Visibility

CS 355: Introduction to Graphics and Image Processing

Two Parts of 3D Rendering

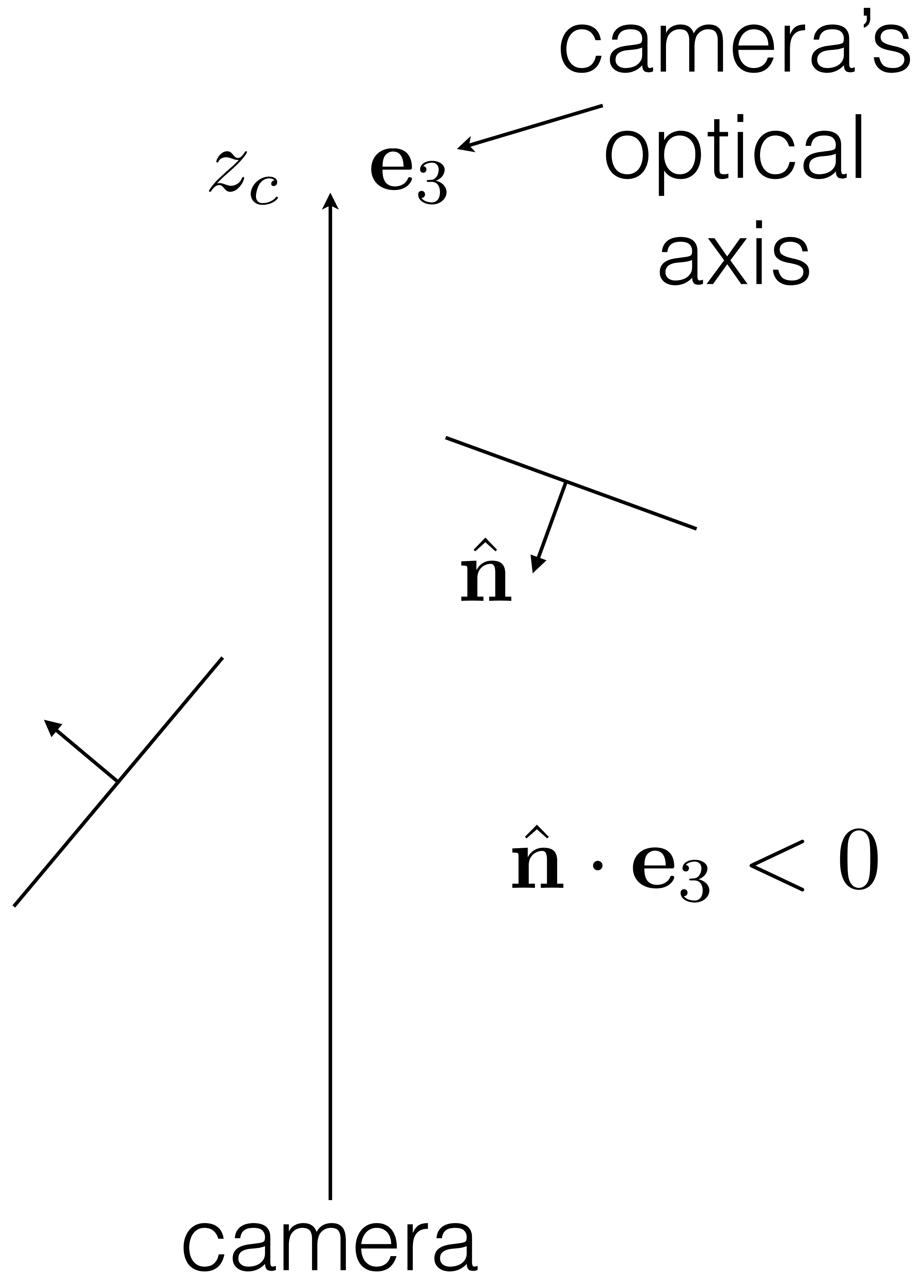
- Two key parts of 3D rendering:
  - What is visible where? (Visibility)
  - What light is coming from there? (Lighting)

Visibility

- Parts of visibility:
  - ✓ Where is everything relative to the camera?
    (world-to-camera transformation)
  - ✓ What is within the field of view?
    (clip matrix / clip tests)
  - What is in front of what else?

