Interactive Visualisation for the Internet in Landscape Planning with VRML

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1 Introduction

Humans, and the world they live in, are three-dimensional. That makes it obvious that landscape planners use 3D environments - in particular digital environments - to plan and to present their work. In the past, problems with computer performance made it difficult to create such scenes. But today, decreasing costs of computer hardware, rapidly increasing computer performance and a wide spectrum of available software make it easy and affordable to work with virtual 3D-worlds. But the real world is not only three-dimensional, it is also dynamic and interactive. Dynamics in a landscape can be separated into three major types [ERVIN 1999]:

- movement through the landscape
- movement of the landscape
- interaction with the landscape

One language for creating interactive worlds is VRML (Virtual Reality Modelling Language), which is the standard format for transporting interactive three-dimensional content over the internet. VRML has many interactive features and can be linked easily with other multimedia content on the internet. This makes it possible to create geographical knowledge- and information-bases for the internet to reach a large number of interested people.

2 VRML – A Short Introduction

2.1 Overview

VRML (Virtual Reality Modelling Language) is one of the leading technologies to create navigable, hyperlinked interactive worlds on the internet. Since 1994 it is the international standard file format (ISO/IEC 14772) for describing interactive 3D multimedia. This language can be seen as the 3D equivalent of HTML. A VRML-scene is a hierarchical structure of shapes, transformations, cameras, and lights. Every object-property is a part of this structure and is named „node“. The hierarchy can have any given number of levels, where each level controls the ones underneath.

Fig. 1: VRML Node Structure
The advantage of VRML is that it is widely platform-independent and easy to create by exporting from standard 3D-Graphics Software. It also works well with the newer browser generations. To view VRML-files, the client computer needs a VRML-viewer, or a java-supporting web-browser. The current version (VRML97) contains a wide range of interactive nodes to bring "life and motion" into these worlds. The integration of VRML worlds into HTML-documents offer the possibility to visualise spatial information for the internet and to create public panels for planning content.

2.2 Interactive Visualisation

Interactive Visualisation means, that the user can interact with the model depending on the complexity level of the scene. In the simplest case, the user can "walk through" the model, or can explore the model by moving or rotating it. More interactive complexity means that users can trigger different actions or move objects in the scene.

There are three different levels of virtual reality. Every level is based on the preceding one and includes additional features which increase the complexity.

<table>
<thead>
<tr>
<th>passive level</th>
<th>active level</th>
<th>interactive level</th>
</tr>
</thead>
<tbody>
<tr>
<td>No control from outside</td>
<td>Movement from outside is possible without limitations</td>
<td>The user can not only experience, but also modify the scene (e.g. Objects can be moved and/or created)</td>
</tr>
<tr>
<td>Defined movement is possible</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Examples:
- Rendered pictures
- Movies
- VRML 1.0
- VRML97
- Network Games

Fig. 2: Virtual Reality Levels [AUKSTAKALNIS & BLATNER 1992]

The complexity of interactive models is increasing rapidly, the more interaction and content is integrated.

3. Specific Needs in Landscape Planning

Landscapes mainly consists of terrain’s, vegetation, water, infrastructure, animals/humans and an atmosphere [ERVIN 1999]. Particularly in landscape architecture structures like terrain’s and vegetation are very essential for the visualisation. But these structures are mostly very complex and thus difficult to visualise - especially for interactive scenes, because of the high computer performance needed to handle the complex structures in real-time.

3.1 Terrain Modelling

Digital elevation models describe the height data of a terrain as Triangular Irregular Network (TIN) or as an elevation grid with a fixed grid size, where one cell defines one unique elevation value. In VRML the elevation model can always be described over a polygon-mesh, but the disadvantage of this technique is that high-detailed models need a
large number of polygons to define a terrain. A lower download rate caused by a large file size is the result. For this reason, VRML can handle terrain models with the “ElevationGrid”-node. The advantage of an elevation grid is, that the grid dimension and cell size can be defined in the beginning of the node. Then only the height-data for each cell (from lower left to upper right) must be entered.

