Noise and Procedural Techniques

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Overview

- What is procedural texturing?
- Advantages and disadvantages
- When to use procedural texturing
- What is noise?
- Ideal noise characteristics
- Spectral synthesis
- Demos...

What is Procedural Texturing?

- Code vs. tables
- Classic time vs. storage space trade-off

Advantages of Procedural Texturing

- Compact
  - code is small (compared to textures)
- No fixed resolution
  - "infinite" detail, limited only by precision
- Unlimited extent
  - can cover arbitrarily large areas, no repeating
- Parameterized
  - can easily generate a large no. of variations on a theme
- Solid texturing (avoids 2D mapping problem)

Disadvantages of Procedural Texturing

- Computation time (big ouch!)
- Hard to code and debug
- Aliasing

When to use Procedural Textures

- Don’t use them just for the hell of it!
- Procedurals are good for animating effects – fire, water, clouds, explosions…
- ..or anywhere where a repeating texture would be obvious
- Combine the best aspects of both techniques – e.g. painted maps + noise to add variation

Procedural Noise

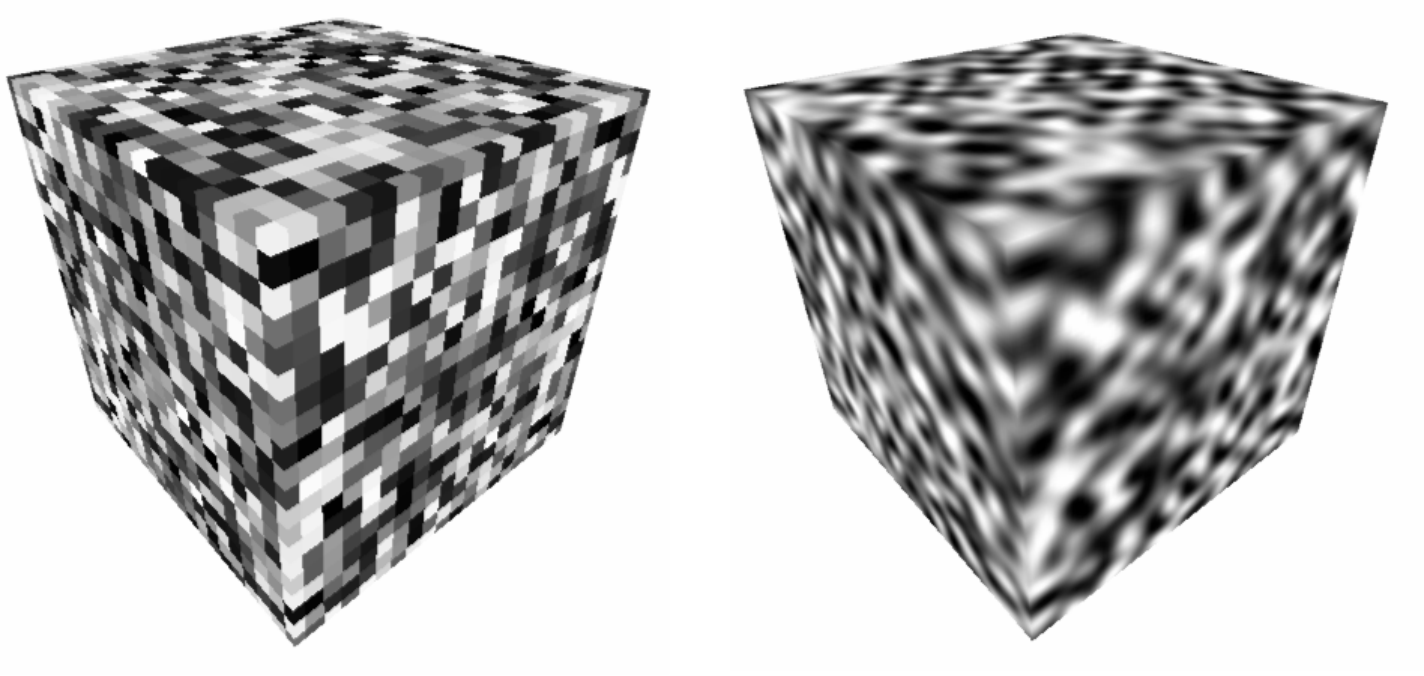
- Noise is an important part of many procedural textures
- Used *everywhere* in production rendering
- Procedural noise provides a controlled method of adding randomness to:
  - Color, texture
  - Bump map / displacement maps
  - Animation
  - Terrains, anything else…

