The Algorithmic Beauty of Digital Nature

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In recent years the development of graphics hardware and efficient rendering algorithms enabled game developers to create large landscapes and render them at interactive rates. However, the shown scenes are still rough approximations that do not reach the complexity of real nature. To obtain sufficient simulations with a degree of realism that comes close to nature, a couple of problems have to be solved. In this extended abstract these challenges are roughly sketched, references are given for further readings.

1 Modelling

Creating a good scene requires powerful modeling algorithms at different levels. First a sufficient set of plant models has to be created. Nature is very diverse: modeling the most important plants that are found in Europe requires thousands of different models, and this is why efficient modeling algorithms for plants have to be found. In our software xfrog we combine rule-based modeling methods with procedural elements. This allows us creating a large variety of models efficiently. For an overview of the method I refer to [1]. Figure 1 shows an example of modeling a sunflower. The user combines components to create the model. The components describe parts of the plant or multiplication algorithms.

The plant models then have to be combined to a virtual landscape. At this stage other modeling programs are needed that enables the user to edit a huge number of plant objects. The plants interact with each other; complex patterns arise due to seeding mechanisms and the fight for resources. Sometimes, the development of a landscape has to be simulated. We developed a series of modeling tools ranging from painting interfaces for plant distributions up to complex ecological simulation algorithms. Chapter Three of [1] gives an overview of possible methods.

2 Level-of-Detail Modeling

Having modeled plant models and positions, we end up with very complex geometry even for a small landscape. A single tree model may consist of millions of surfaces, a complete forest of billions or trillions. Efficient level-of-detail algorithms are necessary to obtain interactive rendering of these scenes. Unfortunately, standard algorithms for computer graphics fail here since a plant consists

M. Kaufmann and D. Wagner (Eds.): GD 2006, LNCS 4372, pp. 5–7, 2007.

Fig. 1. Construction of a sunflower model

of many isolated triangles while conventional surfaces in graphics typically are smooth. Therefore, we developed special Level-of-Detail algorithms for plants that work with pointsets or so-called billboard clouds. In Figure 2 a representation of a complex plant by sets of billboards is shown. If standard clustering techniques are used to determine proper billboards artifacts occur. An improved method uses clustering together with semantic information about the model (see [2]).

3 Rendering

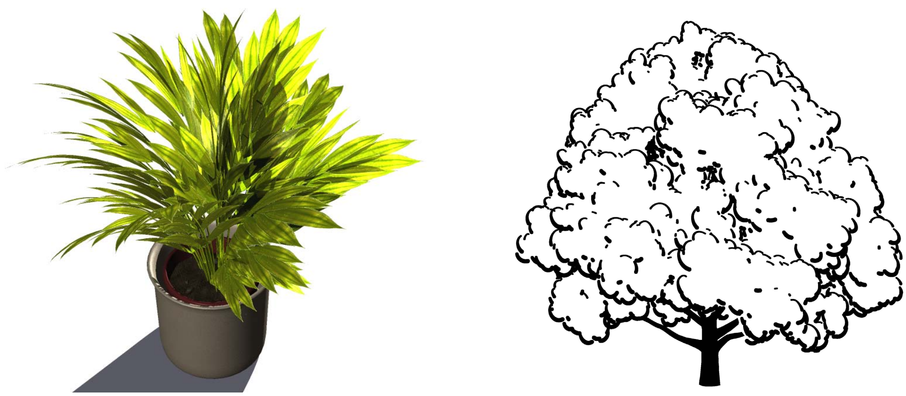
Rendering the models is also an interesting task. The interaction of light with the plant surfaces and especially leaves is not trivial. Subsurface scattering and different optical properties of plant tissues require to adapt standard rendering techniques to these models. This is done by modeling the leaves as layered surfaces with different optical properties. Doing so, we are able to simulate the optical properties (Figure 3(a)).

4 Non-photorealistic Rendering

For many applications photorealistic rendering is not optimal. This is why we also focussed on abstract representations of plants. This encompasses pen-and-ink illustrations as well as watercolor simulations. We combine photorealistic and abstract representations in order to visualize existing and planned elements in landscapes. This is used in gardening, landscaping, and architecture.

(a) (b)

Fig. 2. a) Approximation of a tree model by sets of billboards. Left the original model, in the middle a standard k-means clustering, on the right an improved clustering; b) Landscape with billboard plants.



(a) (b)

Fig. 3. a) Rendering a plant model with translucency; b) Non-photorealistic rendering

References

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2. Behrendt, S., Colditz, C., Franzke, O., Kopf, J., Deussen, O.: Realistic real-time rendering of landscapes using billboard clouds. Computer Graphics Forum **24** (2005)