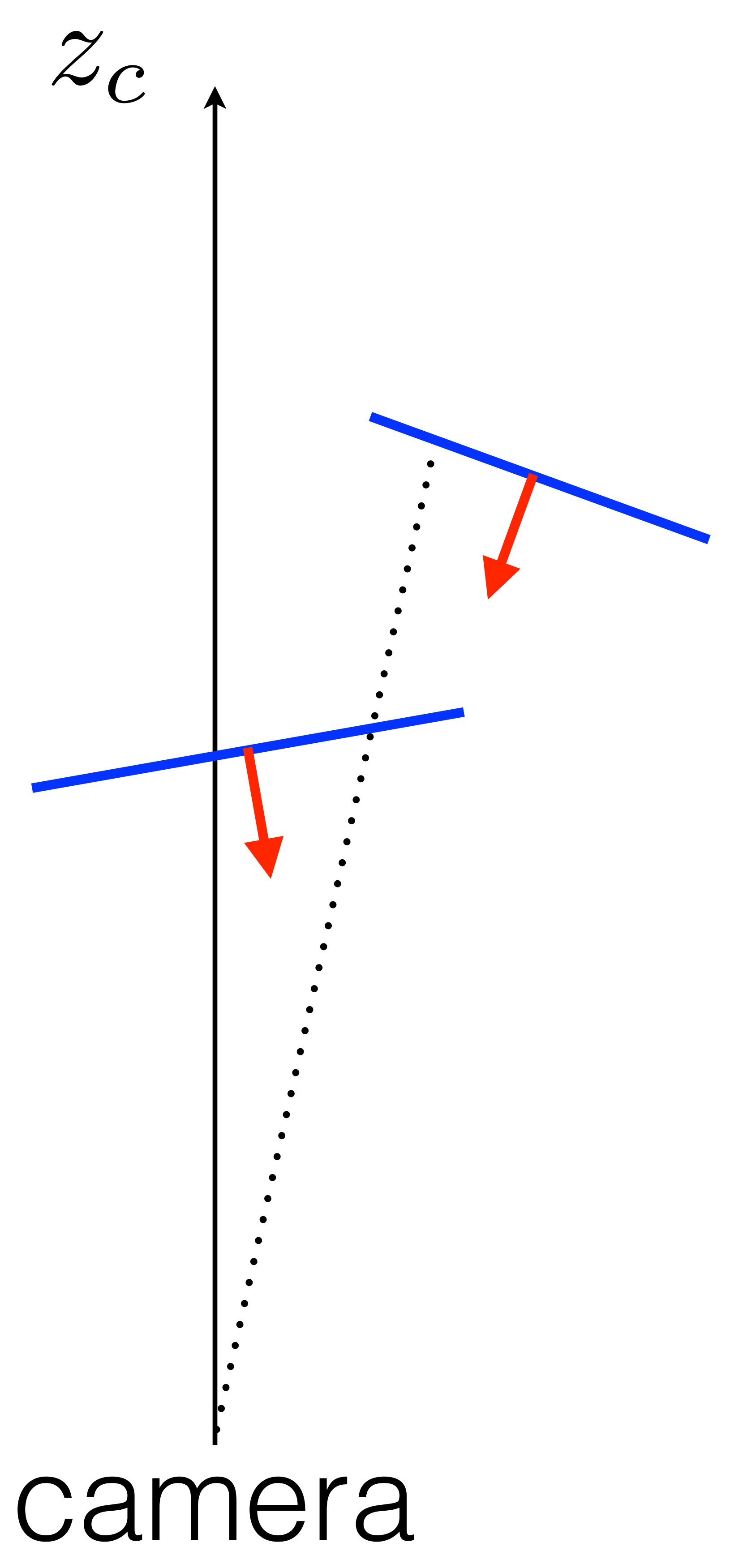
Back-Face Culling

- Simple idea:
    - Faces that point towards camera <u>may</u> be seen
    - Faces that point away from camera <u>cannot</u> be seen
- Can do this test while still in world coordinates



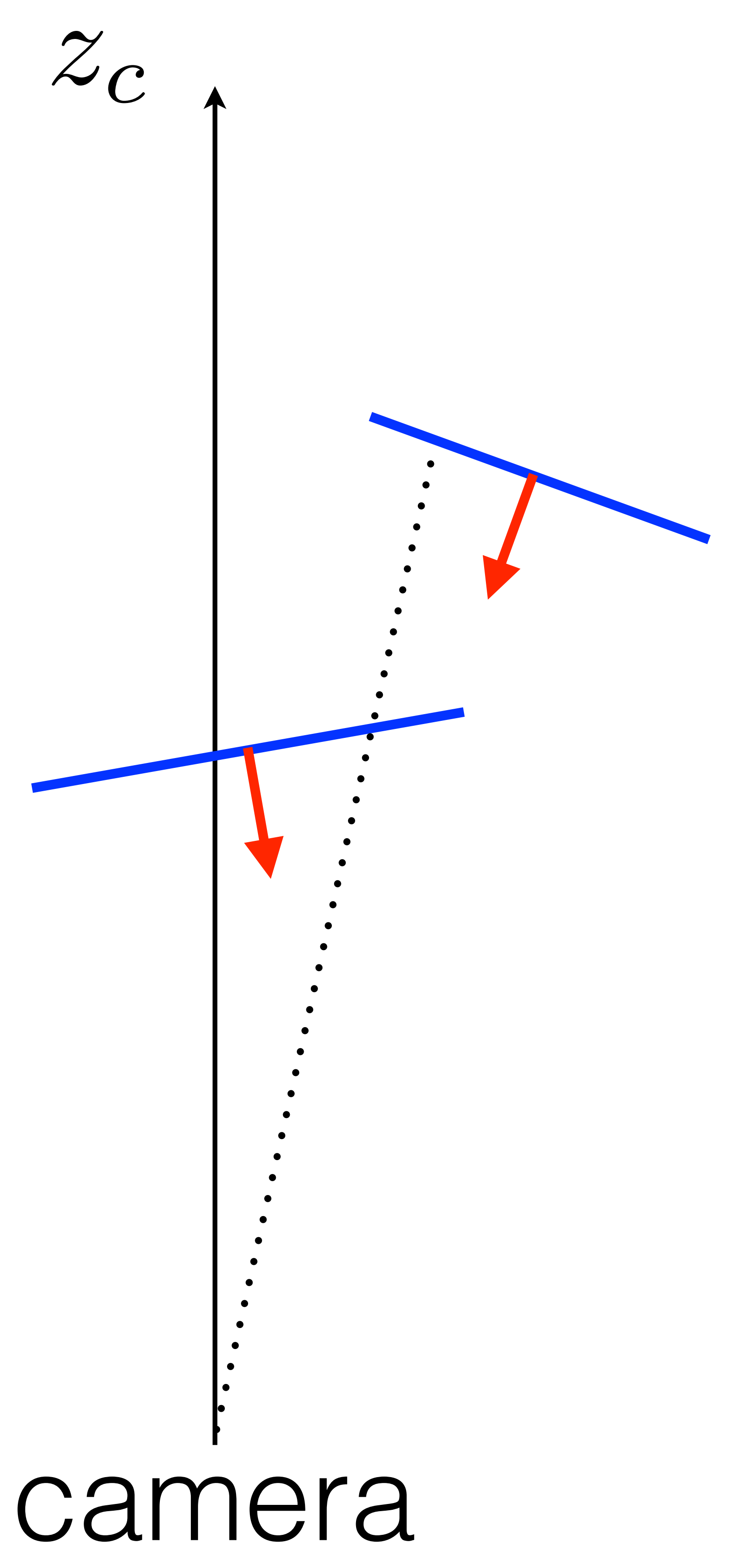
Occlusion Testing

- See what is in front of what else
- Test for things that fall on the same camera position
- If opaque, one object occludes the other



Occlusion Testing

- Three common ways:
  - Ordered rendering (painter's algorithm)
  - Image space testing (z-buffering)
  - Ray casting



