Visualizing botanical trees over four seasons

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1 Introduction

Visualizing the growth process of botanical trees over the spring, summer, fall and winter seasons along with the natural effects of wind, ice and rain on the trees can be a useful tool for scientific research or even artistic display. This paper presents a method for visualizing the growth process of different botanical tree species over the four seasons of a year. The proposed method uses a data model to store a random three-dimensional tree and quickly render it using interactive 3D real-time animation. The tree model contains operations to sprout leaves and grow in the spring and summer, and to change the color of the leaves in the fall, which eventually fall off for the winter. This process can then be repeated interactively to show the full life cycle of a botanical tree. The extension of the system to realistically handle natural weather effects will also be outlined. Tree growth is based on a set of stochastic parameters that can be modified to produce different tree species. Results show efficient real-time animations of realistic looking random botanical trees.

2 Previous work

Early results in real-time 3D animation of botanical trees show that tree structures can be modeled and animated using fractals, built from a set of modifiable stochastic parameters [Oppenheimer 1986]. Both scientific and artistic results were observed. More recently, researchers have animated the behaviour of botanical trees under the strain of external forces [Kanda and Ohya 2003; Sakaguchi and Ohya 1999]. In this approach botanical tree models are built from volumetric data captured by images of a real tree. Results show more realistic trees that are animated to visualize external forces such as wind and human interaction in real-time. Other research has been performed on visualizing the growth and manipulation of botanical plants using L-Systems [Prusinkiewicz et al. 1993; Power et al. 1999], including the competition for space, light and water in the soil [Mech and Prusinkiewicz 1996]. However, none of the previous research on real-time visualization of botanical trees takes into account the different seasonal behaviour of the trees.

3 Tree model

Similar to [Oppenheimer 1986], the underlying data model is a random tree based on the stochastic mean and standard deviation of a specific set of growth parameters. This approach is also similar to [Sakaguchi and Ohya 1999] in that the nodes of the tree are at the joints between branches. Each internal node contains pointers to left and right branch data as well as pointers to the two child nodes. Leaf nodes contain pointers to leaf data. The tree model is illustrated in Figure 1 with data pointers drawn as dashed arrows. The tree model contains recursive operations to support the functionality that is described in section 4.

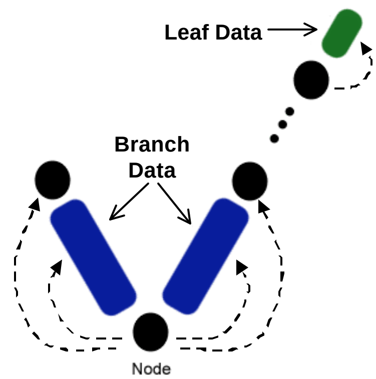

Figure 1: Tree model structure

The main advantage of this new system is the ability to visualize the trees over all four seasons. Interactive natural weather effects can also be integrated with ease.

4 Random growth process

The growth process for the trees in this visualization method is based on a set of stochastic parameters. This ensures that each time the process is executed a completely different random tree will be generated.

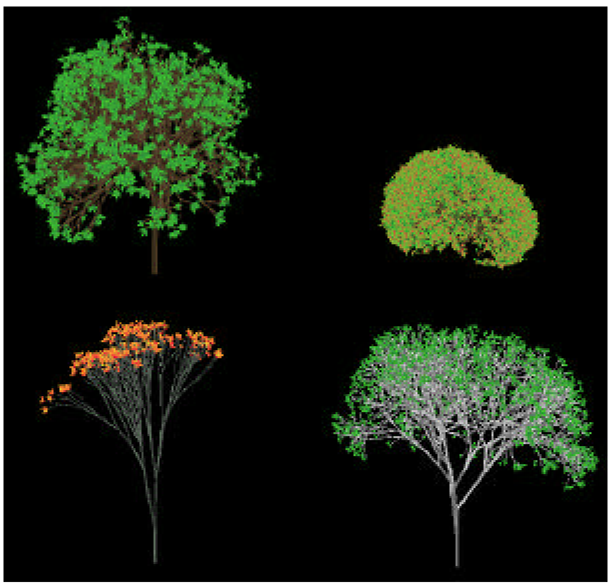

Figure 2: Different species generated by the tree parameters

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A growing tree simulates the summer season. The leaves slowly change to bright and brilliant colors in the fall, and then eventually fall off for the winter season. Finally, sprouting tiny leaves and new growth from the bare winter tree simulates the spring season, and the process continues. When growing, branches grow longer and thicker at different rates, new twigs and leaves are sprouted at random orientations, and leaf colors change randomly when simulating the fall season. Generating the trees is an interactive process. Users can control in real time how long a single tree will grow for, when to start the fall coloring, and how long the winter season will last. By simply changing the stochastic growth parameters, new and interesting tree species can be generated (See Figure 2). As with [Oppenheimer 1986] both realistic and artistic results can be achieved. In all cases, the random botanical trees are animated for visualization.

5 Natural weather effects

In addition to the growth process, visualizing external forces such as wind, rain or ice build-up on branches can also be very useful. Although the current tree model does not provide visualizations of such natural effects, extending the model to allow for those visualizations is a simple task. Each branch of the tree contains information about its orientation relative to its parent branch. This allows for fast rendering of the tree by starting at the root and recursively rotating for the correct branch orientation, rendering the branch, and then translating by the branch length to prepare for the next one. However the relative orientation information can also be used when determining the effects of an external force on the tree. For instance, if a branch is rotated towards the ground with a fixed end point to simulate the effects of ice build-up making the branch heavier, then all of the child branches from there to (and including) the leaves will be rotated automatically. This is the natural effect that one would expect. So the process of visualizing an external force would be to recursively examine each branch, determine the effects of the force on that branch (based on branch length, width, global orientation and the direction of the force), and then rotate the branch, keeping the first end point fixed. Leaf orientations would also be updated in a similar manner. An important issue would be to keep track of the current global rotation throughout the recursion, since all of the orientation information for branches and leaves is relative to the parent branch. Using this technique, rain or ice build-up can be simulated with a downward force and wind can be simulated with a force in almost any direction.

6 Results

The results of the proposed visualization method are efficient real-time animations of realistic looking random botanical trees. Snapshots of one such animation are shown in Figure 3 for one of four simulated tree species. The tree starts as a twig with only a few leaves, grows into a mid-size tree, has its leaves change color and fall off, and then it sprouts new leaves and continues to grow. Figure 3 shows the growth cycle for two full years. (Note that as the tree grew bigger the view was zoomed out so that the tree occupied most of the window at all times).

Figure 3: Snapshots of four-season botanical tree growth

Demo videos of different tree species growing through the four seasons can be downloaded from the project website (http://www.derekbradley.ca/ResearchProjects/RealTrees/).

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