Design Methodology: Animating a Snowlily

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1 Introduction

One of the ongoing goals of computer graphics is to generate images that push the envelope of realism. My particular area of research involves the rendering of photorealistic plant images. I am currently using the photon mapping renderer Dali, courtesy of Dr. Henrik Wann Jensen (Stanford University), to produce renderings of plant models constructed with Vlab software. I have been learning to write shaders that capture the essence of light interactions with leaf surfaces - for example, diffuse transmission of light through a leaf and subscattering of light rays within the layers of a leaf.

While taking the Design Methodology course, I was presented with the challenge of applying a particular design process to some aspect of my research work. A number of speakers in diverse fields ranging from fine arts to evolutionary programming shared their own design principles. A presentation by Kaye Mason, who discussed the design process for animation, caught my interest. All the plant renderings I have made thus far are static - I position the virtual camera and take a single snapshot of a plant model or scene. I realized it would be interesting to create animations whereby a camera flies around a tree or wind rustles a bushel of leaves. Such animations would allow us to view light interactions with leaves and petals dynamically from different vantage points. As the angle between the plant surfaces and light sources change, we could view the gradual shifting of shadows and transmitted rays.

Dr. Gerry Hushlak, a professor from the Art Department, mentioned that one of the central goals of art is to provoke a reaction from the viewer. A realistically rendered, animated plant model, swaying in a breeze, with semi-translucent leaves that cast overlapping soft shadows, would very likely elicit a strong viewer response. It is also worthwhile to add that unlike certain works in the world of art (eg. Tatsumi Orimoto's photos of his mother wearing unconventional, degrading attire), a plant animation should not raise serious ethical questions.

During the course of this two week project I built an export module for Vlab, Graphics Jungle's plant modeling software package. The module exports plant models as Wavefront object files that can be read into Maya. Using Maya, I followed the design methodology described in John Lasseter's paper, Principles of Traditional Animation Applied to 3D Computer Animation, to create a short 10-second animation of a snowlily swaying in a breeze (see Figure 1). Because of time limitations, the project focussed primarily on the animation of the lily rather than realistic rendering of the frames.

2 Applying the Principles of Animation

Because Lasseter's paper is largely targeted at character animation, this section discusses those design principles that

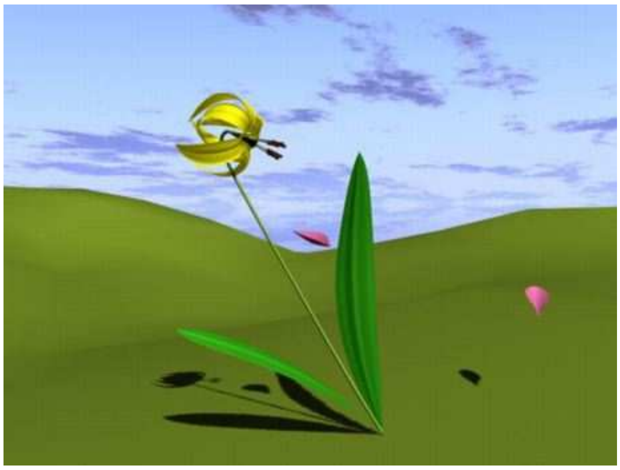

Figure 1: A strong gust of wind hits the snowlily.

work well for realistic plant animation and those that are less relevant. In the end it is surprising to see how many principles can be successfully employed in ten seconds of animation.

2.1 Keyframes: Pose-to-pose Action

The most important design principle for this project was the concept of *pose-to-pose action*, or *keyframes*. The idea is to position a model into key poses at successive time intervals. The frames between the intervals interpolate the motion between those poses; this is known as *inbetweening*. Maya provides a very robust keyframing environment, whereby the user inserts a keyframe marker on the time bar and provides the model's current parameters, such as translation, rotation, or scale. Maya automatically generates the frames between chosen keyframes, calculating the intermediary parameters for the model using spline interpolation. As a result, smooth transitions between keyframes are achieved.