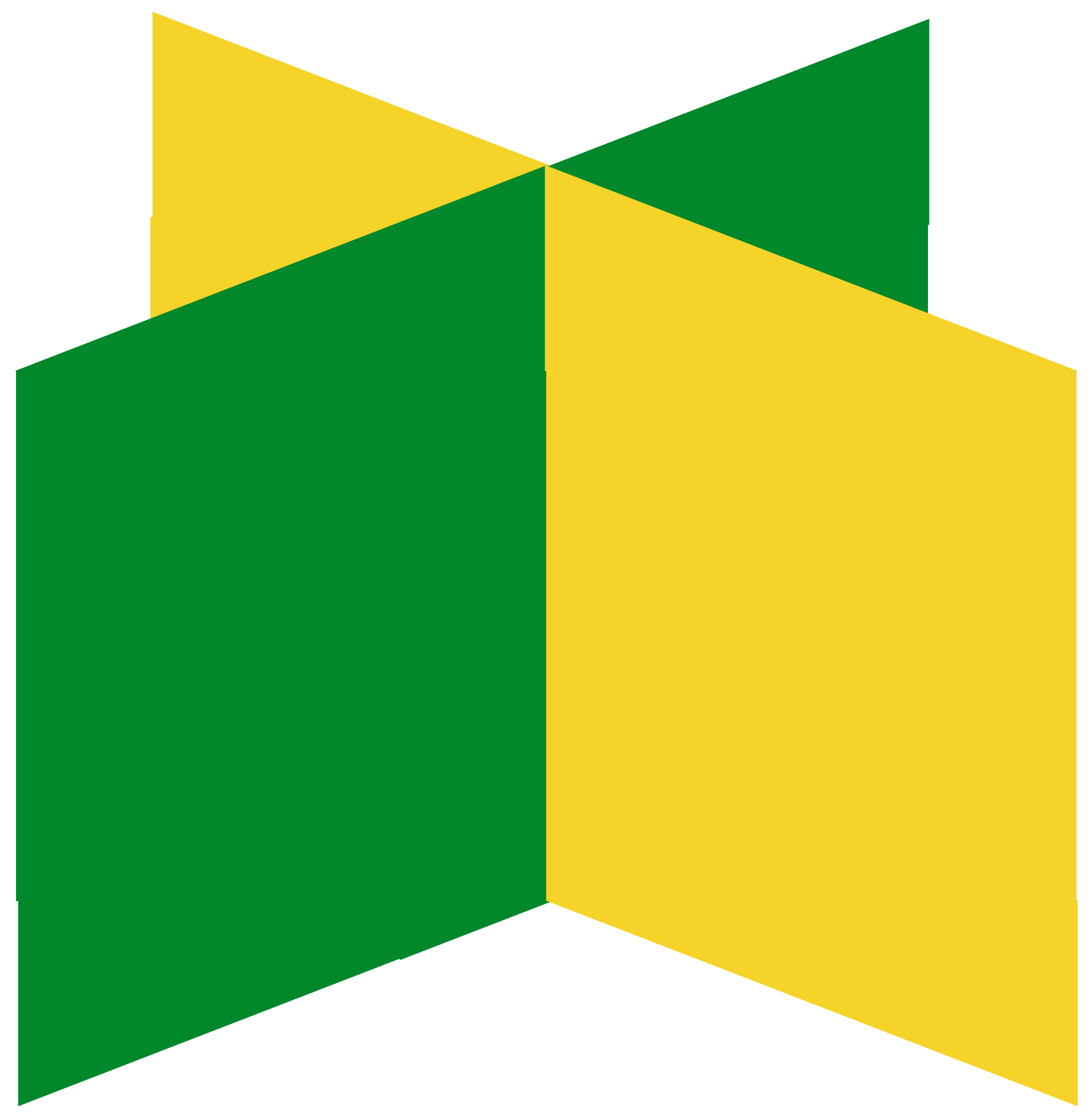
Painter’s Algorithm

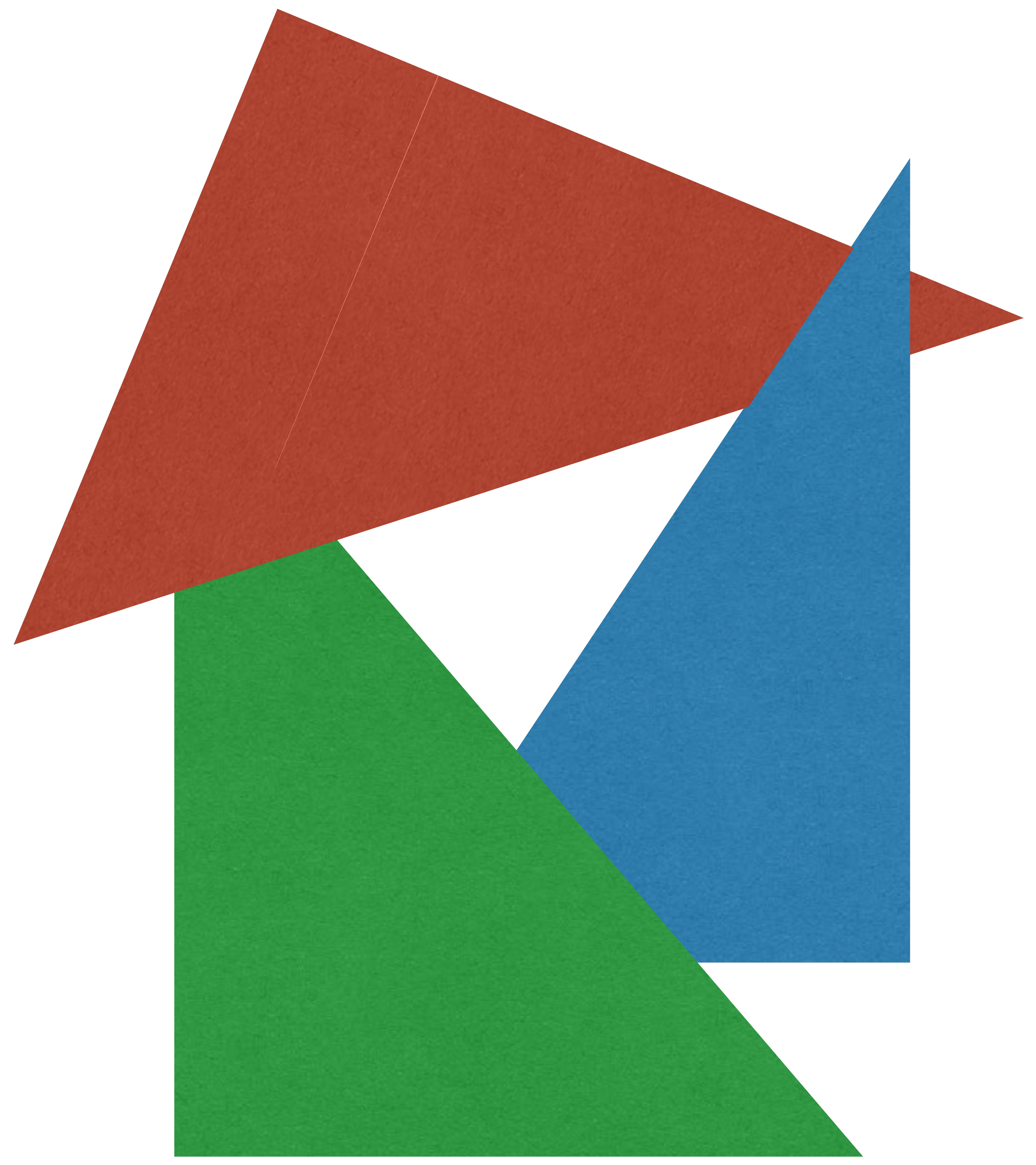
- Simple idea:
  - Render from back to front (decreasing z)
  - Draw things over top of others on screen
  - Last one drawn wins!

