Web-Based 3D

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Summary. Educational software on the World Wide Web can benefit from 3D content. We look at appropriate 3D technologies and give examples of existing 3D learning content on the WWW for different disciplines including pre-school education, optics, biology, and foreign languages. Finally, we discuss the future of such content and its impact on the role of the teacher.

1 Introduction

Modern education has to face the challenge that classical instructional approaches will have increasing difficulty fitting into today’s classrooms, or satisfying the growing demand for life-long learning. New approaches focus on learning by experience, learning to learn independently, and explorative learning. Computers can support these approaches in many ways. As new software technologies arise, so do new opportunities for educational software. In this chapter we look at educational applications of the Virtual Reality Modeling Language VRML and similar technologies, sometimes called Web3D technologies, which provide interactive, three-dimensional content on the Internet. Recently, the term Post-Nintendo kids has been coined, referring to the fact that today most students have been exposed to 3D computer games. With ease they navigate through virtual environments interpreting audio-visual hints as they go. Post-Nintendo kids are used to decent graphical quality and certain kinds of interaction, including direct manipulation, immediate feedback, and continuous navigation. Developers of educational software will have to take this into account to satisfy the expectations of their target groups, just as they used the WIMP (windows, menus, pull-downs) metaphor for the design of their previous software.

2 3D Technologies for the WWW

Many proprietary formats exist for 3D on the Internet. We briefly look at some more common formats in this section.

In QuickTime VR an object actually is implemented as a set of images, called a node. This is also known as image-based rendering. The object is put on a rotating platform and each image is taken from a different angle. When rendering the object, rotating the object is implemented by selecting the associated image.
MetaStream (Abadjev, del Rosario, Lebedev, Migdal, & Paskhaver, 1999) was developed by Metacreations Inc. It is a format for streaming textured polygon meshes over the Internet. For this purpose it uses multi-resolution meshes in a way that allows progressive transmission. Progressive meshes were introduced in Hoppe’s seminal paper (Hoppe, 1996). Given a high-resolution mesh the number of polygons is reduced by repeated application of operations. At the end of this mesh-simplification process a low-resolution mesh results. If the operations applied are recorded the high-resolution mesh can be recomputed by applying the inverse operations. For progressive transmission, i.e., streaming, the low-resolution mesh is transmitted first. Subsequently the recorded operations are transmitted in reverse order. By applying the inverse of these operations the receiver can reconstruct the original mesh in intermediate levels of resolution.

The central data structure of VRML97, the official ISO standard for 3D on the Internet, is the scene graph. Objects are represented as compositions of primitive objects or as polygon meshes (IndexedFaceSet nodes). VRML has different kinds of lights allowing the implementation of user interaction and animations in pure VRML through events, sensors, interpolators, and routes or by programming either in Script nodes using the Java Scripting API or through applets using the External Authoring Interface EAI.

Currently under development and very promising are MPEG-4, Java3D, and X3D.

MPEG-4 (Koenen, 1999) was designed as a streaming format which combines various media types including computer-generated 2D and 3D graphics. As an example one scene might combine audio streams, 2D images, a Website, 3D objects, HDTV, and a movie streamed from a home DVD. All these different sources are organized in a scene graph. They produce different elementary streams that can be transmitted using a variety of transport protocols including RTP and TCP. The elementary streams are buffered and synchronized before forwarding them for decompression and rendering to the appropriate rendering unit. In MPEG-4 3D graphics are represented as BIFS data, short for Binary Format for Scenes. BIFS is a binary format based on VRML97.

Java3D is an API (application programming interface) for programming 3D applications and applets in Java. Java3D provides almost all concepts of VRML97, but requires considerably more programming skills and efforts. The major advantage of Java3D is that the programmer has more control of the rendering process and user interaction, as well as more flexibility for the integration with the rest of the application. There is a VRML loader in Java3D. It reads pure VRML files, i.e., without scripts, and creates a Java3D scene graph which can then be manipulated and rendered by Java3D.

