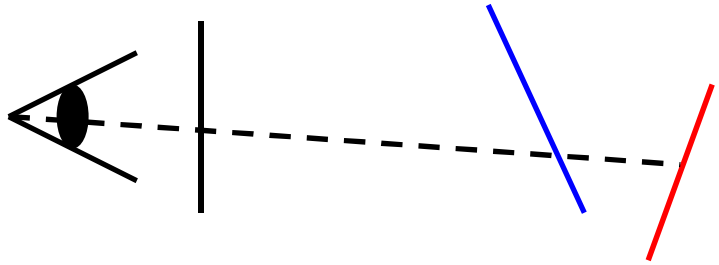
Basic Visibility Algorithms

The Visibility Problem



- What is the nearest surface seen at any point in the image?

- How would YOU solve this problem?

Three of the Simplest Algorithms

Painter's

```
sort objects by z (back-to-front)
loop objects
        loop y
                loop x
                        write pixel
```

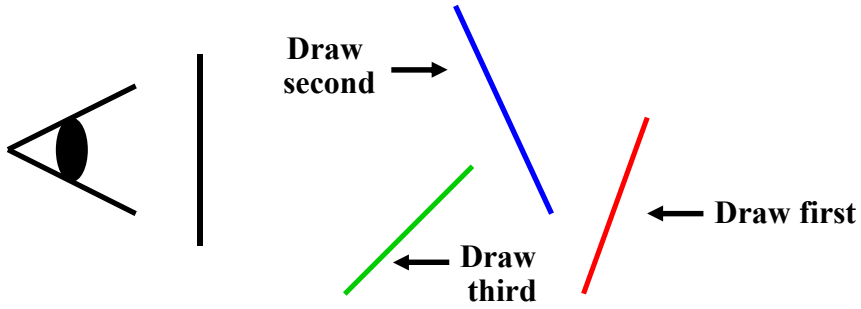
Ray Casting

```
loop y
        loop x
                loop objects
                        find object with min z
                write pixel
```

Z-buffer

```
initialize z-buffer
loop objects
        loop y
                loop x
                        if z(x,y) < zbuf[x,y]
                                zbuf[x,y] = z(x,y)
                                write image pixel
```

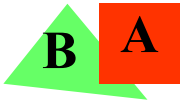
Painter's Algorithm



- Sort objects by depth (Z)
- Loop over objects in back-to-front order
  - Project to image
    - » scan convert: image[x,y] = shade(x,y)

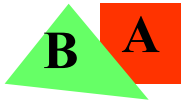
Sorting Objects by Depth

Depth ordering is a *partial ordering.* Outcomes are



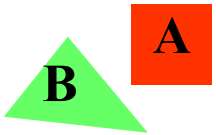
A occludes B

draw B before A



B occludes A

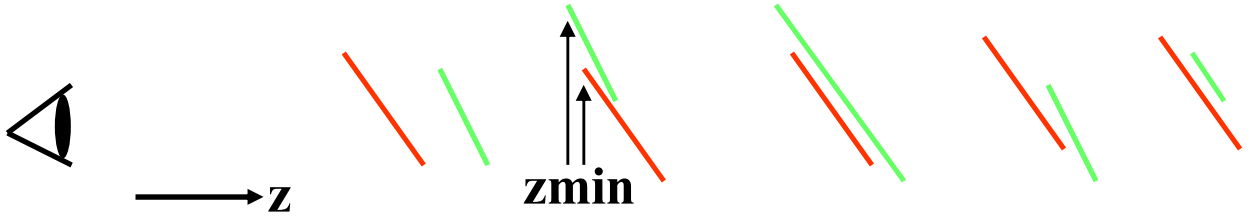
draw A before B



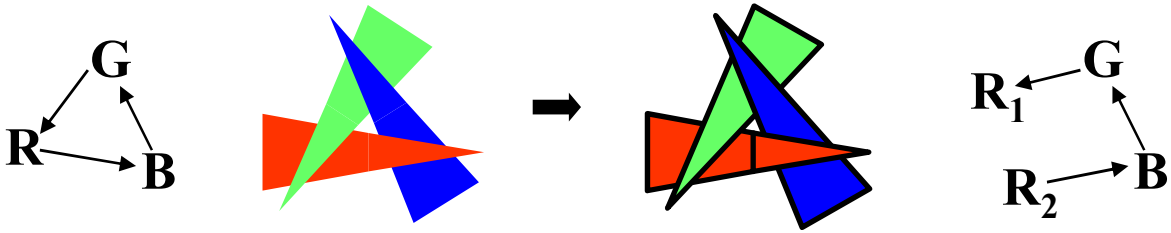
don’ t care

draw in either order

Sorting objects by their zmin doesn’ t always work! (same for zmax)



Sometimes ordering is cyclic! What to do? Split objects!