- Big problem:
  - Polygon depth isn’t strictly ordered
    - Interpenetration
    - Mutually overlapping

This technique isn’t used much anymore,
but the idea shows up in *lots* of places

Painter’s Problems





Z-Buffering

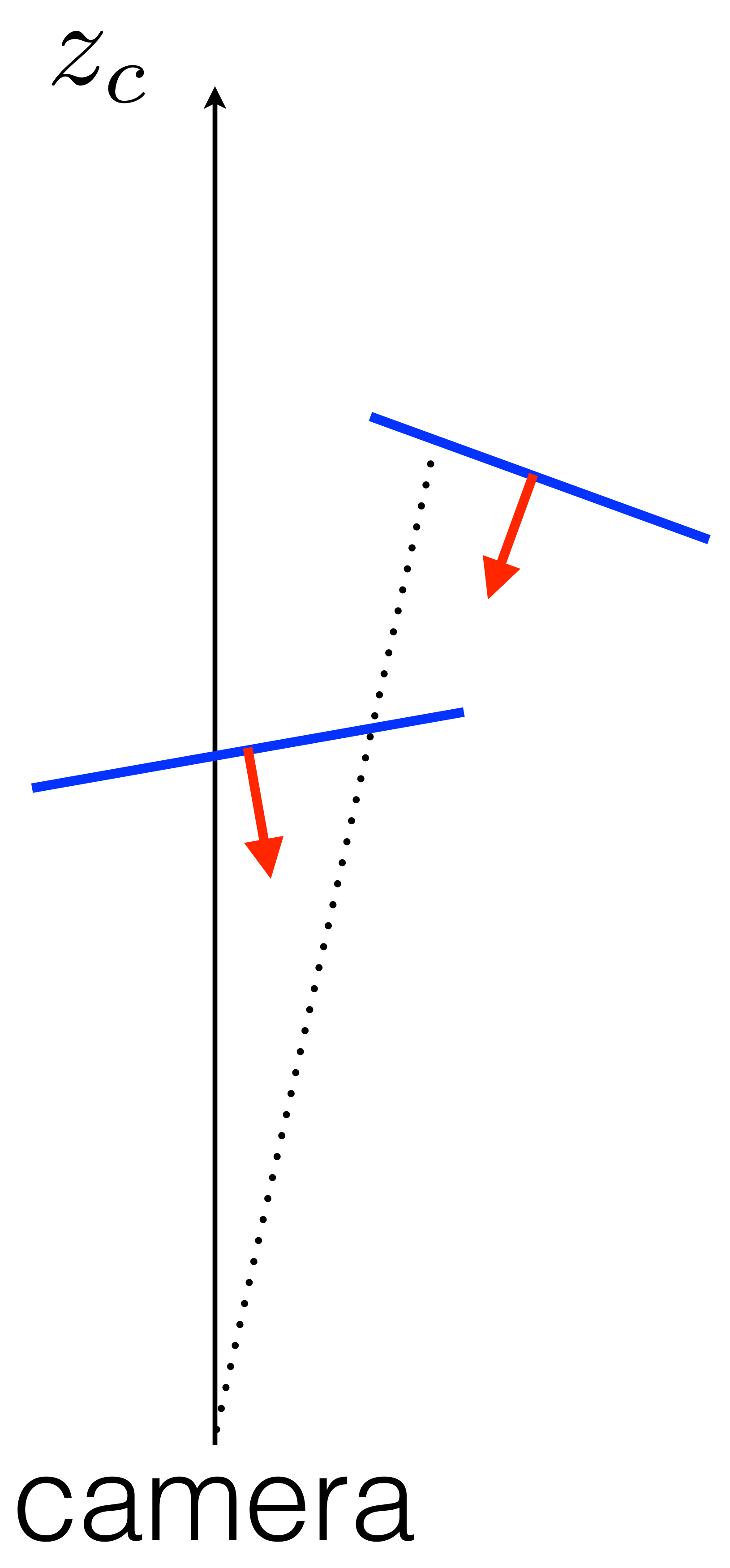
canonical screen coordinates

$$\begin{bmatrix} \boxed{\begin{matrix} x/w \\ y/w \end{matrix}} \\ \boxed{z/w} \\ 1 \end{bmatrix} \sim \begin{bmatrix} x \\ y \\ z \\ w \end{bmatrix} = \begin{bmatrix} \mathrm{zoom}_x & 0 & 0 & 0 \\ 0 & \mathrm{zoom}_y & 0 & 0 \\ 0 & 0 & \frac{f+n}{f-n} & \frac{-2nf}{f-n} \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix}$$

