Image Based Real-time and Realistic Forest Rendering
and Forest Growth Simulation

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Abstract

Real-time and realistic rendering of forest is an important and a difficult work in computer graphics and digital forestry. An image based real-time and realistic forest rendering software is developed in this paper. Three orthogonal billboards are used to represent the geometry and material of a tree, so that the 3D perception is enhanced and weak parallax of usual images based approaches is avoided. Shadows of all trees on the plat ground are generated through the stencil buffer, shadow projection and a mixture of the shadow with grass texture. Different billboards are chosen on the viewing direction and the lighting direction, so that the effect of object torsion due to poor image direction is avoided. Forest growth, forest rendering in different lighting conditions, navigation inside a forest, and flying over a forest are all simulated.

1. Introduction

Plants are a basic elements in virtual environment. They are special in the nature with complex shapes and colors, and with rich details of small, isolated and non-manifold geometry.

Real-time and realistic rendering and growth simulation of a big forest is a challenge in computer graphics and virtual reality. Plant growth modeling present the growth mechanism of plants and plant communities with mathematical formulism and geometric descriptions [2]. The complexity of each tree model and the number of trees included overwhelmed the capacity of a computer in rendering cost, memory cost and processing cost. Different technical approaches have been developed to increase the realism and speed of plant communities [1].

We developed a new image based approach for real-time and realistic forest rendering. It takes the advantage of the texture mapping power of modern video cards. A set of three cross billboards is used to represent the geometry and material of a tree for a direct balance between geometric simplicity and visual complexity, so that the 3D perception is enhanced. This can be used for landscape visualization, for the simulation of walk-through in a forest, and a flight over the landscapes.

2 Related Work

Plant growth modeling and the visualization of plants and forest are the two main topics in this paper.

2.1 Plant Growth Modeling

Successful modeling mechanisms have been established in recent years, in which some are mature software are widely applied.

AMAP plant models [2], with the botanical knowledge of plant architecture of real measured data, reflect plant’s growing process, its space occupation, and the location of leaves, flowers or fruits. AMAP-Genesis\textsuperscript{TM} plant generator integrates the research results of AMAP plant growth modeling [2] with its specific plant procedural growth engine. The tool allows a great richness of different plant architectural shapes at any growth stage. Software AMAP-Orchestra\textsuperscript{TM} provides users necessary tools to design and visualize a large-scale landscape project.
L-system was initially developed by A. Lindenmayer to describe the growth process of living organisms based on fractal patterns. This syntactic method is used to describe plant growing process [9]. Xfrog [5] is a combination of a rule-based approach with traditional geometric modeling techniques, allowing easy generation of branching objects. Xfrog is also a convenient tool for interactive plant modeling. Onyx-tree is easy a professional knowledge based software for procedural modeling, design of vegetation.

2.2 Visualization of plants and forest

Polygon based rendering, point/line based rendering, volume rendering and image based rendering are four basic techniques for fast plant rendering.

Polygon models are the basic representations of plant geometry, and it is the result of mature modeling software [2]. Several methods have been proposed in the past to address polygon decimation and compression [12] [10]. Most of these approaches are classified as three categories: multi-resolution modeling, level-of-detail algorithms, and geometric compression.

Point models and line models are efficient for rendering small polygons since the number of world-to-screen project transformations can be reduced. It is easy to perform visibility culling with these models, so they are efficient in the rendering of plant community [4] [6]. The drawback of this approach exists in discontinuous shading transition due to discrete sampling.

Volumetric texture and volume methods convert the geometry into a series of parallel image slides. So it is more efficient for interactive realistic image synthesis of repetitive geometry. It is geometric complexity independence [3] [10]. But its resolution can not be high due to its memory cost. Volumetric texture [3] and volume rendering [7] are strong for flight simulation, but not weak for navigation in forestry, since the geometry represented is so simple.

