A Procedural Approach for Stylized Bark Shading

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ABSTRACT

The Earth characters in Pixar's feature film *Elemental* (2023) called for a stylized look with bark patterns resembling organic locks of hair (Figure 1). To scale this custom shading to an entire class of background characters, we implemented an artistic-driven procedural workflow that offered rapid iterations on pattern generation without requiring extensive repainting of textures. At its core, our approach is built on a series of in-house geometry tools that auto-generate shading surface attributes in Houdini. These surface attributes were then consumed by our proprietary shading system, thus allowing for flexible shader development. In this work, we detail our new geometry tools and discuss the pipeline necessary to automate the process of texture synthesis and variant creation.

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Figure 1: Following the art concept of the Earth characters in *Elemental* (2023), we introduce a procedural system that auto-generates stylized bark pattern on surfaces. ©Pixar.

1 OUTLINE

We start by breaking down in Figure 2 the main steps of our procedural system to generate stylized bark patterns. The input is a coarse polygonal mesh of the tree trunk, which is subdivided twice defining a smooth surface to generate our shading attributes. Once loaded in Houdini, we allow the user to draw guide curves over the subdivided surface indicating the desired flow of the bark pattern. Our first geometry tool interpolates the guide curves into a smooth directional field tangent to the surface mesh (§2). Next, we scatter points stochastically near the tree roots and advect them along the directional field, thus forming surface streamlines that delineate strands of hair (§3). Additionally, we use both guide and advected curves to compute surface-based 3D diffusion curves in order to create curve-aligned smooth gradients over the surface (§4). These attributes were then baked back onto the input coarse mesh as a single atlas of Ptex files using an in-house wrapper around Houdini Mantra. Lastly, we developed a network of RenderMan shaders that processes these surface attributes into a stylized texture that evokes both hair and bark patterns at the same time (§5).

2 DIRECTIONAL FIELDS

We implemented a surface operator in Houdini that computes the smoothest directional field aligned to user-drawn strokes on the tree trunk surface based on the technique presented by de Goes et al. [2020]. We first resample the stroke curves uniformly matching the mesh resolution and assign every sample to its unit tangent vector along the curve. We then optimize 3D vectors for the vertices of the surface mesh that smoothly interpolate the sample tangents while accounting for the surface shape. At last, we normalize the resulting vectors at every mesh vertex, thus defining a directional field. Image (B) in Figure 2 illustrates the smooth directional field produced by our method using the guide curves from image (A).

3 STREAMLINES

We also developed another surface operator in Houdini that generates streamlines constrained to the surface mesh. This tool receives as input a list of starting points and the desired length for each streamline, in addition to the surface mesh and its vertex-based vectors. Each streamline is outputted as a polyline that approximates the integral curve conforming to the directional field rooted at its respective starting point. To compute streamlines, we implemented a surface-based particle tracing algorithm. First, we project each starting point onto the surface mesh, obtaining the index of a mesh face and the barycentric coordinates representing its closest point. We also set a direction for every starting point by interpolating the vertex-based vectors weighted by barycentric coordinates. Next, we advect each point by tracing a ray along its interpolated direction within its corresponding polygonal face until a mesh edge is hit. We then update the direction at the location of the last edge hit and trace a new ray across the neighboring face. The sequence of edge hits forms our discretized streamlines. These steps are repeated until the desired length is reached, or whenever the last hit indicates a boundary edge or a field singularity (i.e., the interpolated vector has zero length). In our workflow, starting points were scattered near