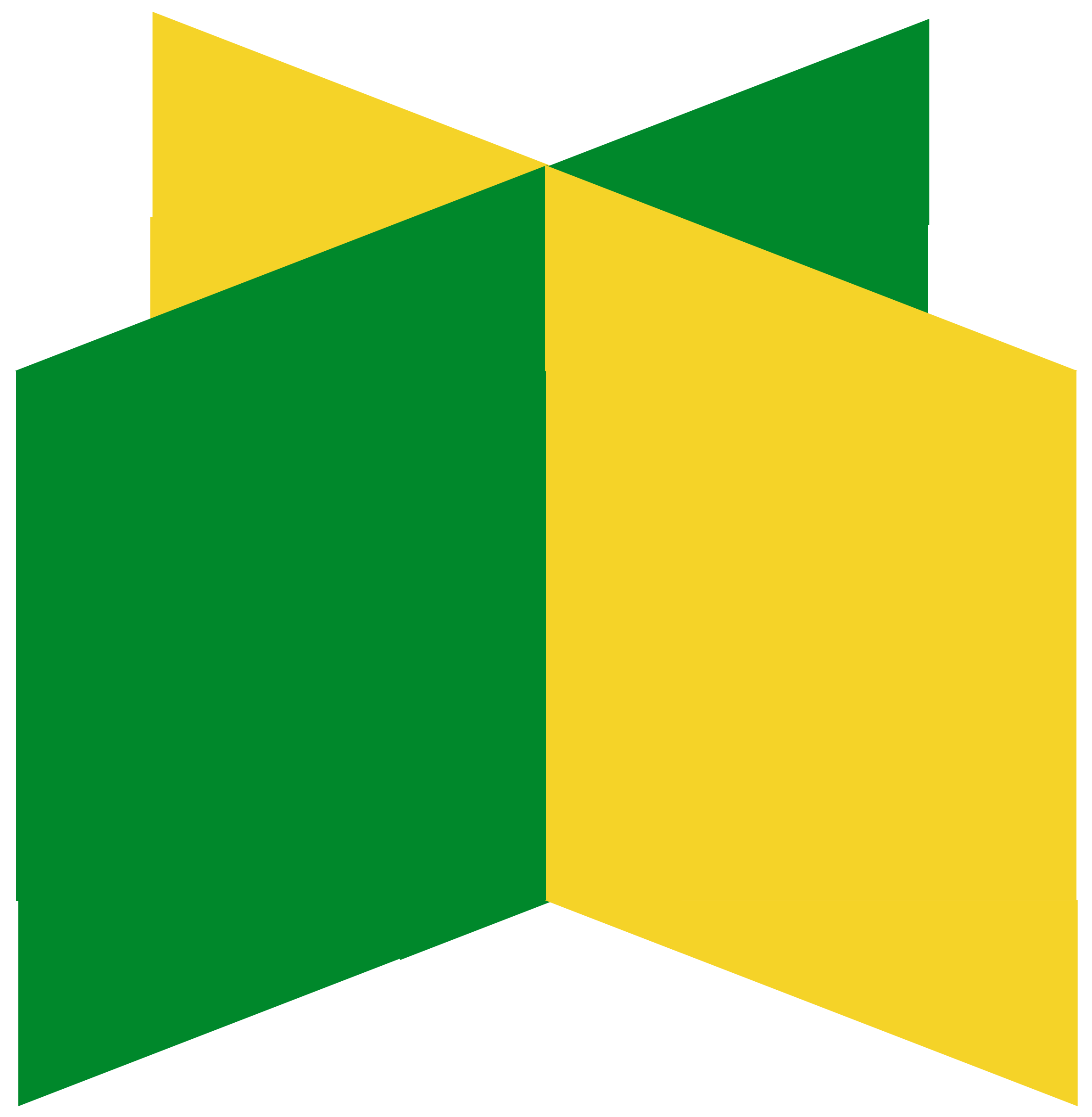
normalized depth

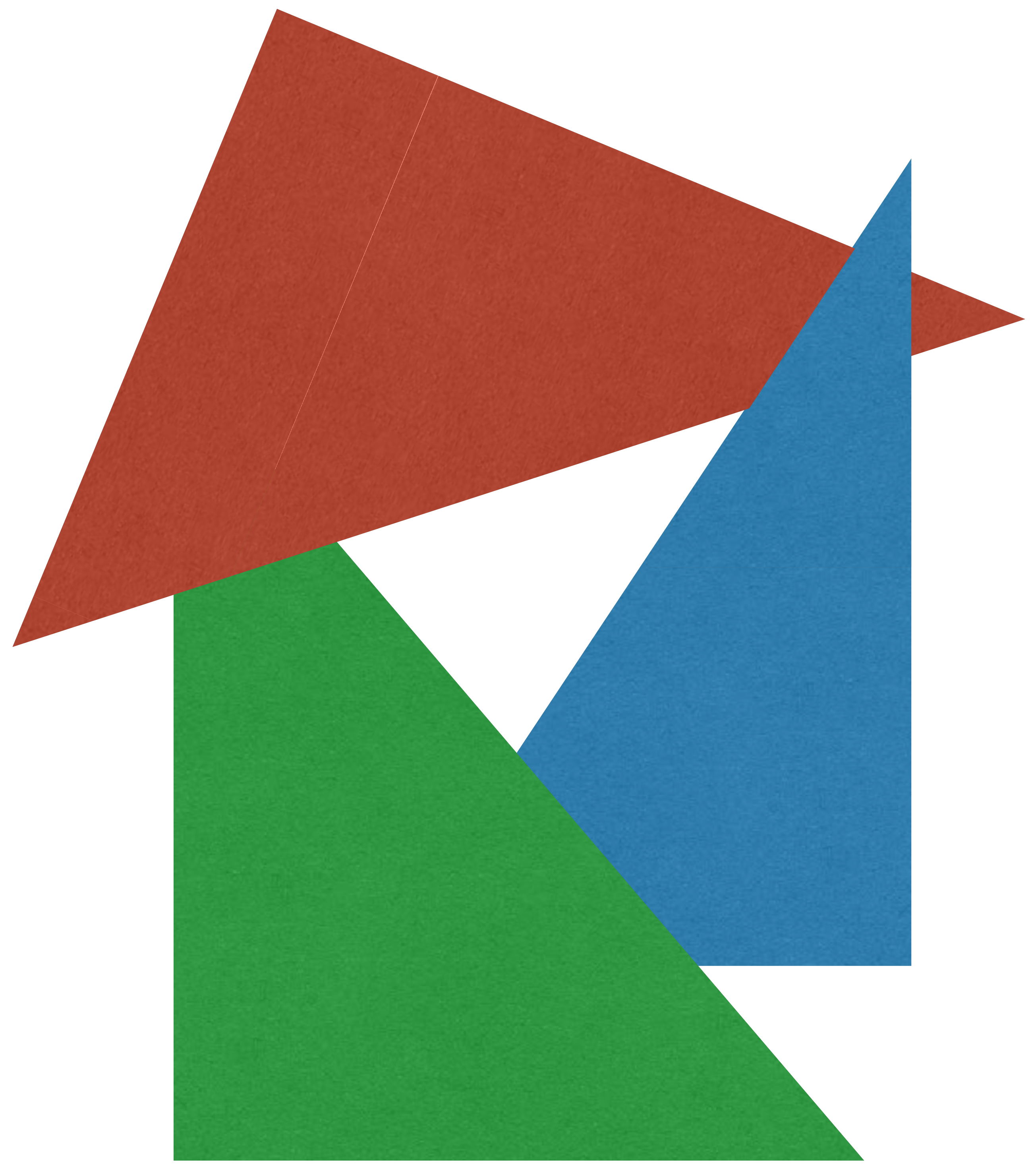
Z-Buffering

- Keep an image buffer that stores the depth of what is rendered at each pixel
- Render in any order
- Draw new stuff only if closer