<table>
<thead>
<tr>
<th>Polygon mesh</th>
<th>Elevation grid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filesize [kB]</td>
<td>654</td>
</tr>
<tr>
<td>Vertices</td>
<td>4096</td>
</tr>
<tr>
<td>Faces</td>
<td>7938</td>
</tr>
</tbody>
</table>

Fig. 3: Polygon Meshes and Elevation Grids

3.2 Vegetation

The high-detailed visualisation of vegetation is very important to create realistic scenes. On the other hand the complex structures of these objects make it difficult to keep the virtual landscape navigable.

There are three main techniques to embed vegetation into a VRML-model:

Vegetation as Polygon Models

Using vegetation visualised with polygons makes it possible to create high detailed objects which are really three-dimensional. Such objects can be created with common 3D-Graphics Software or special 3D vegetation modeller (e.g. AMAP, XFrog, TreePro, etc.), or can be taken from free and/or commercial 3D-libraries. Unfortunately these objects are nearly unusable for interactive worlds on conventional client-computers because of the high polygon amount needed. In many cases it would be impossible to display even one single tree, and a whole forest would multiply the number of polygons, of course. The following images show the comparison of a high-detail tree (using L-Grammar [PRUSINKIEWICZ & LINDENMAYER 1990]) and the same tree abstracted using a cone. The table below shows the polygon statistics. The following example shows that one single high-detail tree needs an amount of polygons which is hard to handle for a client computer. In most cases, a landscape scene needs more than one tree. On the other side, the abstracted cone-tree does not look very realistic.

<table>
<thead>
<tr>
<th></th>
<th>high-detail</th>
<th>abstracted cone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filesize [kB]</td>
<td>7150</td>
<td>24</td>
</tr>
<tr>
<td>Vertices</td>
<td>58.549</td>
<td>282</td>
</tr>
<tr>
<td>Faces</td>
<td>86.698</td>
<td>48</td>
</tr>
</tbody>
</table>

Fig. 4: Vegetation as Polygon Models
**Bitmaps Used as Billboards**

VRML offer the possibility to use bitmap pictures as billboards. A billboard is an object that is always at right angles to the line of sight. This technique is very useful for visualising vegetation in a realistic way without the need of thousands of polygons, but can also be used to simulate other simple objects such as street lights etc. The disadvantage of billboards is that they appear as a line in plan view.

**Fig. 5:** Billboards

The tree in this example shows the same L-grammar tree as above, but as a ray-traced GIF-image with a transparent background.

<table>
<thead>
<tr>
<th>Bitmap billboard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filesize [kB]</td>
</tr>
<tr>
<td>Vertices</td>
</tr>
<tr>
<td>Faces</td>
</tr>
</tbody>
</table>

**Textures**

The third technique to integrate vegetation is to use textures which are mapped over the digital elevation model. This is necessary for the visualisation of bigger areas.

**Fig. 7:** Vegetation as Textures
3.3 Buildings and Infrastructure

In particular in urban planning, it is important to integrate buildings and other infrastructural content. Again it is important to find a good balance between abstraction and reality. To enhance abstracted buildings it is possible to map images of house fronts onto it – this technique is often used to visualise existing buildings. For other urban content like street lights, traffic signs, etc. it is useful to apply the billboard node as described above.

![Buildings in VRML-models](image)

<table>
<thead>
<tr>
<th>Filesize [kB]</th>
<th>Full 3D-modeled</th>
<th>generalized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertices</td>
<td>3435</td>
<td>24</td>
</tr>
<tr>
<td>Faces</td>
<td>6603</td>
<td>30</td>
</tr>
</tbody>
</table>

Fig. 8: Buildings in VRML-models

3.4 Geographic data

Landscape planners often work with geographic data from various GIS-applications. Converting the data into the VRML-format often used to cause problems. Therefore an extension set named GeoVRML was developed. The following list shows the capabilities of GeoVRML 1.0.

- **Coordinate Systems**
  Allows to embed latitude/longitude or UTM coordinates directly into a VRML file.

- **Scalability**
  For managing large models over the web

- **Metadata**
  For creating a generic subset of metadata describing geographic objects, including the ability to link to a metadata description.

- **Introspection**
  Functionality is provided to be able to query a GeoVRML scene and discover the geographic coordinate of any georeferenced point.