2.1.1 Grouping of Plant Organs

When keyframing complex models, Lasseter explains that separate transformations may need to be applied to its individual parts. While planning the snowlily animation, I realized I would need to break the flower down into its constituents, such as leaves, petals, and stem, so they could be animated separately from each other. Because the object file format supports grouping of polygons, the Vlab export module should have the ability to write out a plant model as groupings of organs. The key decision was how to define a grouping. That is, how should the export module decide when to end a grouping of polygons and when to begin a new one? I resorted to parsing the L-system language that describes a plant model. L-systems consist of a series of symbols that act as drawing commands. I decided to begin a new grouping at the occurrence of specific symbols, the candidates being:

The pound symbol describes a change in material color. While grouping of polygons by color might work in some cases, it is not always practical. For example, if the leaves of a plant are all the same color, all leaves will be grouped together. This prevents animation of individual leaves.

@# The at-pound symbol denotes a change in the contour of the plant organ. This would group together organs with a similar shape. However, as with material color, if leaves all have the same contour (most of the time they do), they would fall into a single group.

[] The square brackets indicate the beginning and ending of a segment. They act similarly to "push" and "pop" operators in programming languages. They are frequently used to describe branching segments in a plant model - for example, twigs branching from a stem, or leaves branching from a twig.

By defining any portion of a plant model described within square brackets as a group, I found that new groupings began at the "hinges" of a plant, such as the base of a twig, the base of a leaf, or the base of a petal. This proved very useful, as movement of plant organs often consists of rotations around these hinges (picture a waving leaf attached to a branch). When I imported the object files into Maya, I could freely and independently manipulate the different parts of the plant (see Figure 2).

2.1.2 Hierarchical Modelling

While keyframing can be used to adjust different objects independently, Lasseter suggests that several parts may need to be transformed together. This issue arose with the snowlily animation, where the stem and flowerhead (the petals and reproductive organs) needed to sway in unison. At the same time, the petals on the flower needed to wave independently.

Lasseter proposes a hierarchical modeling system, where the trunk of the hierarchical tree structure is transformed first, followed by transformations in lower branches down to the end. Maya's Hypergraph tool allows portions of a model to be grouped together and placed within a hierarchy. By creating a body grouping consisting of the stem and flowerhead (see Figure 3a), I could rotate the body of the flower as a whole (see Figure 3b). In turn, the flowerhead grouping contains a petals grouping. All the individual waving petals are transformed independently, and their transformations get concatenated with the transformations of the body higher in the tree.

2.2 Arcs and Timing

A second design principle that is very visible in the animation is the use of *arcs*. When a gust of wind blasts the snowlily, several blossoms can be seen swooping through the scene. These blossoms follow the path of spline curves with

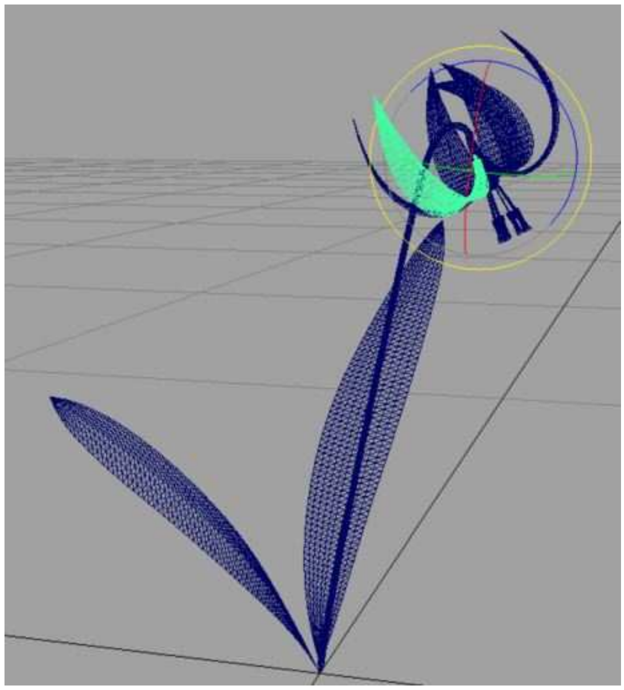

Figure 2: A wireframe view of the snowlily, with a single petal selected.

