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Implementation II

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Objectives

- Introduce clipping algorithms for polygons
- Survey hidden-surface algorithms

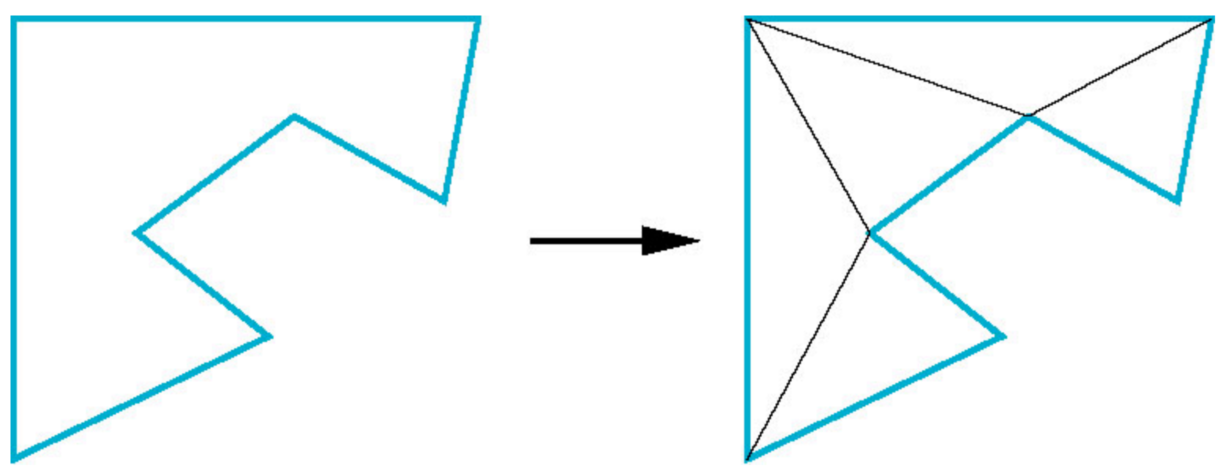
Polygon Clipping

- Not as simple as line segment clipping
  - Clipping a line segment yields at most one line segment
  - Clipping a polygon can yield multiple polygons

- However, clipping a convex polygon can yield at most one other polygon

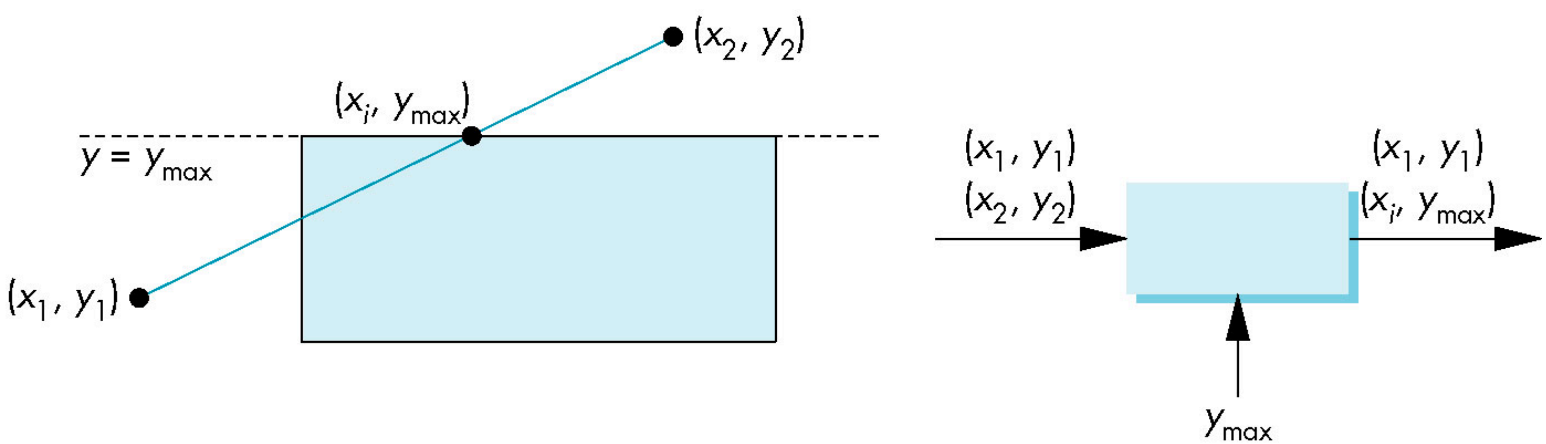
Tessellation and Convexity

- One strategy is to replace nonconvex (*concave*) polygons with a set of triangular polygons (a *tessellation*)
- Also makes fill easier
- Tessellation code in GLU library