- **Navigation**
  Basic support for navigation schemes that are specific to geographic applications.
4. Alternatives

4.1 QuickTime VR®

QuickTime VR® uses the principle of branching movies. That means, that movie-sequences are combined at specific nodes according to their spatial navigation path. The users orientates themselves within a 360 degree panorama and can navigate within the defined nodes. The advantage is that such panorama movies are easy to create and use. The disadvantage is the limited possibilities of navigation and interaction. To view such panoramas, the Apple QuickTime Player is required. Other panorama techniques works with Java-applets, this means, that no plugin, but a java-supporting browser is needed.

Fig. 9: QuickTime VR®

4.2 Java 3D

Java 3D is an API (Application Programming Interface) which extends the Java platform with capabilities for three-dimensional graphics. The difference between Java3D and VRML is, that Java3D is a low-level programming API for 3D graphics rendering. The code must be compiled to move it into an executable form. VRML is a text based modelling language that is interpreted dynamically from the source code. A working group is developing a 3D-browser to combine VRML and Java3D. To run Java3D models a Java-supporting Browser is required.

4.3 Networkgames

A very new alternative to VRML are gaming engines used to visualise landscapes. „Shoot-em-up“ games like Quake are highly optimised to run smoothly on a standard PC, even with a cheap 3D-graphic card. These games can also be played over the internet. There are two ways to create scenes for these games:

a) Level builders, which are mostly easy to use. The problem here is, that these products often don’t have specific landscape construction tools.
b) Export-Plugins for 3D-Graphics Software

There are some minor compromises on graphics quality, but they are compensated by the emphasis on extreme interactivity.
5. Optimising VRML Scenes

5.1 Polygon Reduction

To reduce the size of polygons it is necessary to build the model with major attention on the complexity of the scene. This means, that the planner often needs to work on two different models, which making well-structured project management essential. Once the manually optimised model is finished, it is possible to use reduction filters. These are included in some software-products or outsourced to special optimising software. In particular for VRML, a program named Chisel (Trapezium Software) is able to validate the VRML script and optimise the code by using different reduction algorithms where the parameters can be set manually. With skilful reduction settings you can obtain major polygon reductions with little loss in quality. The following table shows the reduction potential of Chisel using the default settings: Step 1, “Formatted and Cleaned”, means that the file was restructured by removing comments, wrapping lines, and cleaned by removing unused and repeated values. During this process no polygons where removed. In the second reduction step “Reduced”, an abstraction of the model by clearing polygons takes place. Reduction algorithms are used for smallest edges, smallest triangles, parallel edges and coplanar triangles.

Example model: Terrain as Polygon Mesh | Dimension: 1000x1000 [m] | Grid : 20x20 [m]

<table>
<thead>
<tr>
<th></th>
<th>Original file</th>
<th>STEP 1: Formatted and Cleaned</th>
<th>STEP 2: Reduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filesize [Kb]</td>
<td>690</td>
<td>447</td>
<td>284</td>
</tr>
<tr>
<td>Filesize g-zipped [kB]</td>
<td>135</td>
<td>122</td>
<td>85</td>
</tr>
<tr>
<td>Vertices</td>
<td>5202</td>
<td>5202</td>
<td>3423</td>
</tr>
<tr>
<td>Faces</td>
<td>10400</td>
<td>10400</td>
<td>5828</td>
</tr>
<tr>
<td>Polygon Reduction [%]</td>
<td>0</td>
<td>0</td>
<td>37</td>
</tr>
<tr>
<td>Filesize Reduction [%]</td>
<td>0</td>
<td>27</td>
<td>27</td>
</tr>
</tbody>
</table>

Fig. 10: Formatting, Cleaning and Reducing VRML-worlds

5.2 Pixel Optimising

Pixel Optimising is a technique to get the smallest images for textures, billboards, etc. at an acceptable quality level. The internet and VRML can handle primary three different image-formats – GIF, JPEG and PNG.
Graphics Interchange Format (GIF)
The GIF-format consists of a 256-color (8-bit) lookup table (CLUT). That means, that the RGB-values can be managed from one central table, decreasing the file size. These CLUT’s can also be color-optimised according to the image. A primary advantage is, that a GIF-Image can contain transparent areas, which is very useful for vegetation mapped on billboards. The GIF-compression is loss-free (Lempel-Ziv-Welch-compression) and works line by line and with pattern recognition.

