VGP352 – Week 9

- Agenda:
  - Quiz #4
  - Final in-class presentation
  - Procedural textures
    - Animated height maps
    - Generating normal maps from height maps

Animating Height-map – Water

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- We want to animate a height-map that represents small waves
  - Simulate this as a mesh of particles connected by springs
  - Each water particle is “pulled” up or down by surrounding water
- Track various data for simulation:
  - Store wave height in R of texture
  - Store wave velocity in G of texture
  - Wave “mass”, spring constants, and time step are uniforms

Animating Height-map – Water

- Springs apply a force, f_s, proportional to their extension
  - Force applied to a water element by one of its neighbors is:

$$f_s = \Delta h \times K_s$$

Difference in height → Δh; Spring constant → K_s

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- Springs apply a force, f_s, proportional to their extension
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Difference in height

Spring constant

  - Updated velocity is:

$$V_n = \frac{\Delta t \times \sum f_s}{m} + V_{n-1}$$

Elapsed time

Mass of water

Animating Height-map – Water

- Springs apply a force, f_s, proportional to their extension
  - Updated position is:

$$H_n = \Delta t \times V_n + H_{n-1}$$

Animating Height-map – Water

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Animating Height-map – Water

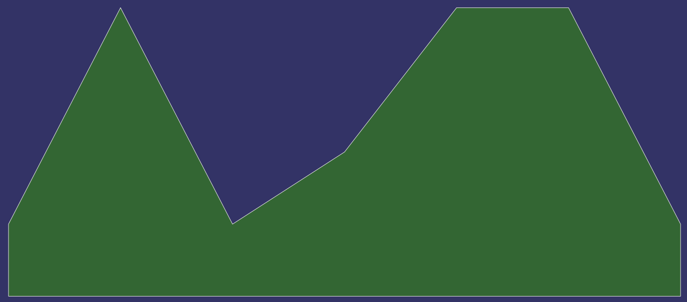
- With no other forces, this simulation would oscillate forever
  - Add one more “virtual” spring to pull each water particle to 0.5
  - This spring should have a *very* small constant

Animating Height-map – Water

```
void main(void)
{
    vec4 me = texture2D(wave_state, gl_TexCoord[0].xy);
    vec2 f_vec = vec2(-4.0 * me.x, 0.5 - me.x);

    f_vec.x += texture2D(wave_state, north).r;
    f_vec.x += texture2D(wave_state, south).r;
    f_vec.x += texture2D(wave_state, east).r;
    f_vec.x += texture2D(wave_state, west).r;

    float F = dot(spring_constant, f_vec);
    float V = (time_over_mass * F) + (me.y - 0.5);
    float H = (time * V) + me.x;

    gl_FragColor = vec4(H, V + 0.5, 0.0, 0.0);
}
```