C2 continuity (see Figure 4). Lasseter claims that arcs help to make an animation look smooth and take away the rigidity and monotony of motion along straight line segments.

Timing is another design principle, in that it determines the speed of an action and therefore lends meaning to movement. The rapid timing of the blossoms reinforces the notion that a strong blast of wind is passing through the scene. Maya allows the user to indicate the start and end times for motion along a spline, as well as to place control points that represent intermediate times. According to Lasseter, the timing of the frames between key poses is also important, as it helps to define the weight of an object. When the blast of wind arrives, the acceleration of the snowlily leaves is less than the acceleration of the stem and flowerhead to emphasize the greater weight and density of the leaves. As well, the overall rapid bending motions of the snowlily suggest that this is a relatively small plant; a ten metre tree, for example, would not react so quickly to a strong gust of wind.

2.3 Stages of an Action

Lasseter breaks down the duration of an action into three stages: anticipation, staging, and follow-through. He considers each of these stages a separate principle of animation.

Anticipation refers to the preparation for the action. It directs the audience's attention and helps them to predict the speed of the action. Lasseter speaks of anticipation in terms of character animation and overemphasizes anticipation in ways that would not be appropriate for capturing realism (eg. Wally the Bee compresses to two-thirds his length prior to flying away). Still, in the snowlily animation, the gentle swaying prior to the strong gust of wind acts as a form of anticipation, as the viewer realizes ahead of time there is turbulence in the air.

According to Lasseter, *staging* "is the presentation of an

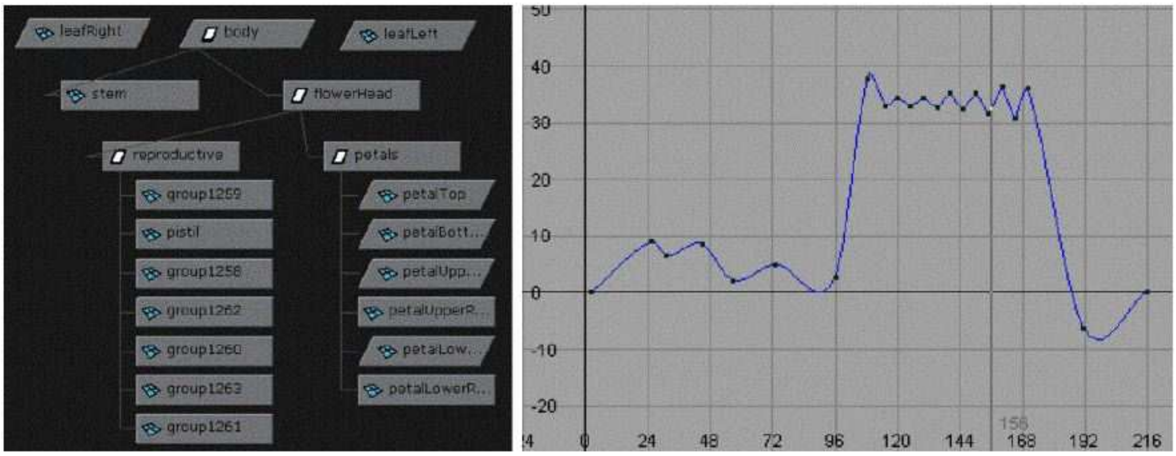

Figure 3: a) *left* Hypergraph view displaying the grouping of plant parts into a hierarchical tree. b) *right* Graph Editor revealing the rotation of the snowlily body as a function of time.

idea so it is completely and unmistakably clear." A strong gust of wind is unmistakably presented by bending the stem of the lily very hard, producing oscillations in the stem and petals, and sending blossoms flying through the scene. The turbulent motion of the clouds also helps to stage the wind.