Joint Photographics Expert Group (JPEG)
Unlike GIF, JPEG-compression is a lossy process. The image will not look the same as the original after compression. JPEG supports truecolor and greyscale-images and is therefore better for photographic images. On the other hand JPEG does not support transparency, why the use as billboards is limited.

Portable Network Graphics (PNG)
The Portable Network Graphics (PNG) format was designed to replace the older and simpler GIF format, combines the advantages of JPEG and GIF (truecolor, transparency with an „real“ alpha-channel), and has extra features like gamma correction (cross-platform control of image brightness), and two-dimensional interlacing (a method of progressive display).

5.3 Level of Detail
For the “level of detail“-node, the planner needs to create several differently detailed objects which are displayed according to the distance between object and viewpoint. This enables a faster navigation through the model, especially through bigger ones.

5.4 File size Reduction

File zipping
VRML browsers also can handle g-zipped VRML-worlds, as long as they have the same file-type extension (.wrl). GZIP is a UNIX compression utility that is the standard compression algorithm for VRML files. This step can often reduce the filesize by 70% (see Fig. 10.). The short compressed file gets downloaded from the server and is automatically unpacked by the VRML browser or plugin.

File splitting
One of the capabilities of VRML is to reference other VRML files into the main file – called “un-inlining“. This allows the planner to manage large models in a much more convenient way. However, at runtime, the browser is forced to make more fetches from the Web server. Un-inlining these files often results in significantly faster loading of the VRML world. This technique is not really a file size reduction, but the splitting into several files results in faster loading.
6. Performance Comparison

To demonstrate speed differences when using VRML on different computer hardware configurations, three different virtual worlds were used to compare the attainable frame-rate of these systems. To guarantee a smooth motion, a minimum frame-rate between 12 and 15 frames per second (fps) is needed. With a frame-rate less than 1 fps, a serious navigation is nearly impossible.

<table>
<thead>
<tr>
<th><strong>Vertices</strong></th>
<th><strong>Judenplatz</strong> Vienna, Austria</th>
<th><strong>Rennwegkaserne</strong> Vienna, Austria</th>
<th><strong>Garden (draft)</strong> Gaflenz, Austria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Faces</strong></td>
<td>1273</td>
<td>4167</td>
<td>11458</td>
</tr>
<tr>
<td><strong>PC Configuration</strong></td>
<td><strong>Frame-rate [fps]</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC233, 128MB RAM 8MB Graphic card</td>
<td>min 4, max 15</td>
<td>3.5, 7</td>
<td>1.2, 3</td>
</tr>
<tr>
<td>PC333, 256MB RAM 4MB Graphic card</td>
<td>min 6, max 15</td>
<td>5, 10</td>
<td>1.5, 4</td>
</tr>
<tr>
<td>PC450, 128MB RAM 8 MB Graphic card</td>
<td>min 7, max 20</td>
<td>5, 11</td>
<td>2, 5</td>
</tr>
<tr>
<td>PC700 256MB RAM 32 MB Graphic card</td>
<td>min 10, max 25</td>
<td>9, 20</td>
<td>3.5, 8</td>
</tr>
<tr>
<td>PC800 256MB RAM 32 MB Graphic card</td>
<td>min 17, max 25</td>
<td>10, 22</td>
<td>5, 11</td>
</tr>
<tr>
<td>PC1000 512MB RAM 64 MB Graphic card</td>
<td>min 19, max 50</td>
<td>14, 33</td>
<td>5, 12</td>
</tr>
</tbody>
</table>

**Fig. 11:** Comparison of different VRML-worlds on different computer systems

This table shows, that in this test, the computer-processor is the main speed-factor for the tested VRML-worlds.

7. Problems Using VRML in Landscape Planning

Interactive Visualisation is very useful to transport planning content, in particular in disciplines which are working in and with spatial dimensions. For landscape planning it is possible to build three-dimensional projects with VRML to involve the public into the planning process. On the other hand, there are many problems and limitations, caused by the complexity of landscape structures, vegetation, and by the interactive content. It is therefore necessary to optimise the content and the structures to create efficient worlds.
Besides VRML there are alternative techniques, which have other advantages and disadvantages, depending on their emphasis. The main advantage of VRML is, that it is a standard-format for interactive worlds on the internet. The disadvantage is, that it is more static in its development compared to other technologies.

8. References


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