Textures from Nonlinear Dynamical Cascades

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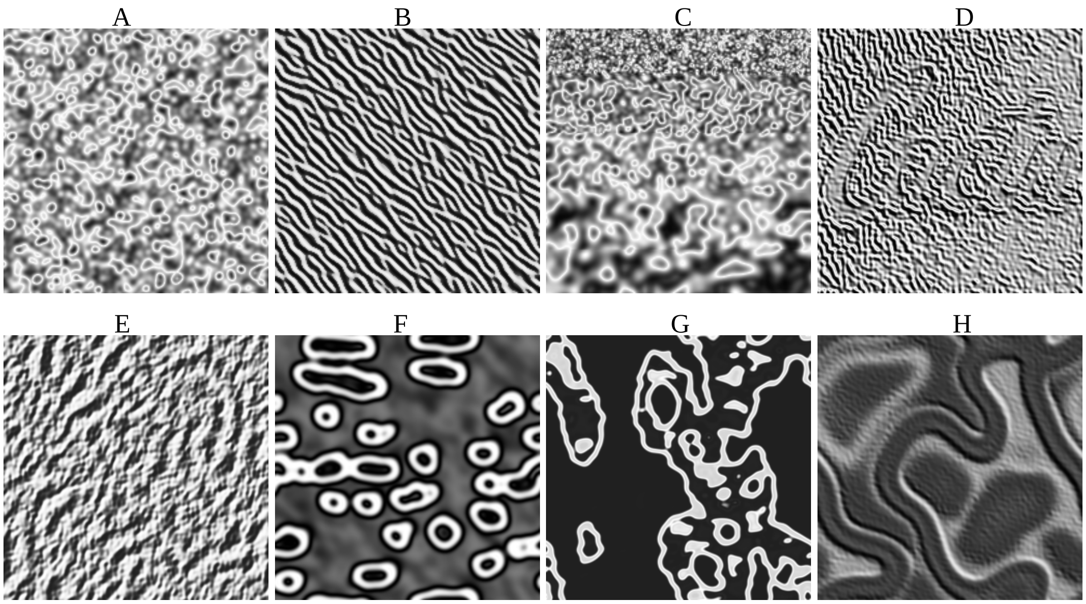

Introduction

A great deal of attention has been paid to the problem of texture synthesis. Procedural techniques have become commonplace. Yet while a proliferation of models, and the success of nonparametric synthesis-from-example methods, has made an extraordinary variety of textures realizable, the creation of novel textures remains a challenge.

We propose a model that combines iteration of nonlinear functions and convolution with multiscale cascade. The textures resulting from this model share characteristics with textures we deem "natural": they exhibit a tension between structure, or smoothness, and randomness, or roughness.

The Model

Our method makes use of iterated nonlinear maps [Devaney 1989; Ott 1993] which provide roughness. Organization is provided to us by the convolution. While repeated convolution yields only trivial textures, and repeated iteration of pointwise maps produces a garble of uncorrelated values, interleaving nonlinear maps with convolution steps can prevent either eventuality. Consider the following schema:

$$A_{i+1} = p(N(A_i)).$$

In the above, p is a map and N is a convolution; both act on a lattice A. The subscript denotes iteration, a discrete dynamical process.

This equation describes a texture synthesis system. Populating a lattice with uniform noise and repeatedly applying a convolution and a map produces structured texture; we stop after a fixed number of iterations (say 5) and use the transient patterns then present. In the interest of speed, we use a small convolution kernel, no larger than 7×7. Textures (A) and (B) were generated by this method.

Because the convolution is linear, it is closed under linear transforms such as scales and rotations. In (C) above, we show an example of a texture where the kernel has been dilated by different amounts in different regions of the image. We may also apply the operator to structured initial conditions rather than to noise. Features in the original image are then expressed in texture features. We show an example of this in (D).

An operator acting on a structured image preserves some large-scale features of that image; we can exploit this in a cascade process wherein lower-frequency levels are upsampled and used as initial conditions for higher-frequency levels. The final texture is the last level of the cascade. Larger-scale details remain, embellished by the action of later operators. Images (E)–(H) above are examples of textures from the cascade. The basic system generates textures with frequency content on a single scale; the cascade admits textures with content on arbitrarily many scales, a characteristic often identified as "natural".

Summary

We present a system for texture synthesis geared towards the computation of natural textures. Natural textures, in our perception, are those characterized by the interplay between smoothing and roughening. Our system is able to rapidly synthesize texture from uniform noise. Given structured input, the system can be used for texture transfer. Multiscale output can be achieved through a cascade of operators. Despite the simple formulation, the system is capable of producing a complex array of texture images.

References

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