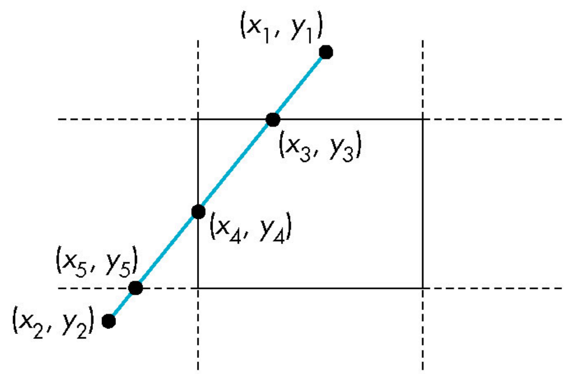
Clipping as a Black Box

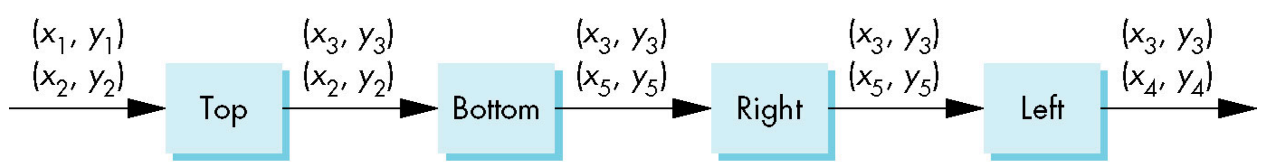
- Can consider line segment clipping as a process that takes in two vertices and produces either no vertices or the vertices of a clipped line segment



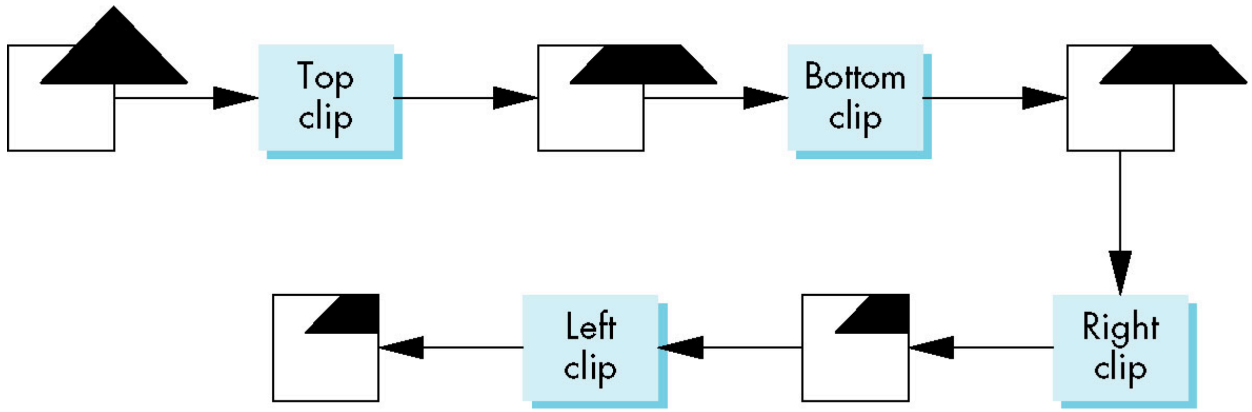
Pipeline Clipping of Line Segments

- Clipping against each side of window is independent of other sides
    - Can use four independent clippers in a pipeline





