CS 563 Advanced Topics in Computer Graphics

Chapter 31 Noise Based Textures

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Introduction

Why?

- Noise based textures tend to look more natural owing to the randomness of the texture
- Might be hard to model seemingly random things... stone surfaces, woods, marble, etc.
- Fool the audience, by using randomness as an advantage

http://www.noisemachine.com/
Who? When? Why?

- Technique was the idea of Ken Perlin
- Perlin had worked on the movie TRON, ~1981, one of the first movies to use CG.
- Back then, everything was constructed from primitive shapes. (sorry, no triangular meshes)
- **REAL** tough to use textures way back then... hardly any RAM
- Perlin started to think about 'noise', ~1983
- Presented at SIGGRAPH 84/85, industry adoption soon after
Desirable Properties

- Repeatable, pseudo-random
- Known range
- Band-limited
- No obvious patterns
- Same in all directions, *isotropic*
- No variance with position, *stationary*
Lattice Noise

- From Perlin (1985)
- 1) Place noise at Lattice points
- 2) Locate cell where a noise value is needed
- 3) Interpolate to find noise
- 1: once 2, 3: many times

Diagram: Lattice Noise

- Noise values specified on integer lattice
- Noise value obtained by interpolation
- 1 unit of distance
Linear Interpolation

- One dimensional Case
  - \( f(x, a, b) = a + (b-a)x \)
  - For a given \( x \), find the \( f() \)
  - Popular name: \texttt{lerp}(x,a,b)
Interpolation Techniques

- Linear Interpolation
  - Blue dots PRNs
  - Black dots x values of PRNs
  - Red dot, where to interpolate
  - Yellow dot, interpolated noise value
  - *Piecewise linear...only depends on left and right pair*
Interpolation Techniques

- 2D Case
- **3D Case**
  - Interpolate twice in x direction
  - Interpolate once in y direction
Interpolation Techniques

- **Lattice case**
  - Interpolate 4 times in x direction
  - Interpolate 2 times in y direction
  - Interpolate 1 time in z direction
- cont...
Interpolation Techniques

- 2D slice of lattice noise
Interpolation Techniques

- Cubic Interpolation
  - More complicated than linear
  - Added computation time, doing curve fitting

![Diagram showing cubic interpolation](image-url)
Cubic Interpolation

- Curve is of the form: \[ ax^3 + bx^2 + cx + d = 0 \]
- \(a, b, c, d\) determined by noise values.
- See four_knot_spline function
- Interpolate 4x in xdir, 1x in y dir (next slide)
- See Rogers(2001)
Interpolation Techniques

- Cubic Interpolation
- **Cubic Interpolation**
  - Lattice... tough to visualize
  - $16x$ in $x$, $4x$ in $y$, $1x$ in $z$
Interpolation Techniques

- Linear versus Cubic
Interpolation Techniques

- Cubic ... overshooting
  - Noise values are close to the limits
  - Unable to fit the curve in and keep all points in limits
Sums of Noise functions

- So far, linear and cubic noise is OK, but not interesting.
- Introduce differing noise functions w/spatial frequencies/amplitudes.
- Sum them up to get more interesting noise
- 'spectral synthesis'
- We want 'band-limited' i.e finite spatial frequencies
- Do some Fourier analysis, eliminate White Noise...
Fractal sum: 

\[
\text{fractal}(p) = \sum \frac{\text{noise}(2^j \cdot p)}{2^j}
\]

\[
\text{fractal}(p) = \text{noise}(p) + \frac{1}{2} \text{noise}(2 \cdot p) + \frac{1}{4} \text{noise}(4 \cdot p) + \ldots
\]
Each additional term... Octave
Smallest detail requires more and more octaves
\begin{itemize}
  \item Differs from fractal a bit... uses absolute value:
  \[
  \text{fractal}(p) = \sum \frac{|\text{noise}(2^j \ast p)|}{2^j}
  \]
  \item Sort of a full wave rectifier effect:
\end{itemize}
- Generalize the Fractal sum..
- Gain, lacunarity

\[ fBm = \sum gain^j(\text{noise}(\text{lacunarity}^j \ast p)) \]

- Change the gain/lacunarity and change the noise
Example:

Octaves = 6, gain = 0.5 lac=8
Basic Noise Textures

- Changing num Octaves (num of terms to add) greatly affects render times...
- `num_octaves = 40`, 10 minute render time Black image.
- `num_octaves = 20`, 2 minute render time Black image.
- `num_octaves = 10`, 1 minutes render time actual image...
Basic Noise Textures

- Oops...
- Gain 0.75, 0.3
Basic Noise Textures

- Max value (1.1, 1.9)
- Lacunarity 8, 2
Use floor function to cause value to abruptly go from 1->0... causes ridges:

Gain=0.25 lac=4 oct=2 exp=2
noise_ptr->set_num_octaves(4);
noise_ptr->set_gain(0.55);
noise_ptr->set_lacunarity(2);
FBM_texture_ptr->set_expansion(6);
Volume filling procedural texture
- Space filling function, add fractal sum of noise functions

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Woven Fabric

- Start with a flat plane
- Undulate plane $y = y + \sin(x)\sin(z)$
- Form the fibers... multiply by $\cos(x)$
- Rotate by 90 degree to get opposing 'threads'
- Add high frequency noise for irregularity
- Add some low frequency noise to get the plane undulating a bit more irregularly

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- Continuously varying index of refraction.
- Uses a volumetric version of Snell's to trace path

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References

- TBD