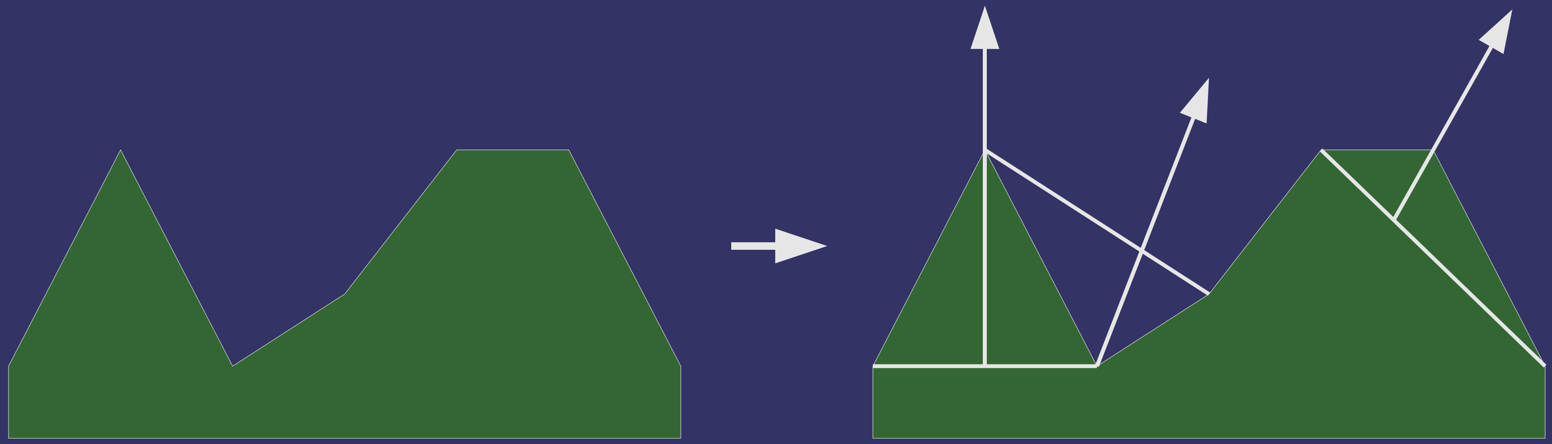
Convert Height-map to Normal-map

- Given a height-map (true bump-map), generate the corresponding normal-map



Convert Height-map to Normal-map

- Given a height-map (true bump-map), generate the corresponding normal-map
  - The X component of the normal is the inverse slope of the line between the east and west neighbors
  - Likewise for the Y component and the north and south neighbors



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  - Using render-to-texture, draw a single, texture-sized quad with texture coordinates ranging from (0, 0) to (1, 1)
  - At each fragment read the 4 neighbor texels
    - Call them n, s, e, and w
    - Be careful of texture coordinate wrap modes
    - Apply scale factor to exaggerate bumpiness

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  - Using render-to-texture, draw a single, texture-sized quad with texture coordinates ranging from (0, 0) to (1, 1)
  - At each fragment read the 4 neighbor texels
    - Call them *n*, *s*, *e*, and *w*
    - Be careful of texture coordinate wrap modes
    - Apply scale factor to exaggerate bumpiness
  - Normal direction is:

```
vec3 a = vec3(0.0, scale, w.x - e.x);
vec3 b = vec3(scale, 0.0, n.x - s.x);
vec3 n = normalize(cross(b, a));
```

