VGP352 – Week 7

- Agenda:
  - Quiz #3!
  - Assignment #3 due
  - Non-photorealistic rendering
    - Cel shading (cartoon rendering)
    - Silhouette edge rendering
    - Technical illustration
  - Assignment #4
  - Readings:
    - Present readings 1 and 2
    - Assign reading 3

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Non-photorealistic Rendering (NPR)

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- In other words, NPR attempts to exaggerate or use alternate representations of imagery to convey or highlight a particular mood or message
  - Cel shading (a.k.a. “toon” rendering)
  - Painterly rendering
  - Technical illustrations
  - etc.

Cel Shading

- Several common cartoon image styles:
  - Character regions filled with solid, single-tone colors
  - Regions filled with two tones: light and dark
  - Regions filled with three tones: light, dark, and highlight

Cel Shading

- Several common cartoon image styles:
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  - Regions filled with three tones: light, dark, and highlight
  - Each is easy to produce on a computer

Cel Shading

- Single tone coloring

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Cel Shading

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  - Solid coloring (flat shading) *without* lighting

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  - If lighting is above some threshold, use the lighter color
  - Otherwise use the darker color

Cel Shading

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  - Solid coloring (flat shading) *without* lighting
- Two-tone coloring
  - Driven by surface lighting
  - If lighting is above some threshold, use the lighter color
  - Otherwise use the darker color
  - Calculate $N \bullet L$ *per vertex* and interpolate across surface, check value per fragment
    - Classically done using texture lookups, but is faster using conditional assignments on shader hardware

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  - Material edge – boundary between two different colors or materials
  - Silhouette edges – edges where one border polygon faces towards the viewer and the other faces away

Cel Boundary Inking

- Most boundary types are calculated during authoring or as a preprocessing step
  - Border edges – edges are added by the artist, by the authoring tool, or are detected in a preprocessing step
  - Crease edges – dihedral angle is calculated during preprocessing. If $N_{surface1} \bullet N_{surface2} < \cos(60^\circ)$, the edge is a crease
  - Material edge – handled the same as border edges

Silhouette Edge Rendering

- Silhouette edges are view-dependent and must be calculated at run-time
  - Conceptually similar to drawing fins in shells-and-fins fur rendering
- Several broad classes of implementations:
  - Surface angle
  - Added geometry
  - Image processing
  - Explicit edge detection

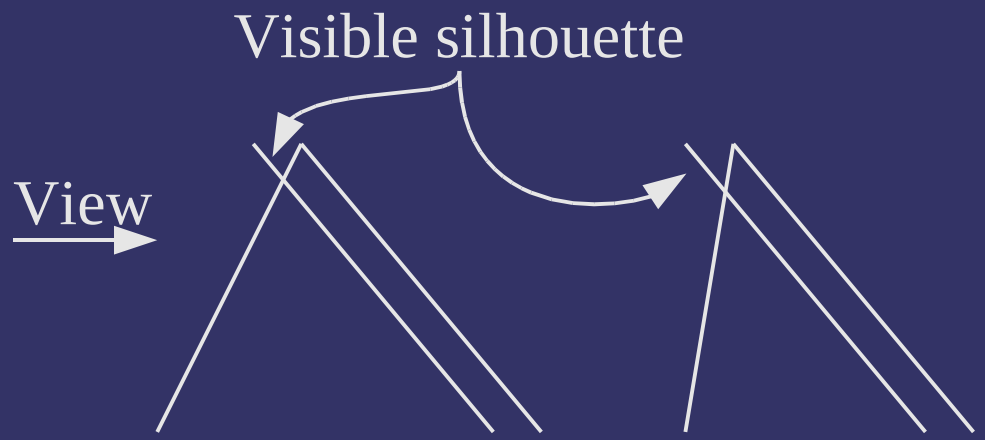
Silhouette Edge Rendering

- Surface angle test is similar to two-tone cel shading
  - Examine angle between V and N
  - If angle is near 90°, use silhouette color
- Pros / cons:
  - *Really* easy to implement
  - Doesn't work on all models
    - Generally fails on models with large flat surfaces
    - Only worked on about 25% of the models in the game *Cel Damage*[1]