Finally, *follow-through* action terminates the motion in a smooth, non-jarring manner. After the windblast, the snowlily rises back to its standing position, but in doing so overrotates before correcting itself. The overrotation substantiates the prior violence of the blast.

2.4 Appeal

Lasseter describes *appeal* as the quality of liking what one sees. In many ways, this principle comes for free in realistic plant animation, as most plants are by nature appealing to look at. Furthermore, Lasseter explains that appeal can be achieved by avoiding "twins", a condition where the construction and actions of a model are symmetric. Biological growth, while sometimes appearing symmetric at a superficial level, is rarely symmetric in actuality (for example, consider the two halves of a face). The snowlily model, besides the fact it is the only model in the animation, could be said to attract attention and therefore portray appeal.

2.5 Remaining Principles

Lasseter lists several other animation design principles that were less relevant to the snowlily animation. The principles of *squash and stretch* and *slow in and out* pertain primarily to bouncing objects or animate characters. These principles encourage deformation of objects and snappiness of motion that may benefit cartoon-style animations, but would take away from the realism of a true-to-life animation. The same could be said for the principle of *exaggeration* - although I have employed exaggeration to a certain extent in the excessive bending of the stem and the looping path followed by one of the blossoms. Would a blossom really follow a 360 degree path around the stem in such a strong wind? Not likely. Does it add entertainment value to the scene? Absolutely! Finally, the principle of *secondary action* could not be explored because of the shortness of the animation.

2.6 Future Animation Work

Due to the short duration of this project I have only scratched the surface or realistic plant animation. One of the major limitations is the rigidity of the surfaces. All motion takes place around the pivot points of the surfaces, but the surfaces themselves are unbending. This gives the snowlily a rickety appearance. Physically based modeling could be added to simulate real wind and its effects. The shaders used in the animation are simple phong shaders that do not fully capture realistic light-surface interactions with plants. One option is to export the Maya generated frames into the Dali renderer and employ subsurface scattering for rendering.

3 Data and Graphical Representation

Richard Levy, a professor in the Faculty of Environmental Design, discussed the role of digital media in the design of virtual spaces. Traditionally, the planning of a new building or city layout requires the drawing of maps on paper or creation of models out of clay to provide a reference for the construction process. Using a blueprint map or model, it is possible to get a view of the final design as well as to decipher measurements that are needed in the actual construction. The problem with a map or model on traditional media is that it is a static source of information. If a viewer examined the exterior view of a cathedral drawn on a piece of paper, but wanted to step inside to view the interior, it would not be possible unless the designer redrew the building from the new vantage point. Unfortunately, creating the new drawing of the interior will require just as much time and effort as creating the exterior drawing. Traditional media have the disadvantage in that both the data its graphical representation are inseparable. A pen and paper diagram of a cathedral conveys geometric data about the building's structure, but there is no way to make immediate use of this data for a new drawing (ie. a new representation).

The introduction of digital tools in Environmental Design has very much revolutionized the design process. For the first time, it has become possible to conveniently separate data and graphical representation. Models of houses, cities, or subway stations can now be reduced to large files of geometric data. The data, in turn, can be imported by a variety