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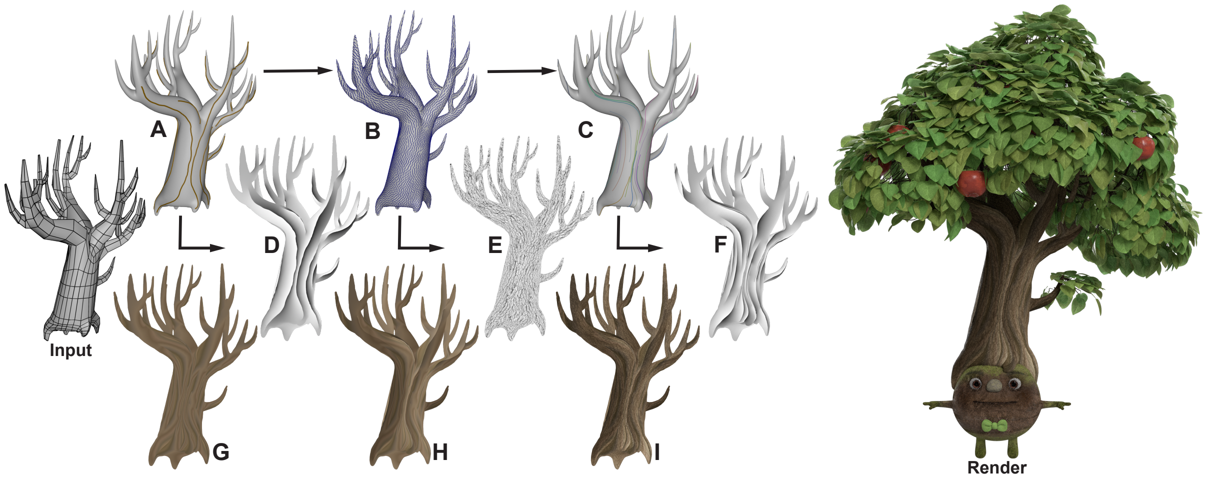

Figure 2: Breakdown of our procedural method to generate stylized bark pattern. (A) Subdivided surface with user-drawn guide curves. (B) Smooth directional field that interpolates the guide curves. (C) Streamlines that integrate the directional field. (D) 3D diffusion curves computed from the input guide curves. (E) Bark tiling aligned to the surface directional field. (F) 3D diffusion curves conforming to our streamlines. (G) Color palette modulated by the streamline 3D diffusion curves. (H) Layering of 3D diffusion curves that mimic strands and locks of hair. (I) Final texture combining 3D diffusion curves and the bark tiling. ©Pixar.

the tree roots using a user-prescribed target count and assigned a randomly generated curve length. Image (C) in Figure 2 shows streamlines computed from the directional field in image (B).

4 3D DIFFUSION CURVES

To convert the guide curves and streamlines into shading attributes, we compute 3D diffusion curves over surface meshes. In general, diffusion curves for 2D images interpolate attributes on either side of constrained curves, thus defining curve-aligned smooth gradients [Orzan et al. 2008]. We generate similar 3D diffusion curves for surface meshes by implementing the mesh cutting algorithm and polygonal discretization introduced by de Goes et al. [2022]. The smooth attributes are thus computed by solving a discrete Laplacian equation over the cut mesh with discontinuous constraints for every cut edge corresponding to a segment of the input curves. Since our input curves have consistent orientations, our constraints set the right side of every curve to one versus zero to their left side, forming a ramp between nearby curves. In Figure 2, images (D) and (F) exemplify the smooth ramps generated using the guide curves and streamlines from images (A) and (C), respectively.

5 SHADING

After exporting our Houdini-generated surface attributes into a single atlas of Ptex files, we designed the final look of the stylized bark pattern by combining three in-house shaders. First, we compute seamless textures by stochastically tiling the surface mesh with an input exemplar aligned to our directional field. This tiling shader was then used to produce a baseline bark texture flowing along our guide curves, as shown by image (E) in Figure 2. The additional shaders were developed to integrate the 3D diffusion curve results. The gradient ramps aligned to the surface streamlines were used to map a user-chosen color palette over the bark baseline, as displayed by image (G). Similarly, we use the smooth gradients associated with the guide curves to modulate the color brightness over the tree trunk surface in order to resemble locks of hair. Finally, we illustrate our shader composition in images (H) and (I).

6 RESULTS

We wrapped our custom tools into a procedural system that produces stylized bark pattern driven by a few parameters, including strokes to guide the bark flow, number of streamlines to fill in locks and strands of hair, color palettes, and tiling frequency. Importantly, by iterating through these high-level inputs, our approach freed shading artists of any manual painting work, while easing the creation of shading variants. We deployed our system to Pixar's feature film *Elemental* (2023), shading a class of Earth character with a total of 50 variants. Figure 3 showcases examples of stylized tree trunks generated by our method.

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Figure 3: Examples of Earth characters from *Elemental* (2023) shaded with our stylized bark patterns. ©Pixar.