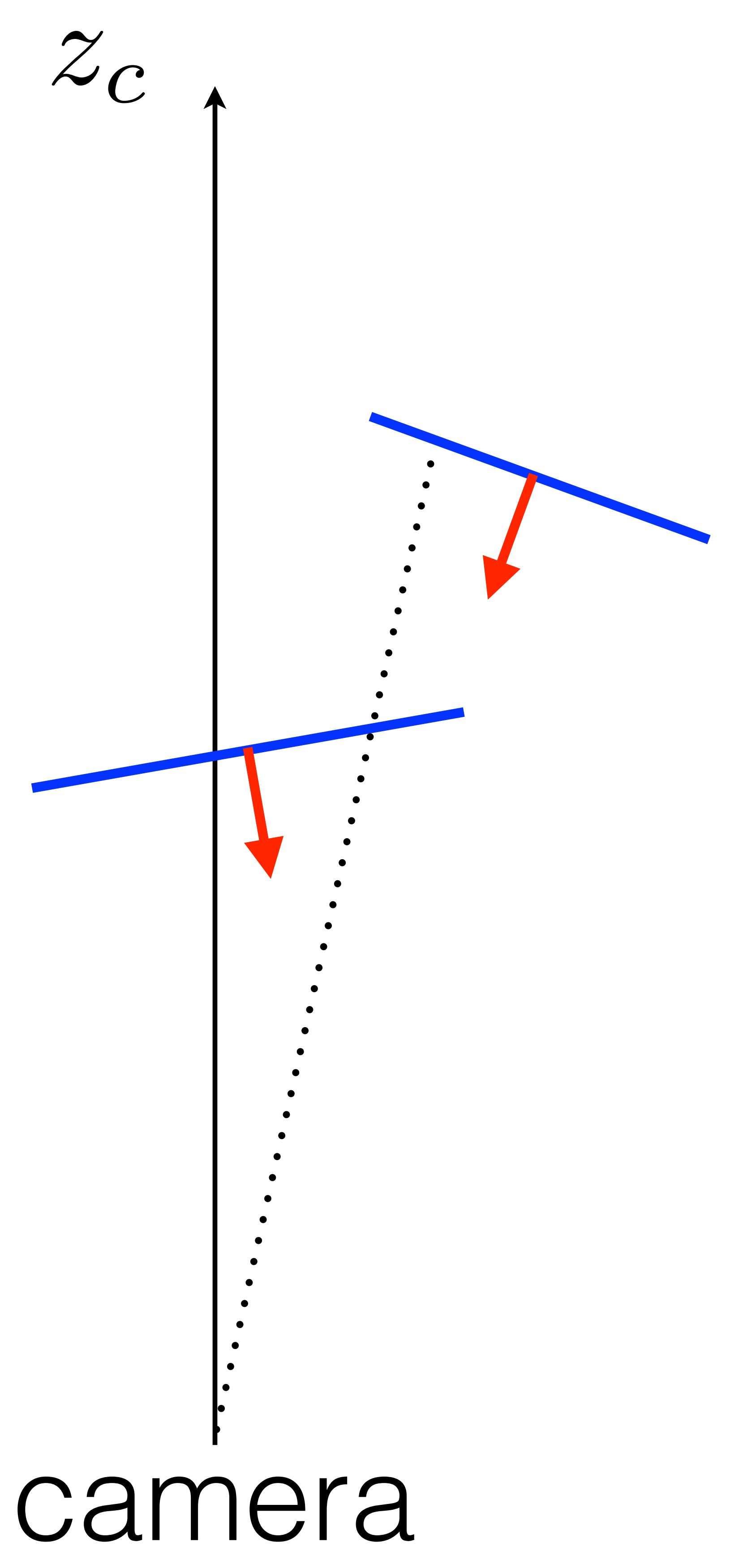
Z-Buffering





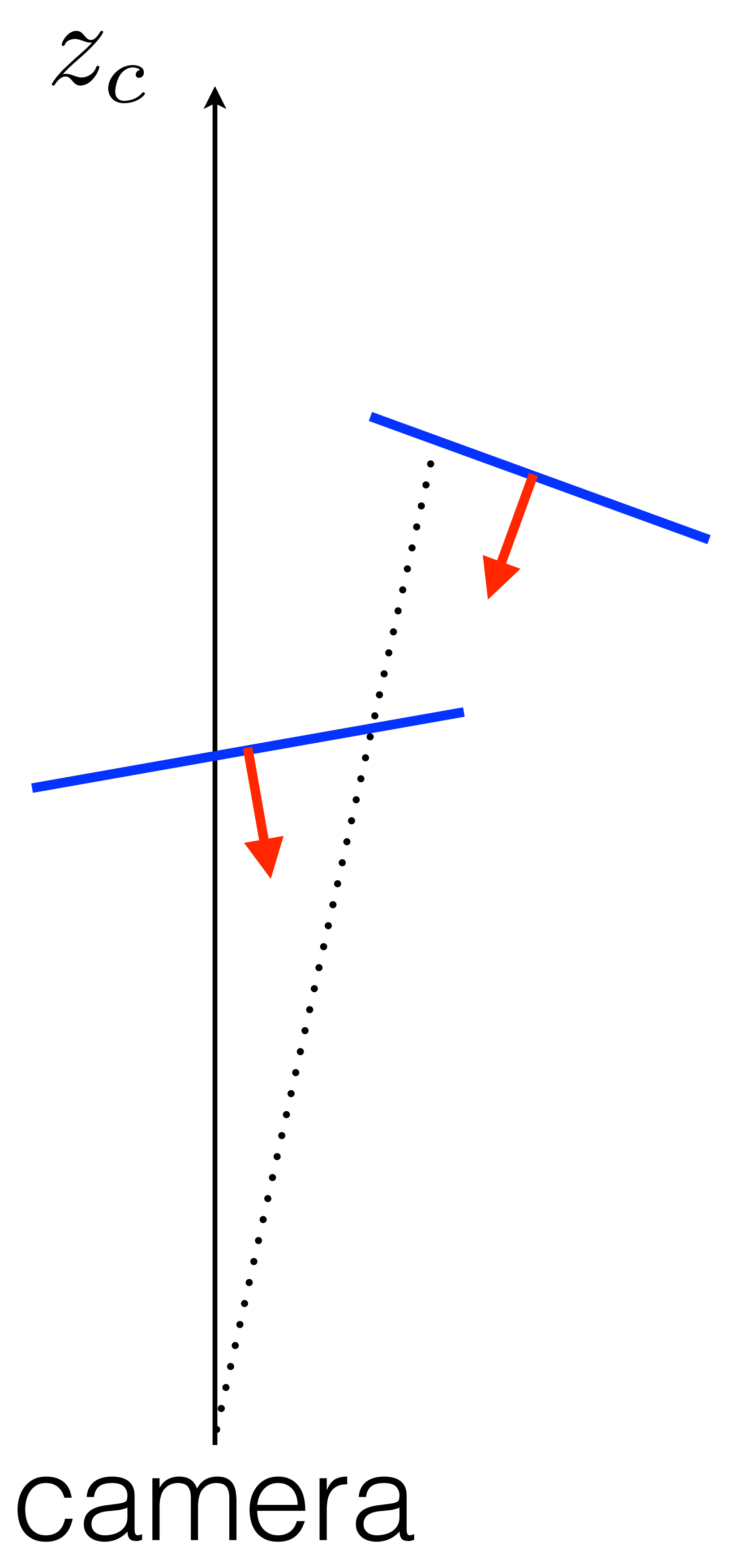
Z-Buffering

- Issue: quantization of the finite-precision *z* buffer
- Round-off error may be an issue (most use floating point)
