Noise!

Positional Noise

Idea: Pick a random number at the whole-number input values and then fit a piecewise smooth curve through those points.

The problem is that, due to the uncertainty of random numbers, you might get a good plus-or-minus distribution, or a not-so-good distribution.

Quintic (5th order) Interpolation Creates More Continuity Than Cubic

Cubic: C1 continuity at the whole-number values
Quintic: C2 continuity at the whole-number values

Gradient Noise

Idea: Place points at the mid-line at the whole-number input values and use random numbers to pick gradients (slopes) there, and then fit a piecewise smooth curve through those points with those slopes.

No matter what, you will get a good plus-or-minus distribution.

Coefficients for Cubic and Quintic Forms

<table>
<thead>
<tr>
<th>Noise values</th>
<th>Gradients</th>
<th>Curvatures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cubic</td>
<td>Quintic</td>
<td></td>
</tr>
<tr>
<td>C_0 = 1 - 3t^2 + 2t^4</td>
<td>C_4 = 1/2 - 3t^2 + 3t^4 - 1/2</td>
<td></td>
</tr>
<tr>
<td>C_1 = 3t^2 - 2t^4 - 1 - C_{N0}</td>
<td>C_5 = 1/2 - 2t^2 + 3t^4 - 1/2</td>
<td></td>
</tr>
<tr>
<td>C_2 = 2t^2 - 3t^4</td>
<td>C_6 = 1/2</td>
<td></td>
</tr>
<tr>
<td>C_3 = 0</td>
<td>C_7 = 0</td>
<td></td>
</tr>
<tr>
<td>C_4 = 0</td>
<td>C_8 = 0</td>
<td></td>
</tr>
<tr>
<td>C_5 = 1 - 10t^2 + 15t^4 - 6t^6</td>
<td>C_{C1} = 1/2</td>
<td></td>
</tr>
<tr>
<td>C_6 = 10t^2 - 15t^4 + 6t^6 = 1 - C_{N0}</td>
<td>C_{C2} = 1/2</td>
<td></td>
</tr>
<tr>
<td>C_7 = t - 6t^4 + 8t^6 - 3t^8</td>
<td>C_{C3} = -4t^2 + 7t^4 - 3t^6</td>
<td></td>
</tr>
<tr>
<td>C_8 = -4t^2 + 7t^4 - 3t^6</td>
<td>C_{C4} = 1/2</td>
<td></td>
</tr>
<tr>
<td>C_9 = 1 - 10t^2 + 15t^4 - 6t^6</td>
<td>C_{C5} = 1/2</td>
<td></td>
</tr>
<tr>
<td>C_10 = 10t^2 - 15t^4 + 6t^6 = 1 - C_{N0}</td>
<td>C_{C6} = 1/2</td>
<td></td>
</tr>
<tr>
<td>C_11 = t - 6t^4 + 8t^6 - 3t^8</td>
<td>C_{C7} = -4t^2 + 7t^4 - 3t^6</td>
<td></td>
</tr>
<tr>
<td>C_12 = -4t^2 + 7t^4 - 3t^6</td>
<td>C_{C8} = 1/2</td>
<td></td>
</tr>
</tbody>
</table>

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Noise Octaves

Idea: Add multiple noise waves, each one twice the frequency and half the amplitude of the previous one.

1 Octave 4 Octaves

Image Representation of 2D Noise

4 Octaves

1 Octave

3D Surface Representation of 2D Noise

3D Volume Rendering of 3D Noise

Has continuity in X, Y, and Z.

Volume Isosurfaces of 3D Noise

S* = Mid-value

1 Octave 4 Octaves

The low half of the noise values are on one side of the surface, the high half are on the other.

Examples

Color Blending for Marble

Color Blending for Clouds

Deciding when to Discard for Erosion
Turbulence

Idea: Take the absolute value of the noise about the centerline, giving the noise a “sharper” appearance and creating “creases”.

Warning: this is not the same as fluid “turbulence”.

Turbulence Example

Normal

Turbulent

How to Use Noise

Have an equation that relates some input value (x, y, or z) to output values (color, height).

How much to amplify the noise effect

Coordinates where you are now

Add Noise to the actual input values to produce new “fake” input values.

Now add the noise value, \( N = NoiseMag \times \text{noise(NoiseFreq \times PP)} \), to the actual input values.

How much to increase the sampling rate

Should PP be in Model or World coordinates? Why?

Surface Shader Only
Displacement Shader Only

Surface and Displacement Shaders together

Surface Only
Displacement Only
Surface + Displacement

What’s the Difference Between These Two Images? Why?

Displacement-mapped
Bump-mapped