Interactive Modeling of Mushrooms

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Abstract

This paper presents a fast and efficient method for modeling mushrooms. Starting from a real world image, the designer defines a silhouette and specifies deformation parameters. Our system then automatically generates a textured triangle mesh model using a procedural modeling pipeline. This approach enables us to create a vast variety of shapes easily using shape morphing.

1. Introduction

Synthesizing realistic images of landscapes covered with vegetation is a challenging and important problem in computer graphics. Complex sceneries include natural living ecosystems such as forests, stone statues or monuments colonized by lichens or covered by fallen leaves in autumn.

One first challenge stems from the complexity and diversity of biological species interacting together and with their environment. The modeling of plant structures [10, 11] as well as the simulation of complex ecosystems [8, 2, 4] has been well researched. Another challenge is to create realistic complex textured models in an intuitive and direct way, while allowing interactive manipulation and visualization of the resulting shape. In particular, several techniques have been proposed to model leaves [9] and bark [6, 12].

Contrary to trees and flowers, mushrooms do not exhibit a regular branching structure. Because most mushrooms develop only on specific substrate and under favorable weather conditions, they play a major role in the visual impact of a natural scene, providing hints to the viewer whether it is autumn or spring, whether it has rained recently or whether the area is in the shade of trees or directly exposed to sunlight.

In this paper, we propose a system for modeling mushrooms with stems and caps after real world images. Our approach consists in using a generic surface of revolution model and characterizing the specific features of every model through deformation and texture parameters. This approach enables us to create different instances of the same model easily, and to store template models into an atlas.

Since the complexity and diversity of mushrooms in terms of shape and texture makes modeling every single mushroom by hand impossible, we present a method that produces a vast variety of models automatically by morphing the control shapes and interpolating their parameters.

Figure 1: *Some mushrooms growing near a tree*

The remainder of this paper is organized as follows. In Section 2, we briefly review some previous work on the modeling of plant components such as tree branches and leaves. In Section 3, we present our mushroom modeling system. We address the modeling of varieties of mushrooms using morphing in Section 4. We conclude this paper with a presentation of examples, followed by a discussion of our results and open problems for future research.

2. Related work

Plant components such as stems or trunks are often modeled using sweeps. Bloomenthal [1] proposed to use generalized cylinders for modeling tree branches. The extruded sur-

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Figure 2: *Different types of mushrooms:* 1*) Chantharellus Cibiarus,* 2*) Clavaria Delphus,* 3*) Disciotis Venosa,* 4*) Helmovka Krvava,* 5*) Holubinka Teckovana,* 6*) Ramania Formosa*

face is defined by sweeping a generating (two dimensional) closed curve along a trajectory (three dimensional carrier curve) normal to the plane of the curve. Generalized cylinders have been used to model leaves supported by a single axis [7, 11]. More complex leaves have been modeled using spline patches [1], or by meshing an implicit contour around a skeletal branching structure [3].

Recently, Mündermann proposed a method for modeling a vast variety of lobed leaves interactively [9]. Given a leaf silhouette, the algorithm automatically computes the skeleton and approximates the leaf by using spline curves interconnected into a branching structure. The leaf model can be then edited by controlling the bending, twisting and turning of each lobe.

3. Shape generation

There is a vast variety of different mushrooms in nature: more than one hundred thousand different kinds have been classified in biology. This multitude of mushrooms displays an infinite variety of shape, size and texture (Figure 2). In this paper, we focus on typical mushrooms with a stem and a cap (Figure 2 shapes 1, 4 and 5).

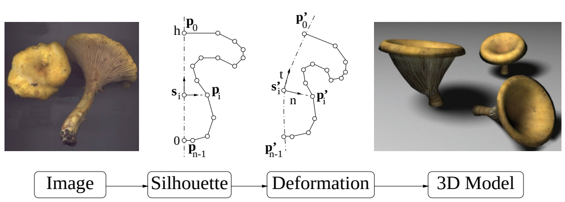

Figure 3: *The mushroom modeling pipeline*

Our approach to shape generation is similar in spirit to Mündermann's lobed leaves [9]. The creation of the textured mesh model of a mushroom in performed in three steps (Figure 3). The surface of a mushroom is created by rotating a silhouette curve around an axis. The texture mapping coordinates are generated procedurally simultaneously to map the three images of the stem, the gills and the cap onto the triangle mesh. At the end of this process, the model can be deformed using axial deformations [5] for bending and twisting, and local Free Form deformations to produce some imperfections that greatly enhance the realism of the final model.