Ideal Noise Characteristics

- Can't just use rand()!
- An ideal noise function has:
  - *repeatable* pseudorandom values
  - specific range (typically [-1,1] or [0,1])
  - band-limited frequency ~= 1
  - no obvious repeating patterns
  - invariance under rotation and translation
- "Random yet smooth"

What does Noise look like?

- Imagine creating a big block of random numbers and blurring them:



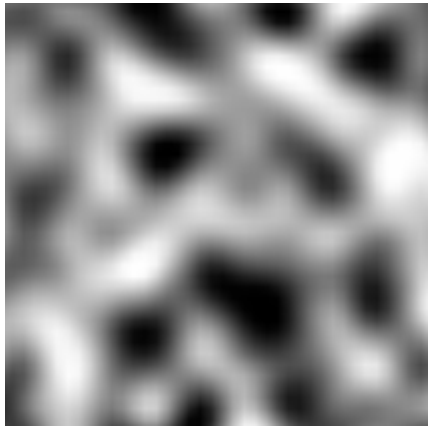
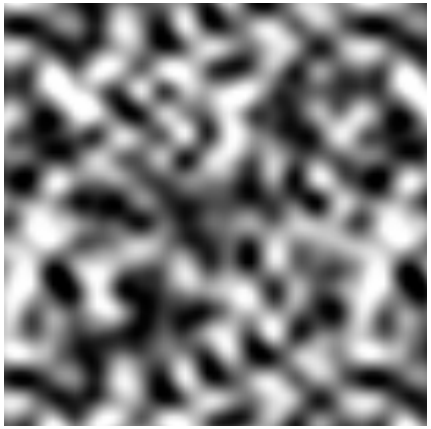
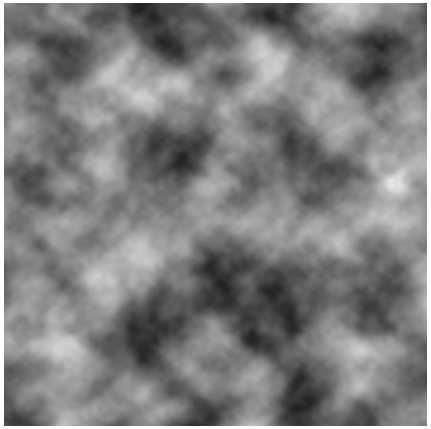
What does Noise look like?

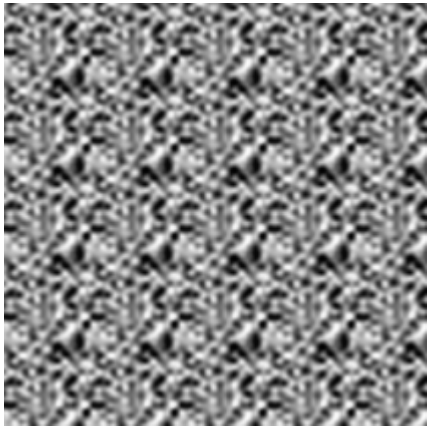
- Random values at integer positions
- Varies smoothly in-between. In 1D:

Spectral Synthesis

- Narrow-band noise by itself is not very exciting
- Summations of multiple frequencies are!
- Like Fourier synthesis (summing sine waves)
- Each layer is known as an "octave" since the frequency typically doubles each time
- Increase in frequency known as "lacunarity" (gap)
- Change in amplitude/weight known as "gain"

