Pushing the limits of L-systems for time-lapse vine growth in "The Time Machine"

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Figure 1. A final composite of the L-system vines and flowers

Background

Dreamworks Pictures film "The Time Machine" presented a number of interesting problems related to creating time-lapse photography using computer animation. I was assigned with the task of making realistic vines creep and grow along the surface of the green house as the main character began to move forward in time. In order to keep such a complicated task manageable, I needed to organize the order in which things were processed to keep things workable as changes were made. The pipeline needed to be designed in such a way so that the maximum amount of processing is taken care of at the earliest stage.

The vine growth animation for Time Machine required me to generate a unique and manageable growth system and a rendering system that complimented this movement. The work was completed with Side Effect Software's Houdini and Pixar's Photorealistic Renderman.

Motion

Vine motion was broken into two categories designated pre-cook and post-cook. The procedural animation of generic vine models was separated into the pre-cook phase. These were basically individual vines grown straight up from world center which had all of their individual characteristics baked in. The term "pre-cook" refers to the fact that, because the generation of this animation was so computationally expensive, the animation itself was done only once and then saved and applied multiple times within the scene later.

Thus, post-cook motion is any animation done to the vines after reading those sequences of cooked vines off disk. This motion happened on a per frame basis so that individual frames could be rendered on the render farm without any simulation roll-up costs.

Pre-cook motion

The Houdini L-systems operator was excellent for sculpting the look of a plant, but was limited in its ability to adjust values to cause motion over time. An alternative approach to create animated motion on the L-system would be to do all motion of the vines in a procedural network after the L-system has cooked. This was impossible since, after exiting the L-system environment, you leave behind all hierarchical information. A branch no longer knows where it grew from, so rotating the data along the bases to move them like kinematics becomes impossible.

The first thing we did was to feed each vine a different generation value so that they had unique growth behavior. A simple procedural curve network was used to create a number of different growth patterns. Each vine builds itself on one of these curves, selected by the index of the vine. Thus, variable curve values allow for the appearance that branches are overtaking one another by increasing and decreasing speed at different times.

One of the challenges was to insert some behavior into the rule that gave the look of constant breathing of the branches. I wanted to make the branches look as if they had constant jitter going on to create a time lapse effect. To achieve this, I placed little rotation "motors" all over my vine joints. Every generation found its rotation rule and randomly rotate/pivot/twist the orientation of each branch. This caused my branches to jitter a bit every frame, and often slide around a little over time if probability leaned in either the positive or negative direction over time. Since this was a recursive rule, as long as the vine gained new generations, the rotation values would always be changing, causing twig fluttering.

Post-cook motion

The vine animation along the side of the greenhouse needed to be carefully timed with the camera pan. Since there was a set number of pre-cooked frames of each vine's growth, I was able to start each vine growing exactly when I wanted it to. The Director asked to have individual vines be shorter or taller at different times, so I needed a system to be able to offset the start frame of each vine as needed. To achieve this, I imbedded an offset into the height of each birth point of the template geometry.

Using the ability to assign varying parameters to different copies of the same geometry, I was able to read in the sequence of vines along a series of points. By modeling the height of the template points slightly, I was able to interactively time the vine growth so that they didn't grow out of camera, didn't start or finish too early, or any other timing related problems.

Vector Blur

Motion blur was used to create look that indicated that the vine had repositioned itself a number of times while the shutter was open for the duration of a frame. Houdini allowed me to fabricate vectors indicating motion blur that didn't necessarily correspond to the motion taking place in the animation. The vectors were created by adding together two directions to each point per frame. The first value represented the direction that the point was actually traveling in during the growth.

The second value was generated by rolling 4d noise vectors based on position through the points of the vine, giving me smooth, flowing blur around the vine. Adding these values gave me the direction of the motion blur for each portion of the vines.

Given those directions, I still needed to make sure that the blur did not "push" the geometry around, but only blurred it. I backed the position of every point halfway along the vector that that frame would be blurring, assuring that the geometry would always be centered along the blur and not appear to pop every frame.

This magic combination of steps allows me to create smeared, "time lapse" looking blurs across different parts of the vines at different times. This technique was used in varying degrees on most of the plants in Time Machine.