3.1. Silhouette

The minimal input to the model is a 2D mushroom silhouette, denoted as $\mathcal{C}$. It can be edited interactively using a Spline curve editor, or derived from an image of a mushroom. The silhouette curve is split into three sub-curves that characterize the stem, the gills and the cap of the mushroom.

Our system implements template silhouette models stored in an atlas of shapes that were created after biological observations and drawings. This significantly speeds up the silhouette design process, and provides the designer with some realistic base models that can be further edited and modified interactively.

3.2. Sweeping process

The axis of the mushroom, denoted as $\mathcal{S}$, is defined as a 2D Spline curve, which may be edited interactively. At every point $\mathbf{s}$ of the skeleton, we define a local frame system, denoted as $(\mathbf{s}, \mathbf{t}, \mathbf{n})$ where $\mathbf{t}$ and $\mathbf{n}$ refer to the tangent and normal vectors to the curve $\mathcal{S}$ at vertex $\mathbf{s}$ (Figure 4). The surface of revolution is created by rotating the silhouette curve around the skeleton $\mathcal{S}$. More precisely, the triangle mesh surface of the mushroom is created as follows.

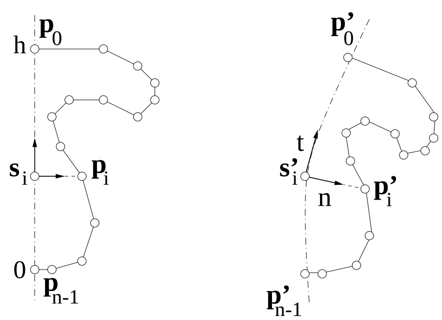

Figure 4: *Axial deformation of a mushroom*

The curve $\mathcal{C}$ is first discretized into segments by sampling it with n vertices denoted as $\mathbf{p}_i$, $i \in [0, n-1]$. Every vertex $\mathbf{p}_i$ is projected onto the skeletal curve $\mathcal{S}$ as a skeletal vertex $\mathbf{s}_i$. Let s denote the number of silhouette curves used to generate the surface of revolution. The vertices of the triangle mesh, denoted as $\mathbf{m}_{ij}$, are defined by rotating the vertices $\mathbf{p}_i$ in the

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local frame $(\mathbf{s}_i, \mathbf{t}_i, \mathbf{n}_i)$:

$$\mathbf{m}_{ij} = R(\theta_j)(\mathbf{p}_i) \qquad \theta_j = \frac{2j\pi}{s} \qquad j \in [0, s-1]$$

$R(\theta_j)$ denotes the rotation matrix around the tangent vector $\mathbf{n}_i$ in the local frame $(\mathbf{s}_i, \mathbf{t}_i, \mathbf{n}_i)$.

3.3. Texture mapping

The scanned images of the mushrooms also provide texture information. We rely on three texture images, globally denoted as $\mathcal{I}$, for the stem, gills and cap respectively. During the triangle mesh generation process, we compute the texture coordinates u_{ij} and v_{ij} of the vertices $\mathbf{m}_{ij}$ using a planar mapping for the cap and the gills, and a cylinder mapping for the stem. Let r denote the radius of the cap, computed as the maximum distance $\|\mathbf{p}_i - \mathbf{s}_i\|$. The texture coordinates for the vertices of the cap and the gills are set as follows:

$$u_{ij} = \frac{\|\mathbf{p}_i - \mathbf{s}_i\|}{r}\cos(\theta_j) \qquad v_{ij} = \frac{\|\mathbf{p}_i - \mathbf{s}_i\|}{r}\sin(\theta_j)$$

Let h denote the maximum height of the stem and $z(\mathbf{s}_i)$ the height of vertex $\mathbf{s}_i$ along the skeleton, the texture coordinates for the stem are defined as:

$$u_{ij} = \frac{z(\mathbf{s}_i)}{h} \qquad v_{ij} = \frac{\theta_j}{2\pi}$$

3.4. Deformations

Deformations are essential for realism as mushrooms are often slightly bent or feature curved stems. In our system, we use axial deformations [5] to produce curved stems, as shown in Figure 4.

We have created a mushroom modeling and morphing interface to create the mushroom models shown throughout this document. The different mushroom models were created in less than 5 minutes, which includes the creation of the silhouette curve after images and the control of the axial deformation. Figure 1 show some mushrooms growing in the shade of trees in the grass or over rocks.

4. Morphing

In this section, we present our morphing technique that produces a vast variety of models automatically given a few control shapes. This technique enables us to simulate a database amplification which is essential to create complex sceneries with many different mushroom models.