Fractal Sum

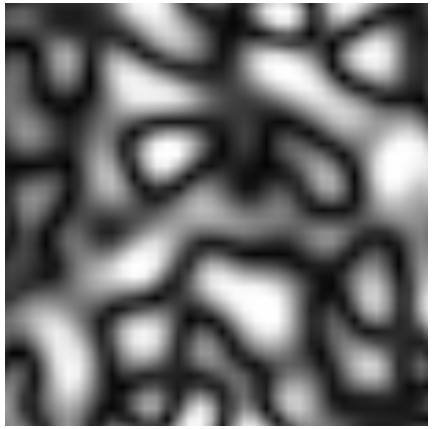
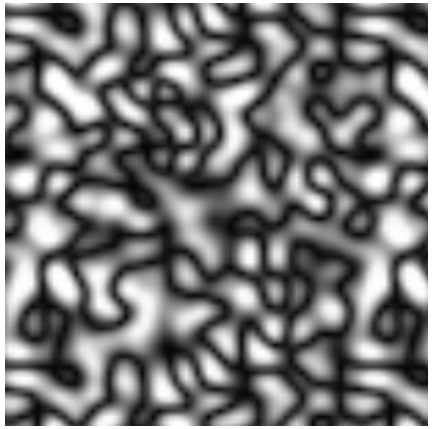
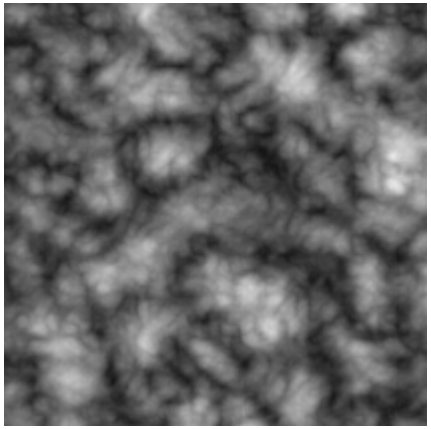
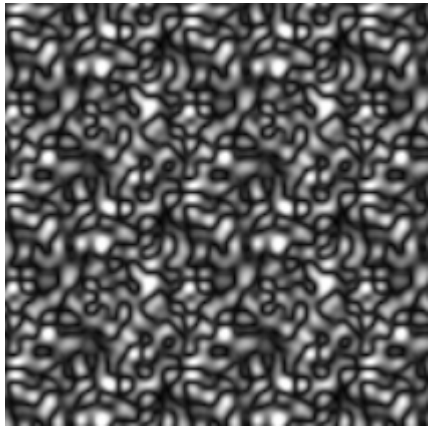
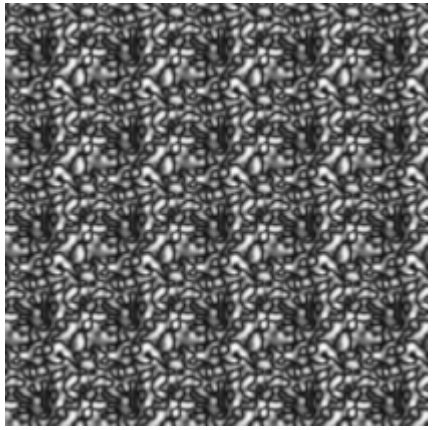


Turbulence

- Ken Perlin's trick – assumes noise is signed [-1,1]
- Exactly like fBm, but take absolute value of noise
- Introduces discontinuities that make the image more "billowy"

```
float turbulence(float3 p, int octaves, float lacunarity, float gain)
{
  float sum = 0;
  float amp = 1;
  for(int i=0; i<octaves; i++) {
    sum += amp * abs(noise(p));
    p *= lacunarity;
    amp *= gain;
  }
  return sum;
}
```

