VGP352 – Week 8

- Agenda:
  - Noise
  - Noise based procedural textures
  - Wang tiles

Brief history of noise

- Developed by Ken Perlin in the early 80s
  - Ken worked on the revolutionary graphics for the movie *Tron*
  - Frustrated that everything in *Tron* looked so “machine-like,” he wanted to get out of the "machine-look ghetto."

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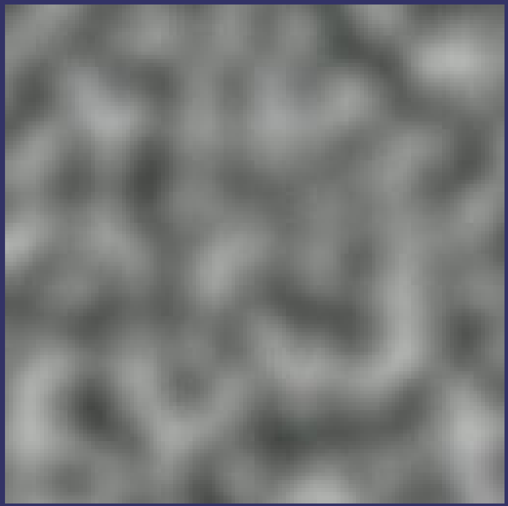
  - What movie won?
  - *E.T. the Extra Terrestrial*
    - Defeating *Blade Runner* and *Poltergeist*

Brief history of noise

- In 1983 Perlin worked on creating a space filling, apparently random signal function
  - Needed to appear random
  - Needed to be controllable
  - Needed all the features to be approximately the same size
  - Needed all the features to be roughly isotropic
  - Needed to have a range [-1, 1]
- First presented as a course at SIGGRAPH '84
  - The paper followed at SIGGRAPH '85
  - The Academy Award for Technical Achievement followed in 1997

Using Noise

- In Perlin's words, “noise is salt for graphics.”
  - Salt by itself is boring
  - Without salt, food is boring too



Original image from http://en.wikipedia.org/wiki/Perlin_noise

Using Noise

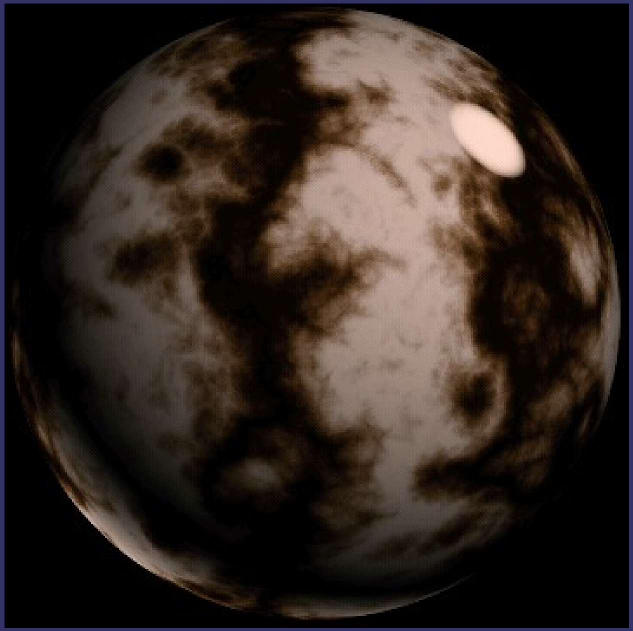
- Noise is typically used in multiple frequencies
  - Each frequency band is called an *octave*
  - As octave frequency increases, the amplitude decreases

$$NOISE(p) = \sum_{i=0}^{N-1} \frac{noise(f_i p)}{a_i}$$

Using Noise

- Add noise to boring functions or textures to make them interesting
  - Marble is the *classic* example

$$\sin\left(x + \left|NOISE\left(y\right)\right|\right)$$



Original image from http://www.noisemachine.com/talk1/23.html, copyright Ken Perlin

Implementing Noise

- Use GLSL noise function
  - Most (all?) implementations are *really* bad
  - Some go as far as to return a constant value for all inputs
- Implement noise in C, generate large noise texture
  - Has tiling artifacts
  - Can consume a lot of texture memory
- Implement noise in GLSL code
  - Several implementations exist
    - See *GPUGems 2*
  - Most use several textures for tables
  - Use 60 – 80 GPU instructions

References

Perlin, K. 1999. Making Noise. Presented at GDCHardCore. http://www.noisemachine.com/talk1/

Perlin, K. 2002. Improving noise. In *Proceedings of the 29th Annual Conference on Computer Graphics and interactive Techniques* (San Antonio, Texas, July 23 - 26, 2002). SIGGRAPH '02. ACM, New York, NY, 681-682. http://mrl.nyu.edu/~perlin/noise/