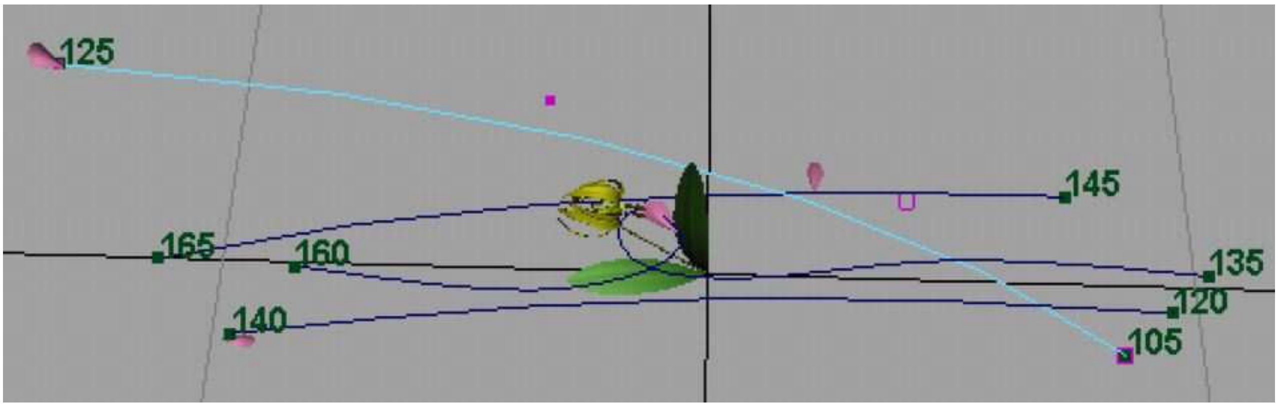

Figure 4: Splines indictae the paths of the blossoms as well as their start and end times.

of applications that interpret and represent the data in different ways. For example, the data file for a bridge can be read by a CAD program in order to view the model. The view can be recomputed on the fly, because the geometric data is readily available and simply needs to be reinterpreted from the new vantage point. The same data file can also be read into a structural stress application to view the stresses on the joints and beams that carry the weight of the bridge: same data - but a completely different representation. Richard pointed out that in this way data has become more important than the graphic representation. To painlessly acquire a new graphic representation, it is essential to have an independent body of data in the first place.

Richard's remarks instantly struck a chord with my own project. The plant models that I export from Vlab are stored in the Wavefront object data format. My sole intention was to be able to read the plant models into Maya for animation purposes. Within the past two weeks, however, two individuals expressed interest in using the object files for their own research. Dr. Mario Costa Sousa is currently working on non-photorealistic rendering of plants. His renderer also reads the object file format and it could accept the snowlily model. The exact same data that produced the solid, phong shaded lily in the animation now produces a stylized pencil sketch (see Figure 5). Colin Smith is developing subdivision schemes for surfaces, and is also employing the object format for reading models. Within a few weeks we will be looking at subdivided snowlily models. From one data file, we are getting three distinctly different graphical representations.

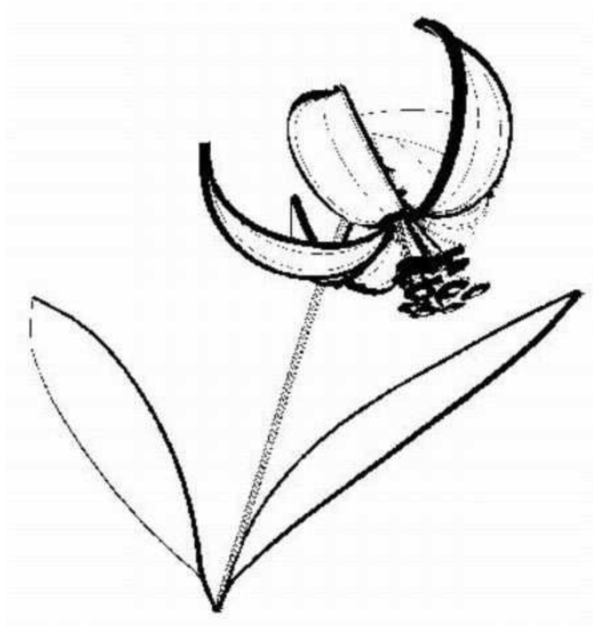

Figure 5: Non-photorealistic rendering of a snowlily in pencil sketch style (courtesy of Dr. Mario Costa Sousa).

4 Conclusions

The goal of this project was to produce a realistic animation of a snowlily following the design principles set out by John Lasseter. While the end product is an animation that could still benefit from further work, it successfully employed seven of the eleven animation principles. Most of the unused principles are aimed more at cartoon-style character animation and would therefore take away from animation where realism (rather than entertainment) is the goal.

Bibliography

Lasseter, John. Principles of Traditional Animation Applied to 3D Computer Animation. In *Proceedings of SIGGRAPH '87*, pp. 35 - 44. July, 1987.