Convert Height-map to Normal-map

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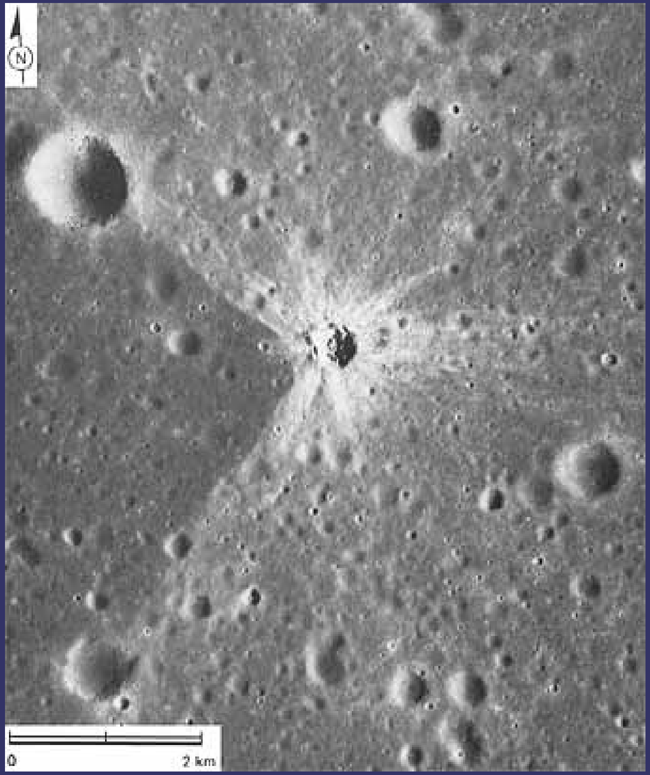
```

  - Convert components to [0, 1] range and write to `gl_FragColor`

Break

Crater Shader

- Task: create a procedural texture for impact craters on, for example, the moon

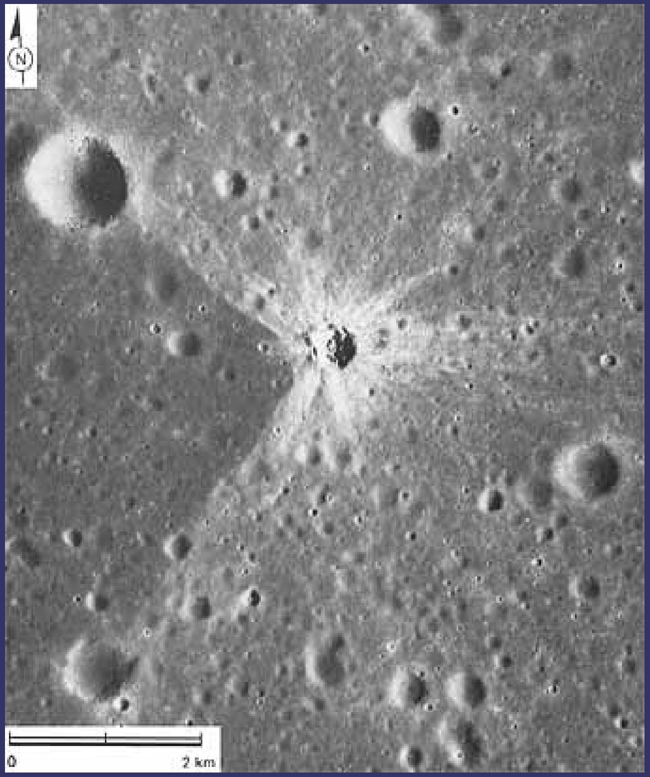


Original image from http://www.hq.nasa.gov/office/pao/History/SP-362/ch5.2.htm

4-March-2008

Crater Shader

- Two parts to this shader



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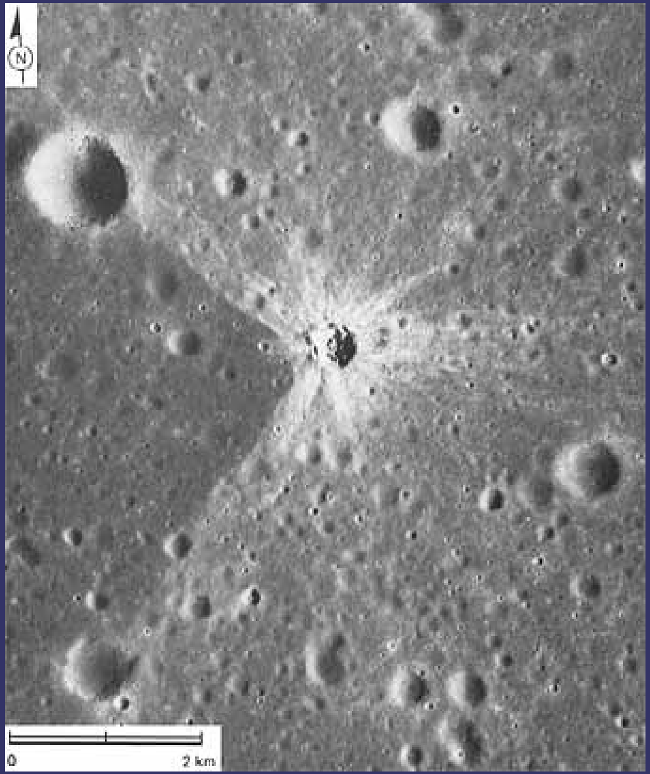
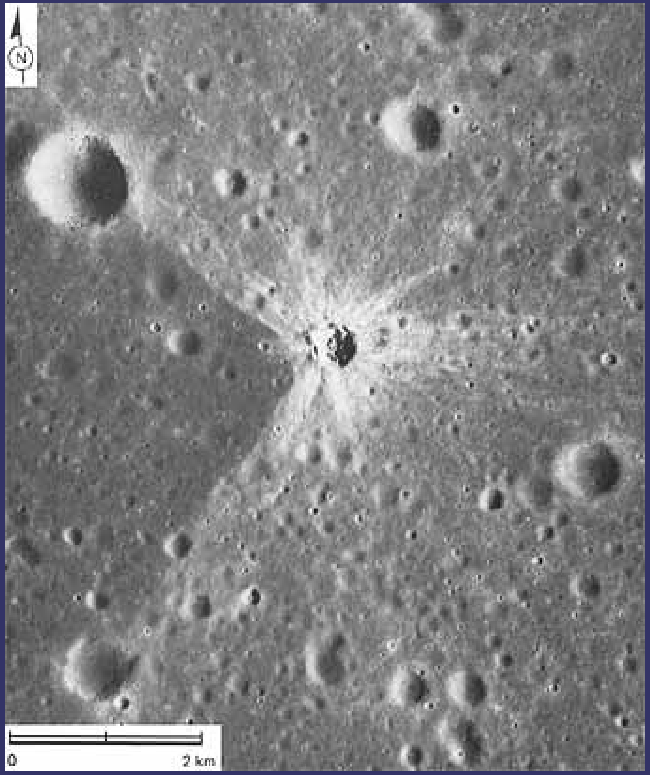
Crater Shader