[1] *Real-Time Rendering*, p. 295

Silhouette Edge Rendering

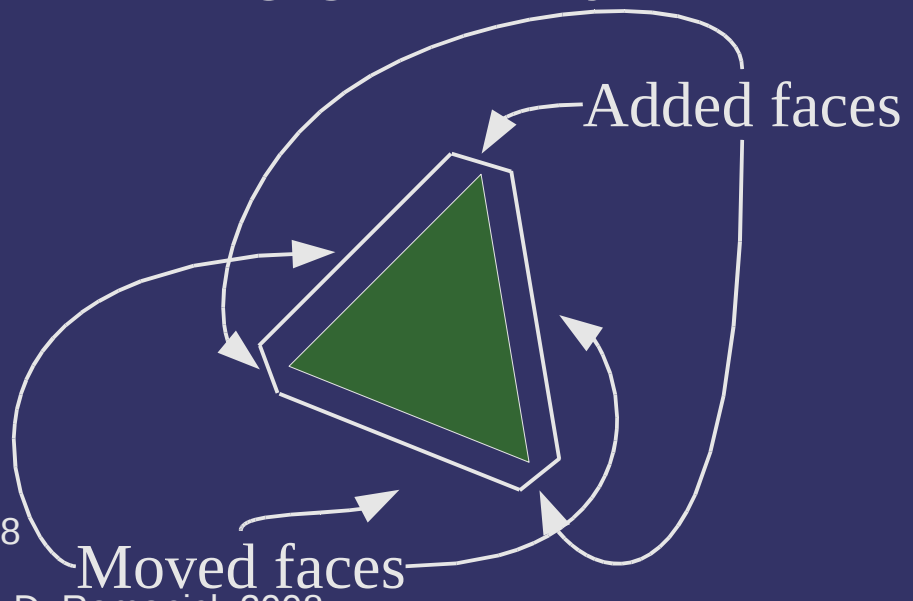
- Back-face biasing:
  - Render back-facing geometry by moving it towards the camera by some small delta



  - Amount to bias back-face depends on both slope of back-face and slope of front-face

Silhouette Edge Rendering

- Edge expansion:
  - Move each face out by some distance along the plane's normal
    - *Not* the vertex normal!
    - Adjust the distance according to the desired silhouette thickness
  - Create new geometry to fill in the gaps
  - Render back-facing geometry



Silhouette Edge Rendering

- Shell expansion:
  - Similar to edge expansion
  - Render shell as object geometry expanded along vertex normals
    - Normals must be identical for vertices shared by two polygons
    - Otherwise degenerate edge polygons must be added
    - Render only back-faces of shell

Silhouette Edge Rendering

- Image processing:
  - Render surface normal and depth a texture
    - Store normal in RGB and most significant portion of depth in alpha
  - Process texture with separable edge detection filter
    - Card and Mitchell recommend using the Sobel edge detection filter
    - Store each pass in a texture
    - Composite both textures together over scene

Silhouette Edge Rendering

- Explicit edge detection:
  - Draw each edge of the object as a line
  - At each vertex, store the normals of the two adjoining polygons
  - If one normal points towards the viewer and the other away, draw the line as a silhouette
  - If the two normals point significantly away from each other, draw the line as a crease

Break

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Gooch-style Technical Illustration

- Many similar ideas to cel shading
  - Use alternate shading
  - Highlight creases
  - Highlight silhouettes

Gooch-style Technical Illustration

- Shade objects from warm to cool instead of light to dark
  - Still conveys information about the curvature of the object
  - Maintains visibility of details in areas that would be dark or difficult to light

Gooch-style Technical Illustration

- Shade objects from warm to cool instead of light to dark
  - Still conveys information about the curvature of the object
  - Maintains visibility of details in areas that would be dark or difficult to light
- Shade in similar manner to cel shading
  - Calculate $N \bullet L$ per vertex
  - Use interpolated value per fragment to look up in a 1D blue-green to yellow-orange gradient texture

Gooch-style Technical Illustration

- Draw crease edges in white
  - This helps provide information about the model's orientation

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  - If an edge is *both* a crease and a silhouette, it should be drawn as a silhouette

Gooch-style Technical Illustration

- Draw crease edges in white
  - This helps provide information about the model's orientation
- Draw silhouette edges in black
  - If an edge is *both* a crease and a silhouette, it should be drawn as a silhouette
- Silhouette and crease edges are handled differently, so the image processing method of inking probably can't be used
  - Using the explicit edge detection method allows silhouettes and creases to be drawn in a single pass

References

Gooch, B., Sloan, P. J., Gooch, A., Shirley, P., and Riesenfeld, R. 1999. Interactive technical illustration. In *Proceedings of the 1999 Symposium on interactive 3D Graphics* (Atlanta, Georgia, United States, April 26 - 29, 1999). I3D '99. ACM, New York, NY, 31-38. http://www.cs.utah.edu/~bgooch/ITI/

Next week...

- Procedural textures
  - Noise
  - Simple noise based textures
  - Wang tiles

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