Zucker, Matt. 2001. The Perlin noise math FAQ. http://www.cs.cmu.edu/~mzucker/code/perlin-noise-math-faq.html

http://freespace.virgin.net/hugo.elias/models/m_perlin.htm

Break

Wang Tiles

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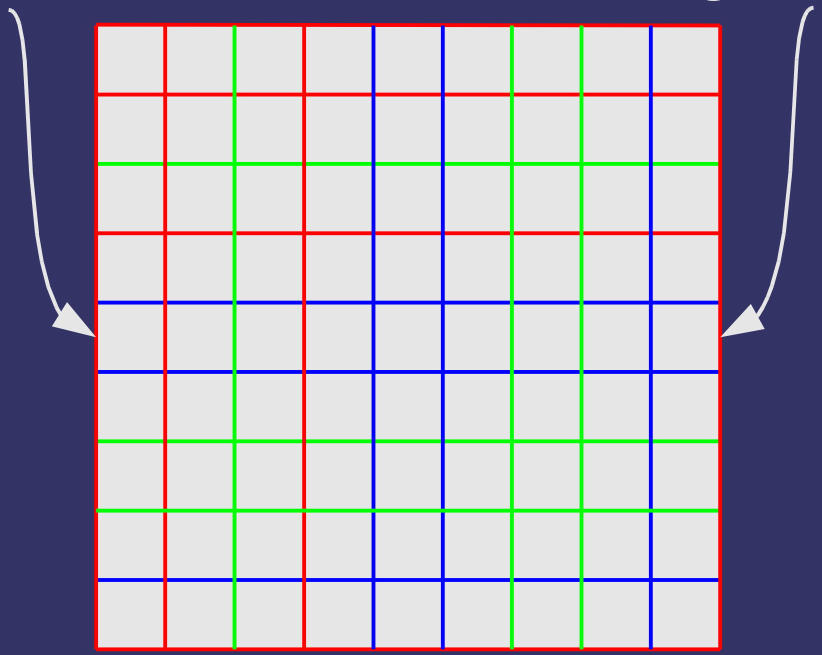
  - Even a 2048x2048 texture will show tiling artifacts
  - *And* it will use 16MB of texture memory...yuck!
- Create a “mosaic” from small a few small “tiles”
  - If the tile selection is pseudo-random, as few as 32 tiles can have a *very* large repeat period
  - Unlike mosaic tiles, texture tiles have to match at the edges
    - Either all tiles edges have to match or the selection algorithm has to pick a tile that will match edges with its neighbors

Wang Tiles – Edge Coloring

- Name the four tile edges N, E, S, W
  - The N/S edges can have one of K_v edge "colors"
  - The E/W edges can have one of K_h edge "colors"
    - A tile with an N edge of color X must be south of a tile with an S edge of color X
  - A tile with each possible combination of edge colors must exist
    - There must be at least $K_v^2 \times K_h^2$ tiles

Wang Tiles – Tile Arrangement

- Assuming we have a set of tiles...
  - Generating tiles from a sample source image is a larger topic than we have time for
- Arrange tiles in a $K_v \times K_h$ pattern in a 2D texture
  - Neighboring tiles must obey edge coloring rules
  - Even neighbors across border edges!



Wang Tiles – Tile Arrangement

- Given a pair of edge colors, the following place-ment algorithm is use:

$$Index(e_1, e_2) = \begin{cases} 0 & if\ e_1 = e_2 = 0 \\ e_1^2 + 2e_2 - 1 & if\ e_1 > e_2 > 0 \\ e_2^2 + 2e_1 & if\ e_2 > e_1 \geq 0 \\ (e_2 + 1)^2 - 2 & if\ e_1 = e_2 > 0 \\ (e_1 + 1)^2 - 1 & if\ e_1 > e_2 = 0 \end{cases}$$

Wang Tiles – Tile Selection

- Given texture coordinate (s, t):
  - Calculate tile index
    - $O_h = t / T_h$
    - $O_v = s / T_v$
  - Hash tile index to calculate edge colors
    - $C_s = H(H(O_h) + O_v) \% K_v$
    - $C_n = H(H(O_h) + O_v + 1) \% K_v$
    - $C_w = H(O_h + H(O_v * 2)) \% K_h$
    - $C_e = H(O_h + 1 + H(O_v * 2)) \% K_h$
    - Notice that $C_e(x, y) = C_w(x + 1, y)$
  - Convert edge colors to row / column indexes

Wang Tiles – Tile Selection

- Given texture coordinate (s, t):
  - Calculate row / column position in texture
    - $t_{base} = I_h * T_h$
    - $s_{base} = I_v * T_v$
  - Calculate texel offset within tile
    - $t_{offset} = t \% T_h$
    - $s_{offset} = s \% T_v$
  - Sample the texture!
    - Final coordinate is ($s_{base} + s_{offset}$, $t_{base} + t_{offset}$)

Wang Tiles – Hash Function

- Implement as a permutation table
  - Use a texture rectangle that is 1 texel tall
    - Use roughly 4x entries in table as possible edge colors
  - More recent hardware can use uniform arrays
    - Geforce 6 or Radeon X800

Wang Tiles – Filtering Gotchas

- Mipmap filtering can be a problem...
  - The 1x1 level blends all of the tiles together...bad!!!
  - Need to clamp the minimum LOD to the level lowest level that doesn't blur across tile boundaries
  - This is *much* easier with texture arrays

Next week...

- More procedural textures

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