- Nonlinear by depth (coarser farther away)



Z-Buffering

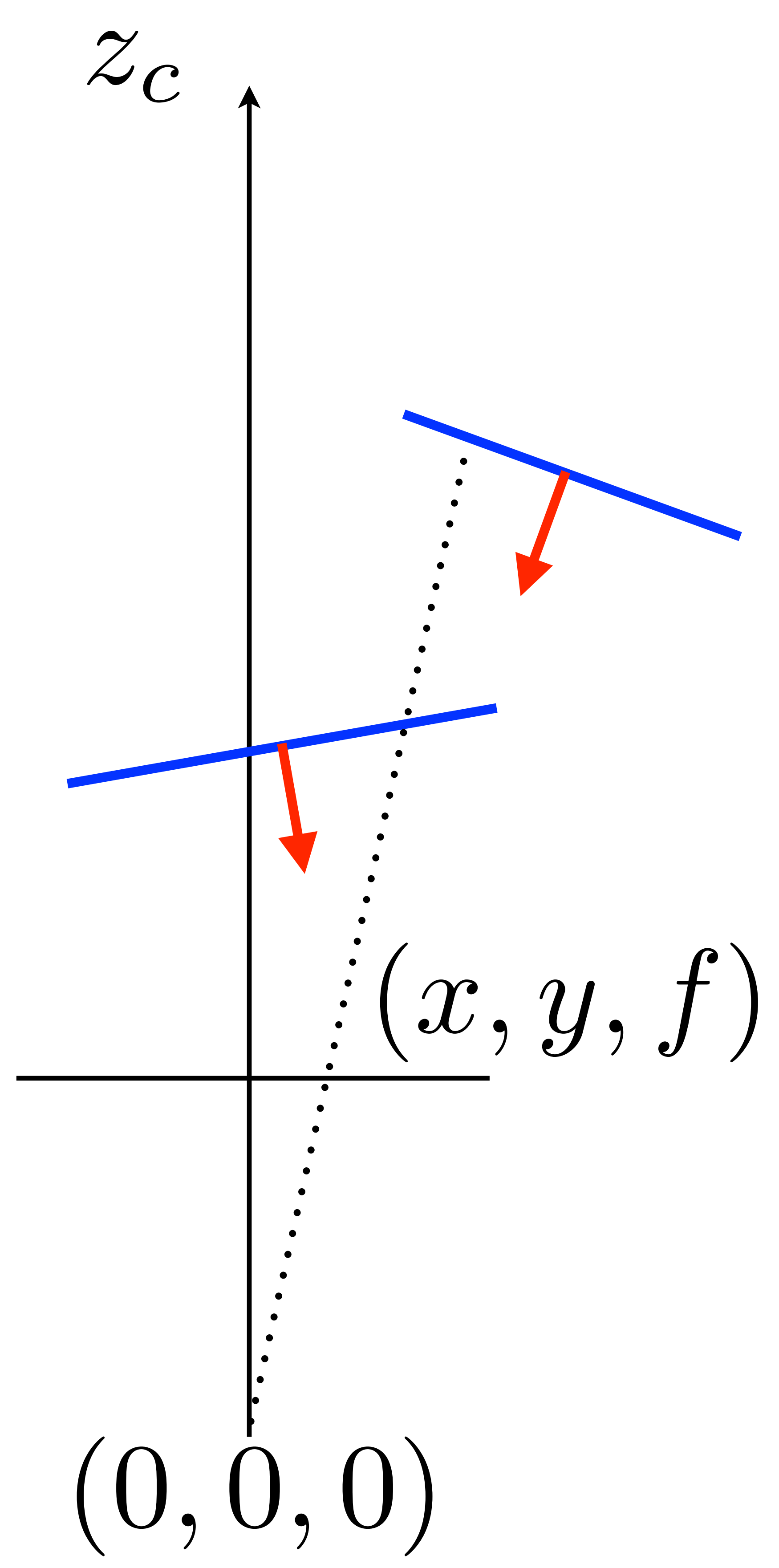
- Issue: discretization of the image z buffer
- Hard to do antialiasing (partial painting of pixels on boundaries)