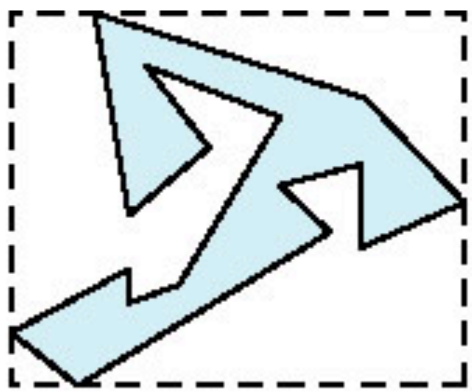
Pipeline Clipping of Polygons



- Three dimensions: add front and back clippers
- Strategy used in SGI Geometry Engine
- Small increase in latency

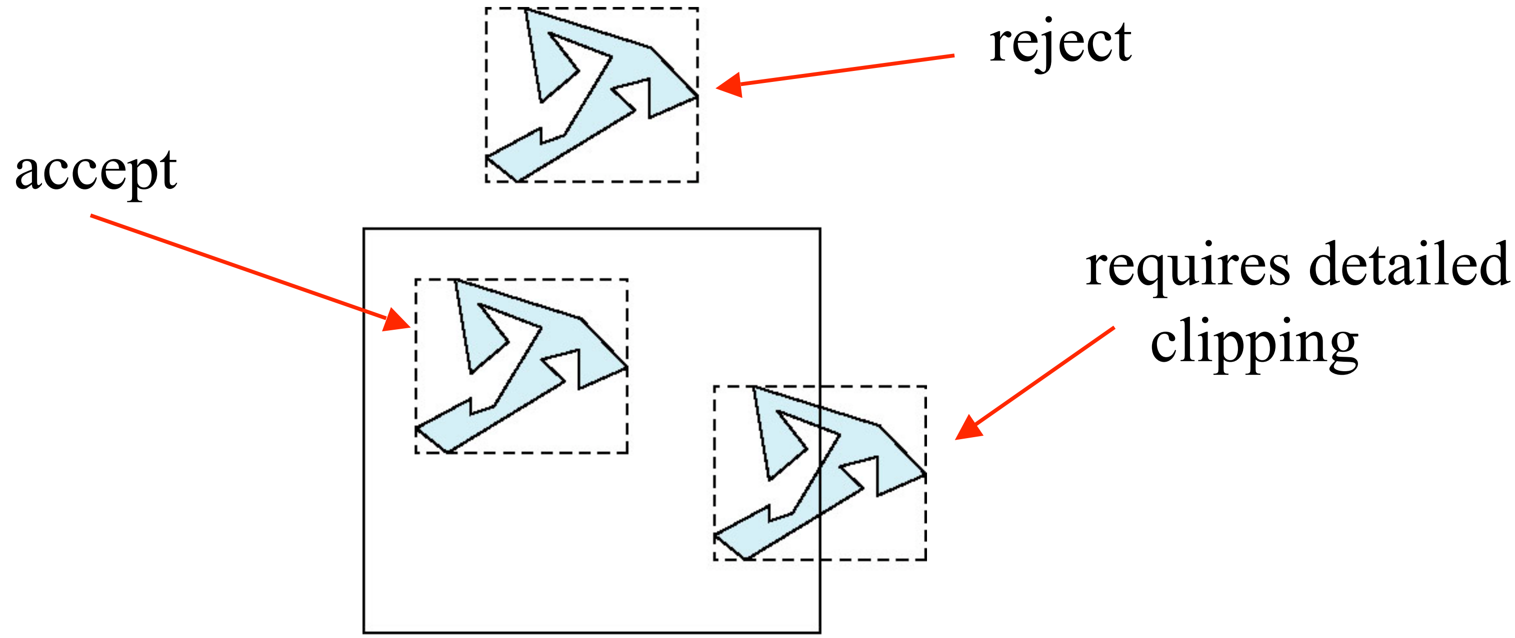
Bounding Boxes

- Rather than doing clipping on a complex polygon, we can use an *axis-aligned bounding box* or *extent*
  - Smallest rectangle aligned with axes that encloses the polygon
  - Simple to compute: max and min of x and y