- Two parts to this shader
  - Height / normal
  - Color



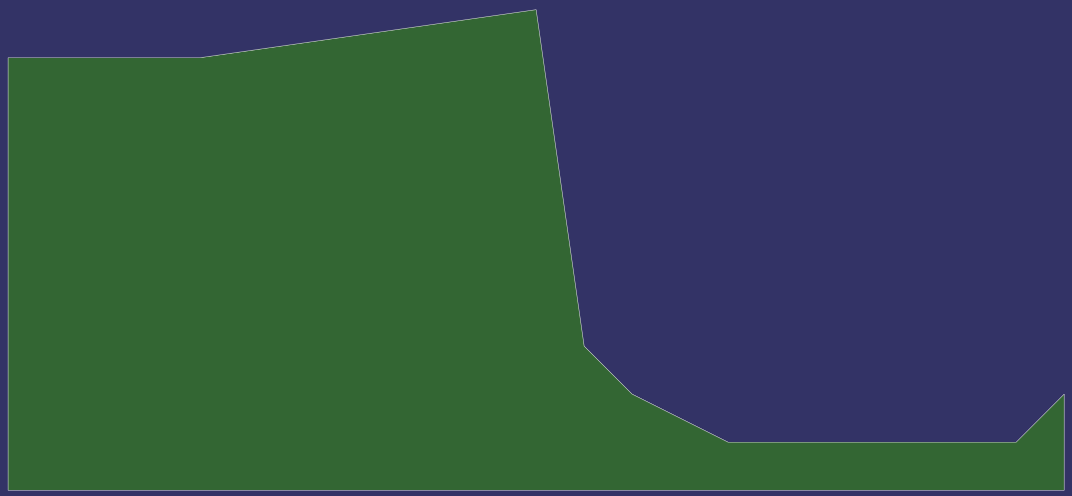
Crater Shader

- Two parts to this shader
  - Height / normal
  - Color
  - Attack each separately, then try to unify



Crater Shader – Height

- Craters are generally circular
  - Height varies with distance from center



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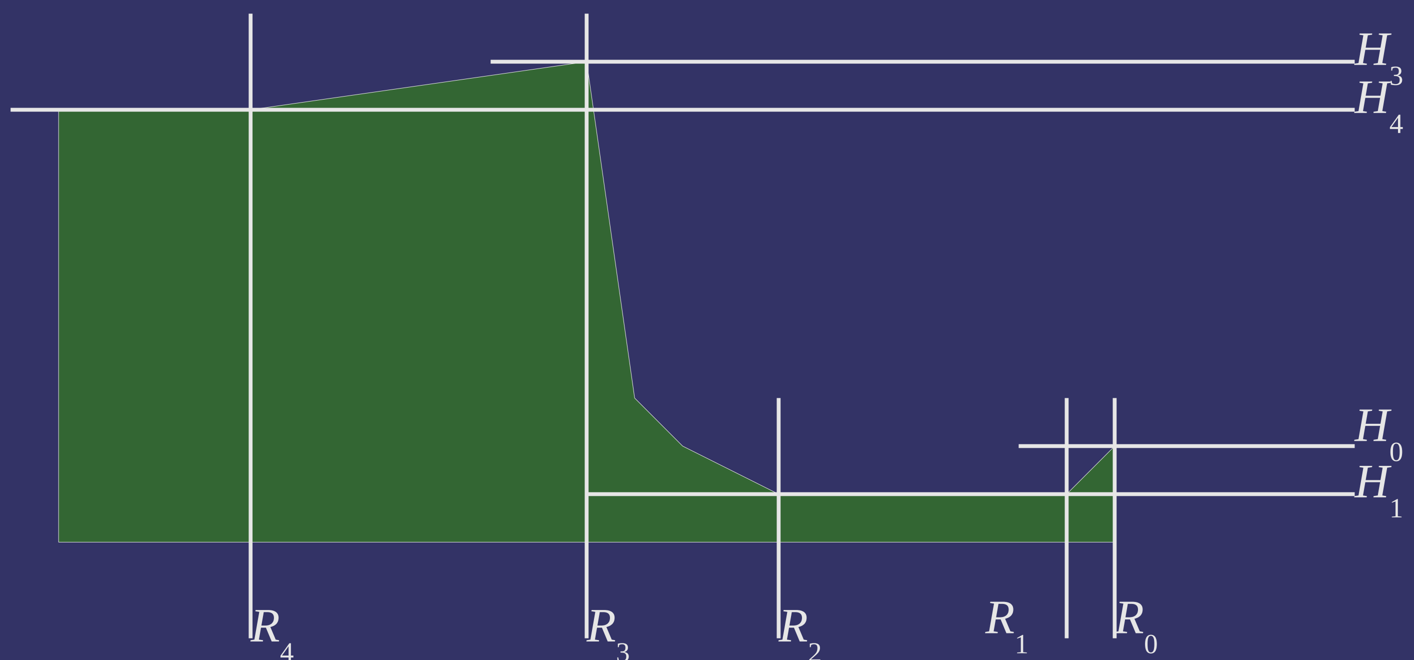
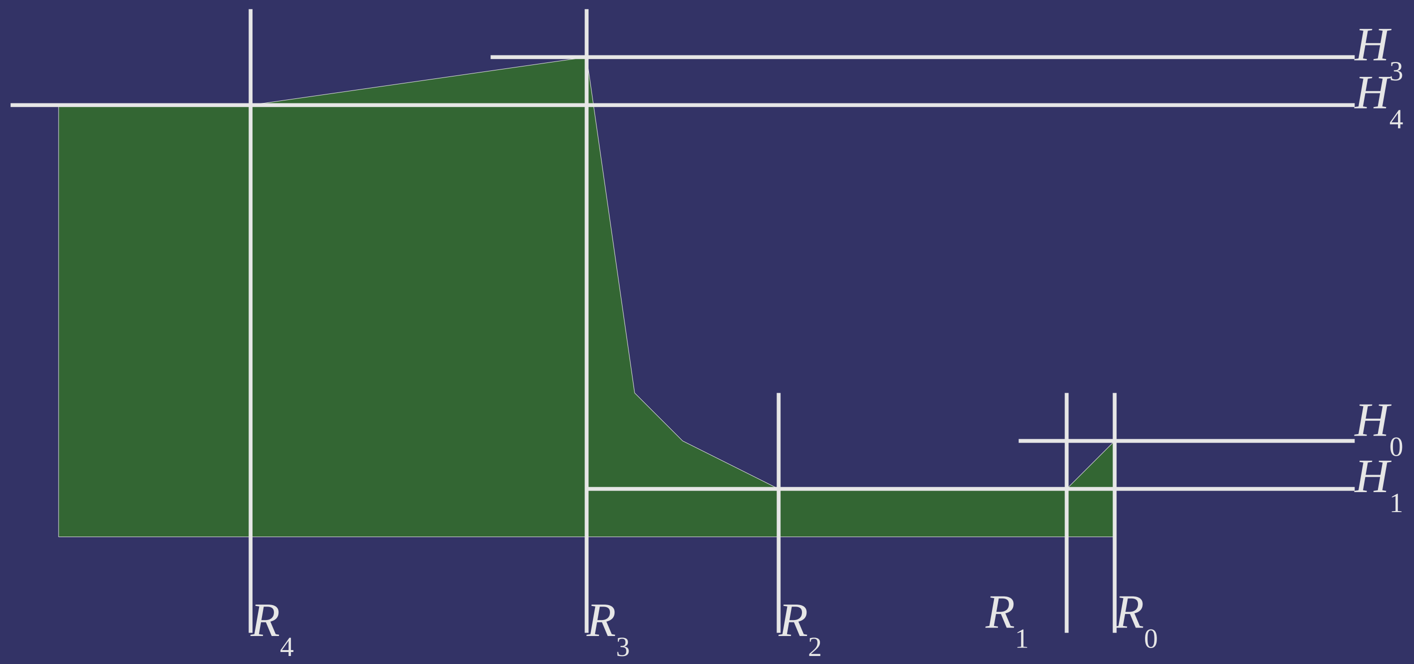
Crater Shader – Height

- Craters are generally circular
  - Height varies with distance from center
  - Associate a height with each distance where there is a change



Crater Shader – Height

- Select an interpolation scheme between each region
  - R_0 to R_1 and R_1 to R_2 could be linear, R_2 to R_3 and R_3 to R_4 could be exponential, etc.



Crater Shader – Height

- In shader:
  - Determine fragment distance from center

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r = length(position - center);
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if (r < crater_parameters[1].x) {
    ...
} else if (r < crater_parameters[2].x) {
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} else ...
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  - Determine fragment location in region