Painter's Algorithm

- Strengths
  - Simplicity: draw objects one-at-a-time, scan convert each
  - Handles transparency well
- Drawbacks
  - Sorting can be expensive (slower than linear in the number of objects)
  - Clumsy when ordering is cyclic, because of need to split
  - Interpenetrating polygons need to be split, too
  - Hard to sort non-polygonal objects
- Sometimes no need to sort
  - If objects are arranged in a grid, e.g. triangles in a height field z(x,y), such as a triangulated terrain

- Who uses it?
  - Postscript interpreters
  - OpenGL, if you don't glEnable(GL_DEPTH_TEST);

Z-Buffer Algorithm

- Initialization

```
loop over all x,y
        zbuf[x,y] = infinity
```

- Drawing steps

```
loop over all objects
    scan convert object (loop over x,y)
        if z(x,y) < zbuf[x,y]          /* compute z of this object at
        this pixel & test */
            zbuf[x,y] = z(x,y)      /* update z-buffer */
            image[x,y] = shade(x,y)        /* update image (typically RGB) */
```

Z-Buffer Algorithm

- Strengths
  - Simple, no sorting or splitting
  - Easy to mix polygons, spheres, other geometric primitives
- Drawbacks
  - Can't handle transparency well
  - Need good Z-buffer resolution or you get depth ordering artifacts
    - » In OpenGL, this resolution is controlled by choice of clipping planes and number of bits for depth
    - » Choose ratio of clipping plane depths (zfar/znear) to be as small as possible
- Who uses it?
  - OpenGL, if you glEnable(GL_DEPTH_TEST);

Ray Casting

- A very flexible visibility algorithm

```
loop y
 loop x
    shoot ray from eye point through
     pixel (x,y) into scene
    intersect with all surfaces, find
     first one the ray hits
    shade that surface point to
     compute pixel (x,y)' s color
```

Comparison of Visibility Algorithms

Painter's:

- Implementation: moderate to hard if sorting & splitting needed
- Speed: fast if objects are pre-sorted, otherwise slow
- Generality: sorting & splitting make it ill-suited for general 3-D rendering

Z-buffer:

- Implementation: moderate, it can be implemented in hardware
- Speed: fast, unless depth complexity is high
- Generality: good but won't do transparency

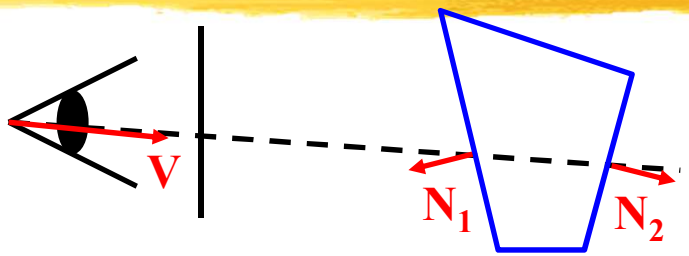
Ray Casting:

- Implementation: easy, but hard to make it run fast
- Speed: slow if many objects: cost is O((#pixels)×(#objects))
- Generality: excellent, can even do CSG, transparency

Really Hard Visibility Problems

- Extremely high scene complexity
  - a building walkthrough (QUAKE)?
  - A fly-by of the Grand Canyon (or any outdoor scene!)
- Z-buffering requires drawing EVERY triangle for each image
  - Not feasible in real time
- Usually Z-buffering is combined with spatial data structures
  - BSP trees are common (similar concept to octrees)
- For *really* complex scenes, visibility isn't always enough
  - Objects WAY in the distance are too small to matter
  - Might as well approximate far-off objects with simpler primitives
  - This is called geometry *simplification*

Backface Culling



- Each polygon is either front-facing or back-facing
  - A polygon is backfacing if its normal points away from the viewer,
  - i.e. V•N >= 0
- When it works
  - If object is closed, back faces are never visible so no need to render them
  - Easy way to eliminate half your polygons
  - Can be used with both z-buffer and painter's algorithms
  - If object is convex, backface culling is a complete visibility algorithm!
- When it doesn't work
  - If objects are not closed, back faces might be visible

More visibility

- Block occlusion (HP extension, now NVidia extension)