Bounding boxes

Can usually determine accept/reject based only on bounding box

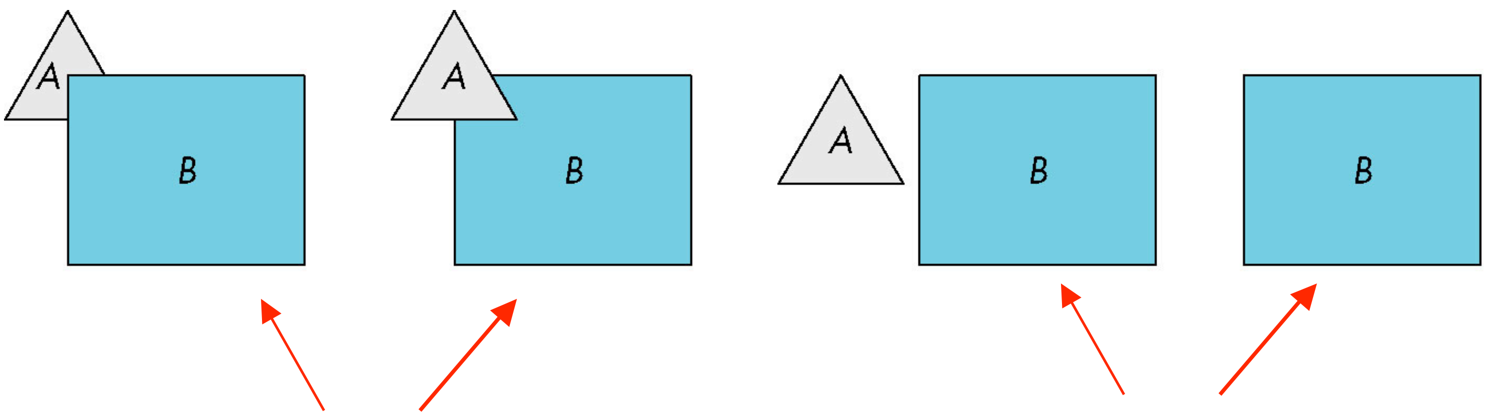


Clipping and Visibility

- Clipping has much in common with hidden-surface removal
- In both cases, we are trying to remove objects that are not visible to the camera
- Often we can use visibility or occlusion testing early in the process to eliminate as many polygons as possible before going through the entire pipeline

Hidden Surface Removal

- Object-space approach: use pairwise testing between polygons (objects)

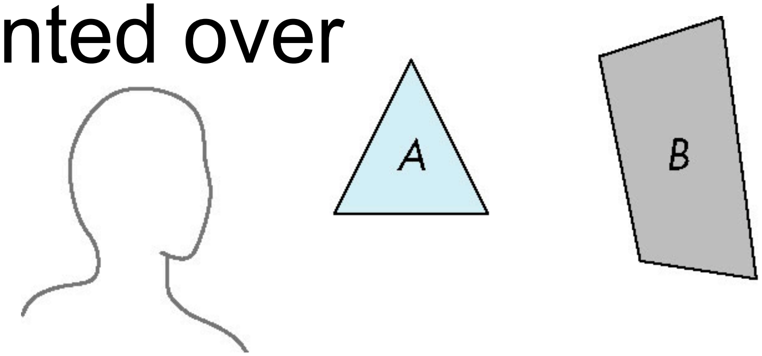


partially obscuring　　　　can draw independently

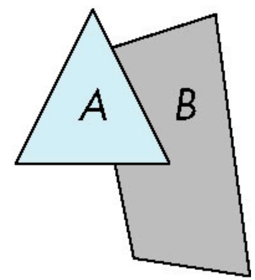
- Worst case complexity $O(n^2)$ for n polygons

Painter's Algorithm

- Render polygons a back to front order so that polygons behind others are simply painted over