Imposter models are used to convert the complex geometry of a model into a single texture image. Its advantage is its geometric complexity independence [8] [11], so it is efficient for rendering repetitive scene, like plant community [11]. The drawback of imposters is its lack of geometric depth, so many layers of images, or many sets of images [1], are required to compensate.

A popular way for image-based rendering is billboards, which present an illusion of a complex geometry through 2D cross images, so that the poor geometric depth is ameliorated, and the geometric complexity is still low. The drawback of a billboard is its weak parallax for close viewing and the illusion may vanish as soon as the billboard is seen from above. One difficulty of billboards resides in a mixture of alpha blending with depth buffer for a proper hidden removal, and with stencil buffer for shadows.

We would like to show that it is feasible to use three cross billboards to realize a fast and realistic rendering of a big forest in our software ForestRoom: Forest Rendering and Simulation with Image models. With a link to plant growth modeling software, it is possible to simulate the growth of a forest.

3 Key techniques

A set of three cross billboards (Figure 1), i.e. three static orthogonal rectangles, are used to represent the geometry and material of a tree, so that they look like different 3D aspects of the same object from different viewing directions.

Trees are rendered through alpha blending and depth blending to realize a proper transparency and hidden removal. All billboard images are with four channels. Alpha channel of a pixel is set as opaque if it represents the geometry, and it is set transparent if it represents empty. The blending order of the three billboards is from far to near. A billboard is selected to render if the angle between its normal and the viewing direction is smaller than a constant angle, 60 degree.

We use stencil buffer for the shadow on the plat ground of each tree with a mixture of shadow on the grass texture. In order to avoid the effect of object torsion due to poor image direction nearly orthogonal to the viewing direction, different billboards are chosen according to the viewing direction and the lighting direction. Frustum clipping is performed for rendering acceleration.

Therefore, a real-time speed and realism in shading and shadow are all kept.

4 Technical advantage

The new techniques in this paper are integrated in software ForestRoom. It has the following technical features:

Alpha blending: depth test and alpha test are used to realize a proper hidden object removal, inside a tree or between trees.

Shadows: The shadow rendering algorithm is realized through a projective mapping of billboards on a planar ground. This projection is mixed with ground texture.

Mipmaps: the software offers the choice of mipmaps, for different levels of details for the textures, which supports anti-aliasing, soft shadows and smooth image transition of different frames in internal navigation.

Tree clipping: tree clipping for viewing frustum is performed to avoid rendering of tree out of the frustum. Clipping is realized with the viewing matrix.

Sorting: painter’s algorithm is realized with a sorting from far to near of all trees around the viewer. Thus the
transparency error of alpha blending is avoided on the silhouette of an object due to texture image resizing from automatic mipmaps. The order of objects is adjusted when the distance relative to the tree changes, so this rendering is view-dependent.

5 Software functions

This software has the following functions:

**Realism**: each texture image is from plant model faithful to botanic knowledge. Therefore, visual effect of tree architecture looks natural and realistic. Shadows on the ground are shown. Real-time simulation of daytime elapsing is realized according to the change of the sunlight and that of the shadows on the ground.

**Operation modes**: Not only does the software enables to render a forest, but it also allows navigation inside. Different motion modes are included: flying over a forest, free walk through a forest, or automatic drive in a forest.

**Fast speed**: for all these experiences, it is real-time for a moderated forest. Users can choose to display the trees with or without shadows on the ground between a high quality and a high speed.

**Plant distribution**: trees are randomly distributed on the flat ground with a random value of rotation, so that the billboard trees in the forest look natural.

