Announcements

- **Dec 16**, 7-11pm in Siebel 4240.
  Final project presentations and Open House for press!
(Visual) Rendering

Object Frame

World Frame

Eye Frame

Display Frame

Canonical Frame

\[ T = T_{vp} \cdot T_{can} \cdot T_{eye} \cdot T_{rb} \]
# Object-Order Rending

## Image-order rendering stages:

1. Ray generation
2. Ray intersection
3. Shading: assign RGB values

## Object-order rendering stages:

1. Rasterization
2. Depth order
3. Shading: assign RGB values

**Rasterization:**


Painter's Algorithm

- Display polygons in back-to-front order
- Sort polygons by z-value
  - Which vertex?
  - $O(n \log n)$
- Problems…
Key Observation: Each pixel displays color of only one triangle, ignores everything behind it

- Don’t need to sort triangles, just find for each pixel the closest triangle
- Z-buffer: one fixed or floating point value per pixel
- Algorithm:
  For each rasterized fragment \((x,y)\)
  If \(z > \text{zbuffer}(x,y)\) then
  \[
  \text{framebuffer}(x,y) = \text{fragment color}
  \]
  \[
  \text{zbuffer}(x,y) = z
  \]
Clipping:

- Remove triangles behind the eye

Culling:

- View Frustum: Remove triangles outside of viewing frustum.
- Occlusion: Remove hidden triangles.
- Backface: Remove triangles on "back" of objects.
Interpolation and Barycentric Coordinates
RGB Mapping
Texture Mappings
Mipmapping

No Mipmapping

With Mipmapping
Bump Mapping

Without bump map

With bump map

Approximation using bump mapping on a planar surface

Geometry of a bumpy surface
Normal Mapping

Example of a normal map (center) with the scene it was calculated from (left) and the result when applied to a flat surface (right).
Problems with Rendering for VR

Shading:

- Highlights need stereo perspective
- Texture maps look like painted cardboard
- Bump/normal maps look fake
Problems with Rendering for VR

Aliasing:
- Need higher resolution than we ever needed before.
- Staircases become escalators.
- Stereo causes mismatched "escalators" for every edge.
Problems with Rendering for VR

Render target: Use stencil buffer in GPU
Problems with Rendering for VR

Correct for optical distortion.

Latency:
- GPU pipeline has been optimized for triangle throughput.
- Latency compensation
  Post rendering image warp
  Predictive tracking

Geometry errors:
- Thin objects look fake or implausible.
- Holes or isolated points become more noticable.
Some Solutions for Rendering for VR

Antialiasing
- Good but expensive.
- Use MSAA (multi sampling antialiasing) - shading calculations are not done for all of the samples.