Turbulence

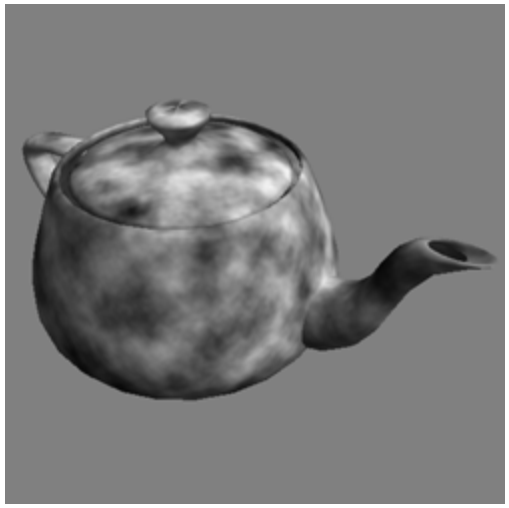
Pixel Shader Noise

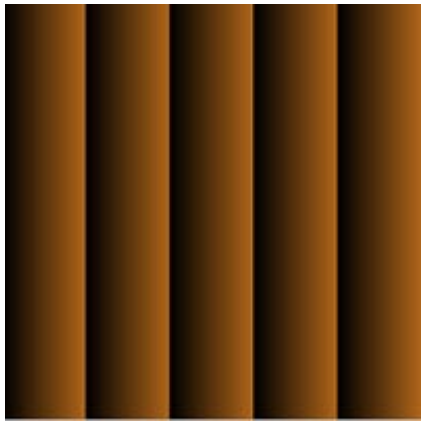
- Implementation of Perlin's original (Academy-award winning) algorithm
- Gradient noise over R^3, scalar output
- Uses 2 1D textures as look-up tables
- Compiles to around 40 instructions

Pixel Shader Noise using 3D Textures

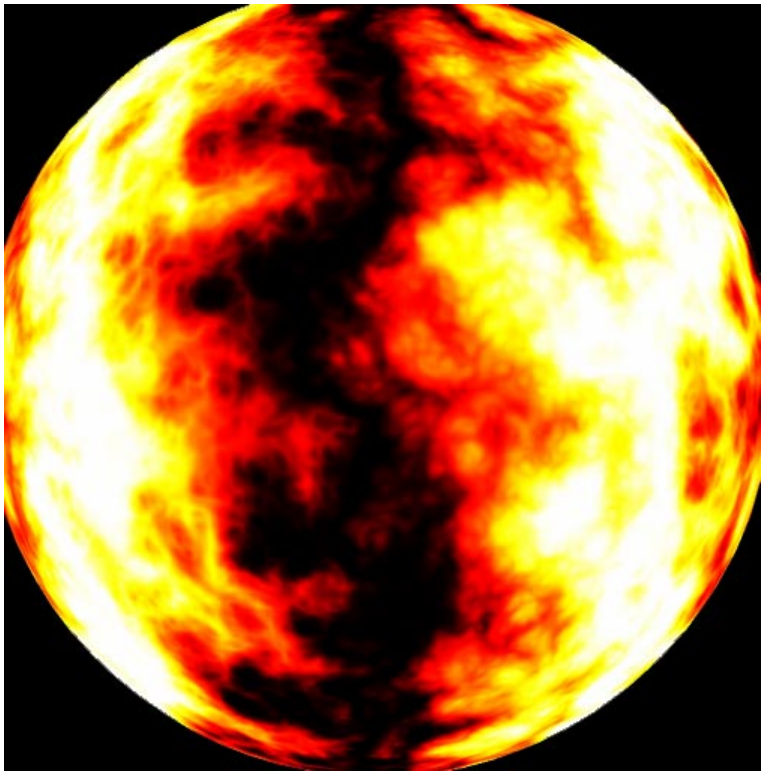
- Pre-compute 3D texture containing random values
- Pre-filtering with tri-cubic filter helps avoid linear interpolation artifacts
- 4 lookups into a single 64x64x64 3D texture produces reasonable looking turbulence

Applying Colour Tables to Noise





Using Noise to Perturb Patterns



Questions, comments, feedback?

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