Today's Menu

- Fractal landscapes
- Noise
- Turbulence (fractal noise)
- Cellular noise
- More texture mapping
**Fractal Landscapes**

Ken Musgrave

- Stochastic midpoint subdivision
- "Fractal"

**Noise**

- Ken Perlin 1984

**Noise Example**

Encoded shading variation. Here $R_d = f(y)$.

Constant color

$R_d = f(y) + \text{noise}(x, y, z)$
Noise Example

\[ R_d = f(y) + \text{more noise}(x, y, z) \]

Noise Example

\[ R_d = f(y) + \text{noise}(x, y, z) \]

Noise

- What is it?
- How is it computed?

Noise

- Bandlimited
- Translation invariant
- Rotation invariant
- Not scale invariant

Random Noise

Not bandlimited, white noise

Noise

- Interpolating random numbers on a grid
Noise:

- Create random vectors on a grid
- Use 3D-Hermite interpolation to generate a noise value
**Noise: Scale**

![Graph showing amplitude vs wavelength and frequency vs wavelength]

**Noise: Turbulence**

\[ T(x) = \sum_{freq} \frac{N(x \times freq)}{freq} \]

Also known as fractal noise

**Noise: Scales**

![Graphs showing different scales of noise]

**Noise: Turbulence**

![Graph showing sum of noise functions]

**Turbulence**

![Image of turbulent noise]

**Noise**

![Image of noise pattern]
**Noise vs. Turbulence**

**Marble Texture**

**Simple Marble Shader**

Vector3f pos = ray.hit_pos * scale;

float turb = turbulence( pos, base_freq );
// make veins along y axis
float noise = sin( pos.y + turb );

compute_colour( result, noise, cm );

**Marble Texture**

**Simple Clouds**
Bumpmapping With Noise

No noise

\[ \tilde{n}^+ = \text{noise}(x, y, z) \]

Bumpmapping With Noise

\[ \tilde{n}^+ = 3 \times \text{noise}(x, y, z) \]

Displacement Using Turbulence

Cellular Noise

- Steve Worley 1996
Cellular Noise

- Place random points in a grid
- Use distance measure as a noise function

\[ F_n(\tilde{x}) = \text{distance to } n\text{'th point from } \tilde{x} \]

Worley F1 (Anson Chu)

Worley F1 in 3D

Worley F2 (Anson Chu)

Worley F2-F1 (Anson Chu)

Figure 2, F2-F1 (Steve Worley)
Cellular Noise

Manhattan Distance, F1 (Steve Worley)

Fractal Cellular Noise

\[ F_n^* = \sum_{\text{freq}} \frac{F_n(\mathbf{x} \* \text{freq})}{\text{freq}} \]

Fractal F1-F4 combinations (Steve Worley)

Fractal Cellular Noise

Fractal F1 - color and bumpmap (Steve Worley)

Fractal Cellular Noise

Fractal F1 - bumpmap (Steve Worley)
**Fractal Cellular Noise**

Fractal F1 - bumpmap (Steve Worley)

**Cellular Noise ++**

(Kurt Fleischer)

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**Other Procedural Textures**

- Reaction Diffusion
- Better noise

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**Next time**

- Monte Carlo ray tracing + questions