Currently the Web3D Consortium is working on the successor of VRML97 called X3D. In contrast to VRML, X3D is closer to an architecture, although X3D is just a language defined by a DTD in XML. The X3D architecture offers a VRML97 based, but reduced core functionality. Extensions, such as the full VRML97 functionality, will be downloaded and installed as profiles when required. Interaction
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and animation can be implemented using a powerful programming interface, which tries to overcome the insufficiencies of the VRML97 programming interfaces (EAI and Java Scripting API).

3 3D Learning Content on the WWW

The technologies described above provide the technical basis to deliver 3D learning content on the WWW and thus this content can become part of distance-learning scenarios. In contrast to educational CD-ROMs such content can be accessed almost everywhere and anytime. A worldwide audience can be reached. This is import if the content is targeted for a small number of experts scattered all over the world or if the high development costs can only be amortized by a huge customer base. Currently the WWW is often used as a huge cross-referenced book, but interactivity and interpersonal communication are turning it also into a new social space (see Chapters 2 and 3). Internet Relay Chat (IRC) is an example of how Internet technologies can help to form new and large virtual communities. 3D computer graphics provides an adequate visual setting for such communities.

3D learning content mostly exists in the form of simulations or multi-user virtual environments. (Further domain specific issues are discussed in chapters 27 to 33.) Following are examples from different disciplines.

3.1 Pre-school education

Although it is not (yet) available on the WWW, the pre-school educational software called FamiliarTales uses Web technologies to implement its 3D learning content (http://www.familiartales.com). The current software consists of three units. In the first unit children discover through play the difference between consonants and vowels. In the next unit children learn the various sounds of the same vowel. In the third unit they learn phonemes, combinations of consonants and vowels. The software uses three-dimensional alphabet blocks in a virtual space. Children choose letters and thus trigger associated sounds and animations.

3.2 Optics

WebTOP is an interactive, Web-based system for learning optics, more precisely diffraction and polarization (Vidimce, Foley, Banks, Chi, & Mzoughi, 2000). A scene consists of optical elements like lenses and slits. The user can change parameters of these elements. Then the simulation will pass light from light sources through the optical elements and image it on an observation screen. For each simulation module there is an HTML document containing the relevant theory, example simulations, and exercises. In the exercises the learner has to modify parameters and observe and explain the influence of these changes.
3.3 Biochemistry
As a supplement to a textbook on biochemistry (Garrett & Grisham, 1999) a set of VRML worlds has been developed at the University of Virginia. Some of these are also available online (Rourk, 2000). These worlds show molecular structures and animated transformations of molecules into different molecules. Animated 3D graphics were chosen to allow a more dynamic presentation than the static images typically found in textbooks. Students can observe a process instead of reconstructing it from a few images.

3.4 Biology
In real life, the cell is a 3D world. Students usually have to carefully prepare their materials and use special instruments to investigate single cells. Biologists at the University of Ljubljana, Slovenia, have developed 3D visualizations of the structure and animations of the function of the living cell (Amon & Valencic, 2000), including metabolism and cell division. First, introductory photographs and drawings are presented to the student, then he can interact with the 3D scene.

3.5 Manufacturing
At the University of Saarland at Saarbrücken a Web-based simulation of virtual shaping in computer aided manufacturing (CAD) has been built which can be used both for Web-based education and as a tool for feasibility studies (Avgustinov, 2000). Working with numerically controlled (NC) machine tools is expensive; simulating the processing of a workpiece and the NC-machine tool on the basis of the NC-code reduces training and development costs. While executing the NC program the simulation detects collisions of the tool with the workpiece and computes the resulting changes in the form of the material.

