Texturing Surfaces Using Reaction-Diffusion

by
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GREG TURK. Texturing Surfaces Using Reaction-Diffusion (under the direction of Henry Fuchs).

Abstract

This dissertation introduces a new method of creating computer graphics textures that is based on simulating a biological model of pattern formation known as *reaction-diffusion*. Applied mathematicians and biologists have shown how simple reaction-diffusion systems can create patterns of spots or stripes. Here we demonstrate that the range of patterns created by reaction-diffusion can be greatly expanded by cascading two or more reaction-diffusion systems. Cascaded systems can produce such complex patterns as the clusters of spots found on leopards and the mixture of spots and stripes found on certain squirrels.

This dissertation also presents a method for simulating reaction-diffusion systems directly on the surface of any given polygonal model. This is done by creating a mesh for simulation that is specifically fit to a particular model. Such a mesh is created by first randomly distributing points over the surface of the model and causing these points to repel one another so that they are evenly spaced over the surface. Then a mesh cell is created around each point by finding the Voronoi region for each point within a local planar approximation to the surface. Reaction-diffusion systems can then be simulated on this mesh of cells. The chemical concentrations resulting from such a simulation can be converted to color values to create a texture. Textures created by simulation on a mesh do not have the problems of texture distortion or seams between patches that are artifacts of some other methods of texturing.

Two methods of rendering these synthetic textures are presented. The first method uses a new surface of triangles that closely matches the original model, but whose vertices are taken from the cells of the simulation mesh. These vertices are assigned colors based on the simulation values, and this re-tiled model can be rapidly displayed on a graphics workstation. A higher-quality image can be created by computing each pixel's color value using a weighted average of the chemical concentration at nearby mesh points. Using a smooth cubic weighting function gives a satisfactory reconstruction of the underlying function specified by the values at the mesh points. Several low-pass filtered versions of the texture are used to avoid aliasing when the textured object covers a small portion of the screen. The proper color value at a pixel is found by selecting from the appropriately filtered level.

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Figure Credits

Some of the figures in this dissertation were made with the generous help of others. I thank all of them.

Special thanks are due to Marc Olano, Carl Mueller, and Andrei State for helping me during the last few weeks before my defense. Marc Olano created Figures 1.6, 1.7, and 1.8. Carl Mueller made Figures 1.2, 1.4, 1.5, 5.7, 5.8, and 5.9. Figure 2.1 was drawn by Andrei State. Figure 5.2 is re-printed from Paul Heckbert's Master's thesis with his permission. Figures 1.3, 1.6, 1.7, and 1.8 were created using a version of Photorealistic RenderMan that was donated to UNC by Pixar (thanks to Tony Apodaca).

Thanks goes to Rhythm & Hues for the horse model that appears in many of the figures. The sea-slug model of Figure 5.13 is courtesy of Apple Computer's Vivarium Program. The giraffe model of Figures 4.14 and 4.15 was created by Steve Speer. The minimal surface in Figures 5.22 and 5.23 was created by James T. Hoffman, and is based on a mathematical description due to Celso Costa, David Hoffman and William Meeks III.

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