exploration utility," in *Proc. ACM Conf. on Interactive 3D Graphics*, Apr. 1995.

[Mason 1994] J. Mason, M. Czernuszenko, D. Plepys, and T. A. DeFanti, "CAVEview: mosaic-based virtual reality," in *Proc. of Conf. WWW 2*, Oct. 1994.

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4.10.8 Applications and related WWW sites

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✿ VRML has been used in many categories, including, architecture, art, astronomy, chemistry, commercial applications, computer science, computer engineering, entertainment, environmental science, history, home spaces-personal, maps and globes, mathematics, etc.

✿ All these above categories have examples hot WWW sites, you may visit:

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

Introduction to the Open Graphics Libraries

- ✿ This course makes use of several popular libraries to help build sophisticated portable graphics applications with minimal effort.
- ✿ The following diagram gives an overview of the packages and how they interact. For the purposes of this course, one can think of the GLU and glut libraries as being part of the OpenGL library or the OpenGL API (application programmer's interface), even though this is not really the case.

OpenGL	provides a software interface to graphics hardware and implements most of the graphics functionality.
glu	provides support for some additional operations and primitive types, and is implemented using OpenGL function calls
glut	designed specifically to be used with OpenGL and it takes care of things like opening windows, redraw events, and keyboard and mouse input. It effectively hides all the windowing system dependencies for OpenGL.