Texture Synthesis Using Reaction-Diffusion Systems and Genetic Evolution

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1 Introduction

We demonstrate that genetic algorithms are an effective means to tune reaction-diffusion parameters for the purposes of automatic texture generation. By combining two biologically-based computational methods, we provide a mechanism to explore the space of image-textures by means of natural selection using aesthetic criteria.

Reaction-diffusion systems are based on a chemical mechanism for pattern formation proposed by Turing [1952] and first used in computer graphics for image-texture synthesis by Witkin and Kass [1991] and by Turk [1991]. Such systems have advantages for image-texture generation, including the ability to be generated in-place on boundary meshes to avoid tears or seams in the texture patterns. A drawback of reaction-diffusion methods, however, is their sensitivity to initial conditions and the consequent unpredictability of the generated patterns with respect to perturbation of input parameters. Our research uses a genetic algorithm to explore the parameter spaces of reaction-diffusion systems, using input from a human participant as the fitness function to guide the evolution. The use of genetic evolution for image-generation was first explored by Sims [1991] using image-generating LISP functions; more recent work includes that of Lewis [2001] that evolved procedural shaders.

2 Gene Selection and Testing

Reaction-diffusion (*RD*) systems are based on a biological model wherein cell properties are fixed during embryo development in a way that depends on the concentrations of one or more chemical messengers. Patterning is based on two concurrent processes: diffusion of chemicals through the tissue, and chemical reactions that produce and destroy chemicals at a rate dependent on their concentrations. RD-systems can be represented by systems of partial differential equations. Our work builds from Turk's methods and uses two separate reaction-diffusion systems: the three-chemical spot-formation system created by Turing and the five-chemical stripe-formation system of Meinhardt.

For each RD system, we create genes having ranges of values over parameters of the discretized RD-equations: six genes are used for Turing's system and five genes for Meinhardt's. Genetic variation is then produced by crossover and mutation methods; two different crossover mechanisms have been implemented, combining genes from either two or three selected images to create a new population of images; mutation methods may perturb a percentage of all genes in population or be specified manually for a specific gene.

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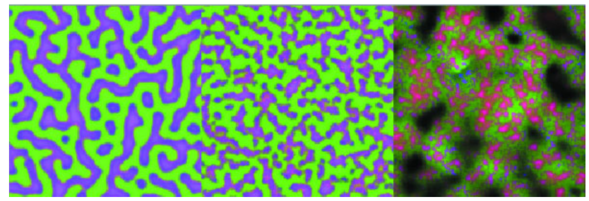

Figure 1: Example population variations.

In use, the system generates an initial random population of nine images; the simulated chemical concentrations in the image cells are scaled to a $[0,1]$ range and translated directly to RGB color values, with each of the three selected chemicals mapped to one of the three color channels. The user then applies mutation and crossover functions to these images through the use of mouse clicks in a graphical interface. After minimal instruction, test-users spend 30 minutes developing RD-textures with their only assigned task being to produce "interesting" images.

3 Results and Applications

Experimentation has yielded preliminary results sufficient as proof-of-concept for the soundness of the approach. The combination of reaction-diffusion and genetic evolution allows users to quickly create visually interesting RD-textures while requiring no knowledge of underlying parameters.

There are many avenues for future research: the use of HSL color-spaces for chemical concentration in place of the RGB color-space; the development of automatic fitness functions based on various metrics for image-content and image-complexity; and the application of evolving textures to synthetic models and environments.

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