6 Implementation

This software is written with C language supported by OpenGL. It is running in a Compaq Presario R300 PC with
Table 1. Efficiency of the software *ForestRoam* according to different rendering parameters

<table>
<thead>
<tr>
<th>Experiment ID</th>
<th>Clipping</th>
<th>Sorting</th>
<th>Mipmaps Rendering</th>
<th>Static Shadow</th>
<th>Mipmaps Shadow</th>
<th>Milliseconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>187</td>
</tr>
<tr>
<td>(2)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>328</td>
</tr>
<tr>
<td>(3)</td>
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<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>312</td>
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<tr>
<td>(4)</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>47</td>
</tr>
<tr>
<td>(5)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>187</td>
</tr>
<tr>
<td>(6)</td>
<td>Yes</td>
<td>Yes, 200 trees</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>78</td>
</tr>
<tr>
<td>(7)</td>
<td>No</td>
<td>Yes, 200 trees</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>188</td>
</tr>
<tr>
<td>(8)</td>
<td>No</td>
<td>Yes, 3400 trees</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>1266</td>
</tr>
</tbody>
</table>

an Intel Pentium 4 CPU 2.80Ghz, ATI Mobility RADEON 9000 IPG video card, 384 Mo of RAM. All billboards are generated from plant data of AMAP Genesis™ software, and the design of a forest is from AMAP .sce file through AMAP Landmaker™.

This technique is tested with three forest examples. Figure 2 and Figure 3 show a young forest with white poplar, apple and holly trees. Four snapshot images have been synthesized with this software. Figure 2(a) is taken in an early morning, and Figure 2(b) is taken at noon time. Figure 3 is synthesized to simulate a forest at sunset. The total number of trees in this example is 3400. All these shows that this technique can be used in two aspects: (1) realistic simulation of forests in different daytime, and (2) an immersive navigation in a forest.

The efficiency of this software is shown with different parameters in Table 1 for the forest in Figure 2 and Figure 3. The parameters include: (1). *Clipping*: view frustum clipping or not, (2). *Sorting*: tree sorting or not accompanied by the number of closed trees to be sorted, (3). *Mipmaps Rendering*: Mipmaps images are used for shading or not, (4). *Static Shadow*: shadow generated from static images, (5). *Mipmaps Shadow*: Mipmaps images are used for Shadow or not, (6). *Milliseconds*: milliseconds spent for each frame. This table shows that object sorting can be a factor of big burden, and frustum clipping is a factor for acceleration.

Figure 4 shows a big forest of 16888 trees. Two species are included. Holly tree and Scot Pine trees are included. The ages of Holly trees used for this example are from 21 to 23. The ages of Scot Pine trees here are from 23 to 25. The rendering speed is from 18 to 22 frames per seconds.

In order to show the application of this technique to forest growth simulation, AMAP plant growth mechanism is applied to the virtual forest in Figure 4. The ages of the simulated Holly trees are expanded from 7 to 23, and the ages of the simulated Scot Pine trees are expanded from 5 to 25. Figure 5 shows the simulated growth the the virtual forest from its initial state to 5, 10, and 15 years later.

7 Conclusion and further work

This paper provides a new image based rendering approach to visualize a virtual forest fast and realistically. The key point of this paper is the application of several techniques: alpha blending, mipmaps, stencil buffer, and object distance sorting. This approach is view-dependent, since the choice of a billboard and the rendering order of different objects are all dependent on the viewer.

This approach can be used for the visualization of the models of forest, crops, landscape, and land use. It can also be used for virtual reality and education.

This work can be improved in the following aspects:

1. The geometry and the billboards are not consistent for a tree with a non-symmetric crown, so more images should be used [11].

2. In order to have a better parallax, a full geometric model should be used to represent a close tree.

3. Multi-resolution billboards should be generated according to the topological structure of plants. It deserve to construct billboards in different levels: side branch level, substructure level, and organ level.

4. Distance sorting is a time consuming process. BSP-tree should be used to have a faster distance sorting.

5. In order to make this approach applicable to the simulation of forest evolution in a fast way, it should be integrated with plant growth modeling and forest growth modeling.

Acknowledgement

Thanks to reviewers for their constructive suggestions. This work is supported by National Natural Science Foundation of China projects No. 60073007, 60473110, and 30371157; by National High-Tech Research and Development 863 Plan of China under Grant No. 2006AA01Z301; by the French National Research Agency within project.
Figure 5. Growth Simulation of a mixed forest of conifer and broad leaf trees.

References