Ray Casting

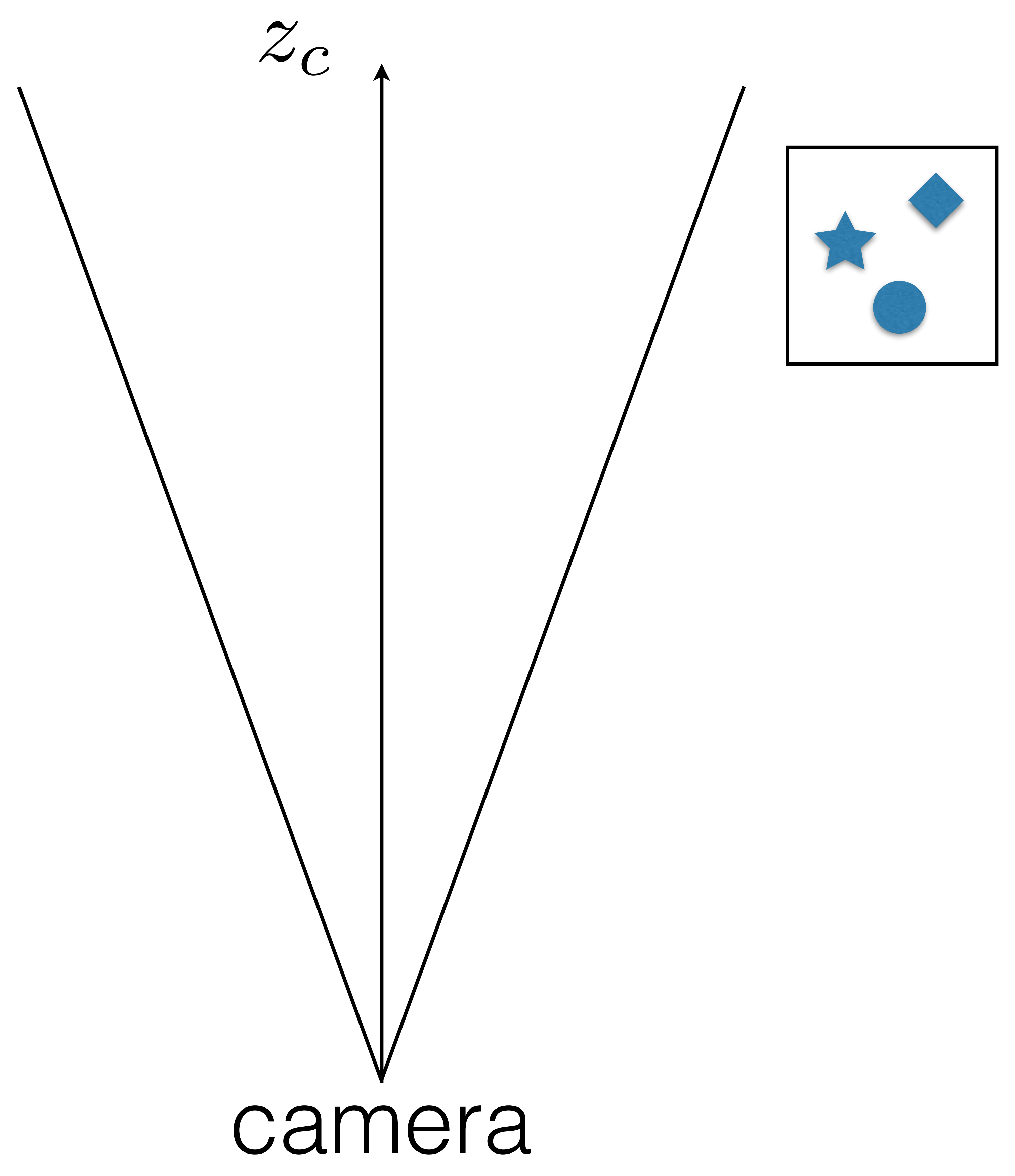
- Idea: shoot a ray out from the camera's focal point through the pixel location
- What does it hit first?
- Lots of ray-primitive intersection tests

(Arthur Appel, 1968)



Objects & Bounding Boxes

- All of these can be accelerated by grouping primitives and using **bounding boxes** (or other shapes)
- Often axis-aligned bounding boxes (AABBs) in original object space
- Transform to a general bounding box in camera space
- *Throw out if all corners are out of view, not visible, etc.*



Coming up…

- Visibility
- Lighting