Fast Forest Visualization on Hierarchical Images and Visibility

Qingqiong DENG[1,2], Xiaopeng ZHANG[1,2], Xiangdong LEI[3], Marc JAEGER[4]

[1]Sino-French Laboratory LIAMA, CAS Institute of Automation, Beijing, China
[2]National Laboratory of Pattern Recognition, CAS Institute of Automation, Beijing, China
[3]CAF Institute of Forest Resource Information Techniques, Beijing, China
[4]INRIA-Rocquencourt, Project DigiPlante, CIRAD AMAP, Montpellier, France
{qqdeng, xpzhang}@nlpr.ia.ac.cn, xdlei@caf.ac.cn, jaeger@cirad.fr

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Introduction

Fast visualization of plant functional and structural information facilitates the understanding of the natural disturbance of trees in a forest. It is an important work in forest management on forest growth, species composition, forest structure and dynamic changes at different scales. Plant growth modeling has been widely researched, and many successful methodologies have been developed, such as L-system (Prusinkiewicz et al, 1990) and GreenLab (Yan et al, 2004). Using such approaches, plant modeling is efficient with high realism. However, the geometric complexity of representing a forest with thousands of plants usually far exceeds the processing and rendering capabilities of current computer hardware. Thus, specific software techniques should be developed for fast forest visualization.

One efficient rendering technique is the image-based rendering. Complex geometry of trees is represented by a few texture-mapped polygons (Meyer et al, 2001), so that the rendering is drastically accelerated. Unfortunately, classical image-based methods usually produce weak parallax effects due weak geometry. Billboard clouds (Behrendt et al, 2005) show a better balance between plant geometry and parallax with a static set of free oriented billboards. However, this method consumes immense memory for textures, and foliage occlusion is not considered.

We propose an improved approach with billboard clouds for interactive visualization of functional structural plant models. A billboard hierarchy is generated corresponding to the plant topology in preprocessing. And a view-dependent billboard level is chosen from the hierarchy to represent the geometry on both distance and visibility of the plant in rendering. Besides, The plant self-similarity (Ferraro et al, 2005) is applied to reduce the memory cost for textures.

Hierarchical Structure of Billboards for Foliage

The hierarchical structure of a plant is use here, where the side branch of the trunk is called as level-1 branch, and their children branches are called as level-2 branch, etc. We define a sub-tree structure for each branch as a set of all its successor branches, their associated leaves and the branch itself. Then a billboard is generated corresponding to each sub-tree level. The form and the number of all billboards in a sub-tree are calculated through the approach of Behrendt (Behrendt et al, 2005) according to the size of the bounding box of the sub-tree. For each billboard, a texture is created for each side by an orthogonal projection of all included geometry onto the billboard. The resolution of all textures is independent of the bounding box size, but it is defined by the user.

One optimal case to represent a sub-tree with a billboard happens when the projected size of the sub-tree equals to the size of the billboard. For each sub-tree, a distance, called optimal distance, is calculated so that the optimal projection will happen. After obtaining optimal distances for all sub-trees, the billboards are organized into a hierarchical data structure according to the levels of their corresponding branches. The optimal distance of each billboard is recorded also.

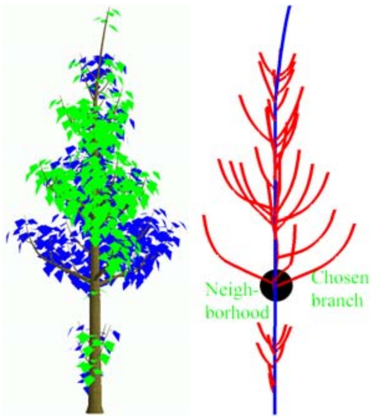
In rendering, the hierarchical structure is traversed until reaching proper nodes, whose optimal distances are not larger than the current distance between the rendered tree and the viewer. In this way, an appropriate LOD model is obtained. In order to alleviate popping artifacts between different levels, neighboring LOD level of textures are alpha blended.

Visibility Algorithm

The positions of branches give a strong hint about the occlusion of organs: leaves held by "rear branches" are more often occluded by other leaves and branches than those held by "front branches". Based on this observation, Deng et al. propose a simple visibility algorithm (Deng et al. 2007) of some leaves on the dot product of the viewing direction and direction of the level-1 branch, which holds the leaves. If the product is positive, all leaves held by this branch are as more or less occluded. But this algorithm does not guarantee a precise visibility. As shown in Fig.1(a), if level-1 branches distribute sparsely around the trunk, the rear branches and leaves (in blue) will not be occluded by the front ones (in green).

In order to overcome the above drawback, the density of level-1 branch is considered as another visibility parameter for each level-1 branch in this new approach. This density is defined as the number of sibling branches falling in the neighborhood of the considered branch (see Fig.1(b)). Then, if a branch is located in a space with low density, the branch and its leaves should be considered as visible, even its corresponding dot product is positive.

Therefore, the density-adapted visibility is used as a scaling factor on the distance in rendering, so that when traversing the hierarchical structure, the optimal distances of occluded sub-trees will be compared with scaled distances. In this way, invisible regions of a tree are rendered with less detail than the visible, so that fewer billboards are rendered while visual quality is maintained.



(a) Front view (b) Density definition

Fig. 1: Visibility calculation

Memory Strategy

However, like other image-based approaches, the memory cost for the texture images of all sub-trees is still a bottleneck in our algorithm. Fortunately, trees show self-similarities: leaves of a tree look like each other, and a branch may be similar to several others. Even one whole tree looks like another tree with the same species and a similar age. So a tree can be represented by a small number of representative sub-trees. Two sub-trees are represented by a common instance if they have the same levels and similar number of leaves, as well as similar number of child branches. Only representative texture images are saved, and one representative is assigned to a sub-tree of the plant. As a result, the memory cost is dramatically reduced.

Application to Forest Management

With this technique, a visualization tool is constructed for tree crown health monitoring (such as color and the number of leaves) and silviculture decision (for example, thinning and selective logging). Structural information was combined with individual empirical growth models here for tree growth projection (Lei et al., 2006). Visualization techniques developed in our study, in conjunction with GIS, were applied to demonstrate the application of realistic visualizations to depict the dynamic change of forest resource at the stand level and the landscape level. Fig. 2 shows an example of larch-dominant mixed forest with spruce, fir, ash and birch etc. in Northeast China. 4992 tree samples are included in this forestry. The shadow is generated through stencil buffer and the projective mapping of billboards on a planar ground. The rendering speed is 2 to 12 frames per second for shading and shadows on the ground.

Fig. 2 Interactive visualization of a larch-dominant mixed stand

Conclusion

We propose a view-dependent image-based rendering method in this paper to construct multi-resolution models for trees and plants. Rendering of both single plant (or stand) and forest (or landscape) are supported. Compared with other image-based methods, the main advantages of our method consist in multi-resolution representations, view-dependency, lower memory costs, and higher efficiency in pre-processing leading to higher data compression. Therefore, a proper frame rate is realized in rendering, and it can thus be used for the applications in forestry visualization.

This approach can only be used to static trees and static plants, so it cannot be directly used for rendering a developing forest. Popping artifacts is still obvious, so that a more continuous method should be developed in the future. Furthermore, at present, only the occlusion within a tree is considered. A more promising aspect, the occlusion among different trees should be taken into account in our future work for further decrease of the geometric complexity.

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