Recall that all our mushroom models are characterized by a generic procedural approach that incrementally creates a textured triangle mesh given a set of parameters. The set of parameters that characterize a mushroom are its skeleton $\mathcal{S}$, its silhouette curve $\mathcal{C}$, its axial deformation $\mathcal{D}$ and its texture image $\mathcal{I}$ for the stem, the gills, and the cap.

Given two reference mushroom models denoted as A and B, our morphing method consists in interpolating the parameters of A and B and creating a new interpolated model C using the interpolated parameters. We rely on the following simple curve and image morphing techniques to evaluate the interpolating texture images $\mathcal{I}(t)$ and axial deformation $\mathcal{D}(t)$. In our system, interpolating texture images are produced by a cross-dissolving method, blending weighted images together. The transformation of axial deformations is performed using the efficient 3D curve morphing technique proposed in [5]. The transformation of the silhouette curves is more involved as care must be taken not to generate intermediate silhouettes curves folding onto themselves or self-intersecting.

4.1. Silhouette morphing

Let $\mathcal{C}_A$ and $\mathcal{C}_B$ denote the silhouette curves of the argument mushroom models whose vertices are denoted as $\mathbf{a}_i$, $i \in [0, n_a - 1]$ and $\mathbf{b}_j$, $j \in [0, n_b - 1]$ respectively. The morphing of those curves is performed in two steps.

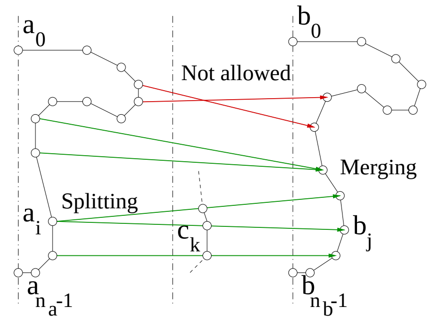

Figure 6: *Graph of correspondence between the silhouette curves, valid arcs are green, whereas forbidden arcs are red*

First, the designer defines a graph of correspondence between the vertices $\mathbf{a}_i$ and $\mathbf{b}_j$ of the silhouette curves so as to match vertices together (Figure 6). The graph of correspondence characterizes how some parts of the silhouette curve collapse or expand. A new vertex $\mathbf{c}_k$ is created for every link (i, j).

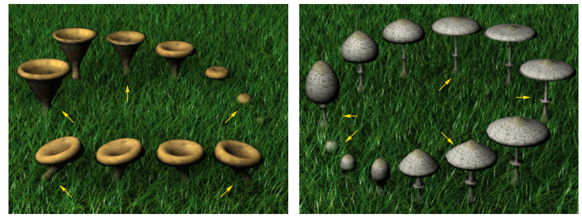

Figure 7: *A variety of mushroom models created by morphing (control shapes are pointed out with yellow arrows)*

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Figure 5: *Some synthetic models of Amanita Muscaria, Copinus Comatus and Cantharellus Cibiarus*

The second step defines the coordinates of the interpolating vertex $\mathbf{c}(t)$ using a simple linear interpolation:

$$\mathbf{c}_k(t) = (1-t)\,\mathbf{a}_i + t\,\mathbf{b}_j$$

4.2. Morphing and control

Figure 7 presents a variety of mushrooms created after a few control shapes. Experiments demonstrated that controlling the morphing process is the critical step. Editing the graph of correspondence between the silhouette curves of five models took 30 minutes to produce smoothly interpolating shapes.

5. Conclusion

We have proposed an interactive method for modeling mushrooms. Our method generates a free form deformable model form an arbitrary silhouette curve. Our approach also enables the designer to create a vast variety of shapes interactively, and to define large atlases of models using a simple and efficient shape morphing technique. We demonstrated the flexibility of our approach by creating several mushrooms of different kinds. This flexibility results from the pipeline architecture of procedural operations.

In the near future, we plan to address several open research problems. Most mushrooms feature imperfections such as small deformations, radial cracks in the cap or longitudinal creases in the stem, or skin peelings. Therefore, it would be interesting to plug in an aging and weathering stage in our pipeline that would create such imperfections. We also plan to extend our modeling system to other kinds of mushrooms with different shapes.

We also plan to develop a simple method for spawning mushrooms in a virtual ecosystem by dispersing mushroom spores over the objects in the scene and transporting or removing spores that are blown away by the wind or washed by rain water flows. The designer should control the regions where mushroom will develop by adjusting the biological parameters of the mushrooms and their sensitivity to direct and indirect lighting, moisture and substrate type. The characteristics of the environment could be coded as texture maps which may be generated either automatically by physically based simulations, or created by hand by the designer.

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