3.6 Computer science
Apart from simulations, multi-user virtual environments are an important way to use 3D for Web-based education. To teach key concepts of agent-oriented artificial intelligence a virtual environment using VRML and Java was developed at the University of Bielefeld (Jung & Milde, 2000). Multiple, autonomous, and communicating agents with limited perception move through a virtual world with the goal to grasp fruit. Students have to implement visual representations including basic animations of their agents in VRML as well as the control process in Java (see also Chapter 27).

3.7 Public speaking
At the University College London, UK, emoting avatars have been developed and used for experiments in psychotherapy for social phobias. In particular, virtual environments are being used to treat public-speaking anxiety (Slater, Pertaub, & Steed,
The user has to talk in front of well-behaved and badly behaved virtual audiences. Currently the system based on the COVEN system ([http://coven.lancs.ac.uk](http://coven.lancs.ac.uk)). This system is not intended for use on the WWW, although it uses VRML97 and other Web technologies. With some adaptations the system could be used on the WWW as a training tool for public speaking.

### 3.8 Foreign-language education

The Virtual Nagoya Castle was developed at the Nagoya University, Japan, as a multi-user virtual world to teach Japanese and English (Boudreau & Okada, 1998). While exploring the virtual landscape of the Nagoya Castle students receive language lessons and practice that language with native speakers. Students can use both keyboard and microphone and speakers for communication. The system creates language profiles for each visitor and uses these both for grouping students and native speakers as well as for selecting language lessons. (See also Chapter 33)

### 4 Multi-user worlds

Multi-user worlds are a new way for people to collaborate. Humans are social beings. In multi-user worlds they can form new communities, which have common interests and are not restricted by the locality, mobility, or status of the person in the real world. In the days of the first telephones, radios, and TV sets, nobody was able to foresee how these media would evolve. It is similar today with predicting the future of multi-user worlds. New technologies change social structures and new demands emerge which can be satisfied by exactly these technologies. Even at hindsight it remains unclear if the demand has produced the technology or whether the technology produced the demand. The success of multi-user worlds depends not only on technology. A successful virtual world can be compared with a movie as being a result of a team of experts with very different skills: programmers, directors, designers, story writers, producers, and marketing experts. Virtual-environment designers should apply the same principles that made early computer games so appealing: third-person view, discovery and exploration, player control, maps, landmarks, closed environments (limited space), complexity management (reduced number of active objects), and constant positive feedback.

A platform of increasing importance for multi-user worlds are game consoles. Since 1995 Sony has sold over 20 million Play Stations. SEGA sold 500,000 Dreamcast consoles in the US in just two weeks. The Dreamcast console and those under development by Nintendo and Sony can be connected to the Internet and thus enable multi-user games. Given the low price of these consoles, they might even be able to supersede personal computers as Internet stations in the home.

### 5 The Role of the Teacher

Creating 3D learning content is a difficult and time-consuming task. While most people are used to word processors and thus can easily switch to Web-authoring
tools, 3D authoring software requires a considerable amount of additional knowledge and training. Fortunately, teachers do not have to do this programming. As can be seen above there is an increasing number of 3D learning contents available and teachers can start experimenting with those. Feedback from such experimentation is needed to improve these early prototypes.

As the simulation-based software becomes more mature and is combined with documentation and exercises the teacher will more and more turn into a guide. This will probably not be the case for multi-user virtual environments. Here the teacher can be online with his students; thus the classroom experience might be partially transferred into the virtual space. On the other hand, it is technically feasible to create largely teacher-independent systems so that students can work both at home and at school without a need for the teacher to be online at the same time. Multi-user worlds support interpersonal communication and collaboration and thus mutual monitoring of students (see Nagoya Castle above) can effectively replace teachers in some situations.

6 Conclusion

Web3D technologies provide the technical basis for interactive, animated 3D learning content as well as virtual classrooms. We have briefly described examples from a variety of disciplines. As it is not a simple task to create interactive 3D models, we do not expect that the amount of 3D content on the WWW will grow with the same speed as that of text-based and 2D Web pages. Nevertheless it will have an immense impact on the way we teach and learn in the future.


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