```
t = (r - crater_parameters[n].x)
 / (crater_parameters[n+1].x - crater_parameters[n].x);
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t = (r - crater_parameters[n].x)
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  - Perform interpolation

```
h = mix(crater_parameters[n+1].y,
   crater_parameters[n].y, t);
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    ```

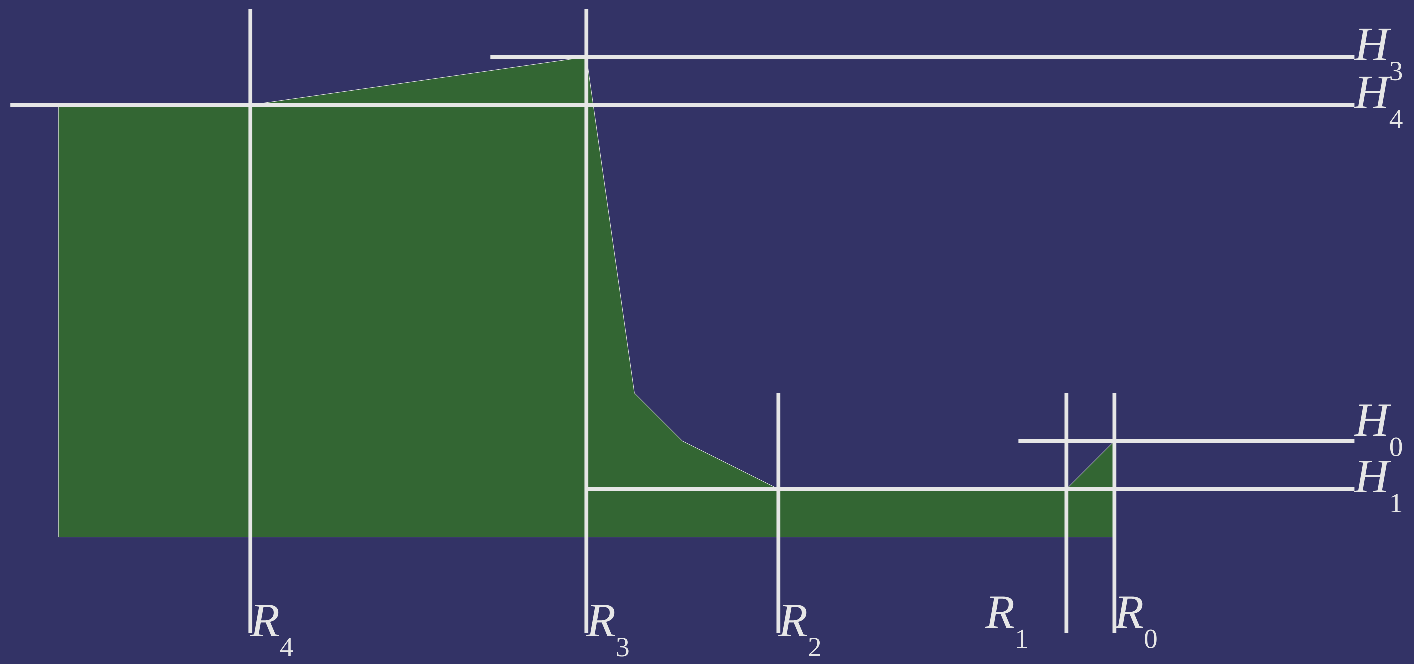
  - Perform interpolation

    ```
    h = mix(crater_parameters[n+1].y,
       crater_parameters[n].y, t);
    ```

  - Write calculated height

Crater Shader – Color

- Color works in a similar manner
  - Use one color inside the crater with alpha set to 1.0
  - Use another color outside the crater
    - Set alpha to 1.0 in “spokes” from crater
    - Falloff to alpha = 0.0 off spokes



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  - Need to know distance from center *and* angle (i.e., polar coordinates)
  - Place spokes separated by fixed angles
    - Spokes are determined by a cosine wave in polar coordinates
    - $r_{spoke} = \cos(\alpha \times frequency)$

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  - Need to know distance from center *and* angle (i.e., polar coordinates)
  - Place spokes separated by fixed angles
    - Spokes are determined by a cosine wave in polar coordinates
    - $r_{spoke} = \cos(\alpha \times frequency)$
  - Select random length and thickness for each spoke
    - Noise to the rescue
    - Thickness is determined by raising $(r_{spoke} \times amplitude)$ to a power

References

Ebert, David, et. al., *Texturing and Modeling: A Procedural Approach*, second edition, Morgan-Kaufmann, 1998. pp. 315 – 318.

- This section provided the inspiration for the crater shader.

Next week...

- Depth of field post-process effects
- Discuss final
- Discuss final project

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