B behind A as seen by viewer



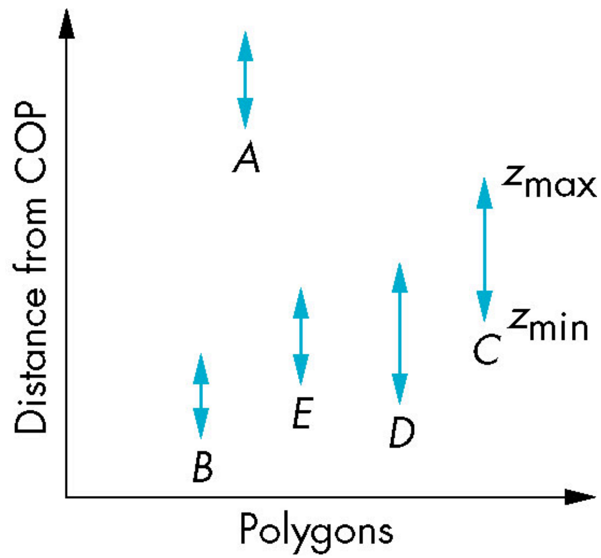
Fill B then A

Depth Sort

- Requires ordering of polygons first
  - O(n log n) calculation for ordering
  - Not every polygon is either in front or behind all other polygons

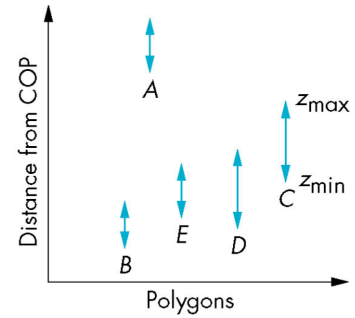
- Order polygons and deal with easy cases first, harder later

Polygons sorted by distance from COP

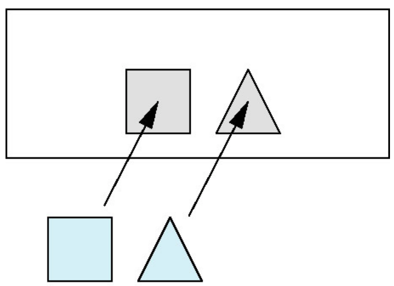


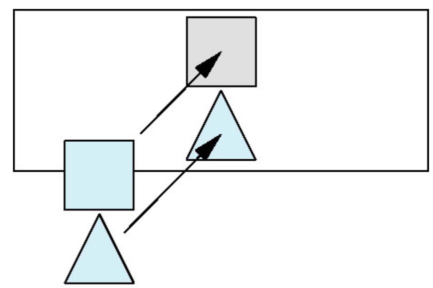
Easy Cases

- A lies behind all other polygons
  - Can render

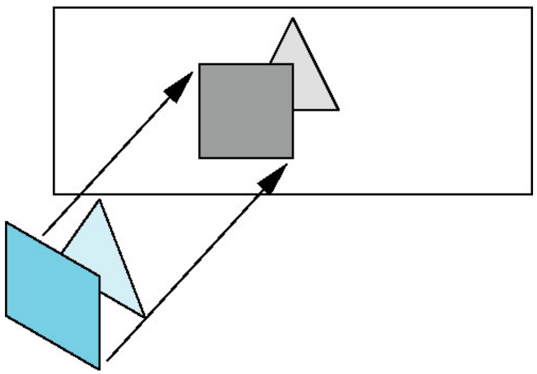


- Polygons overlap in z but not in either x or y
  - Can render independently

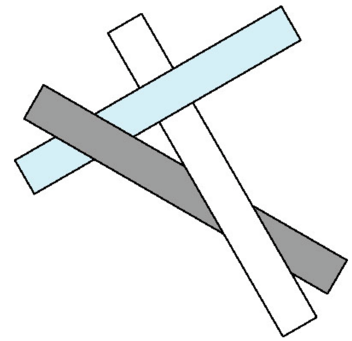




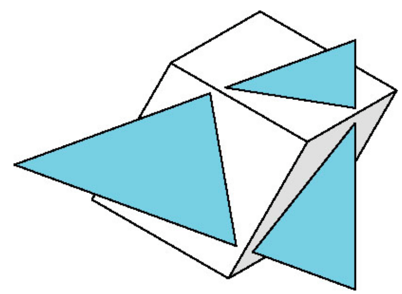
Hard Cases



Overlap in all directions but can one is fully on one side of the other

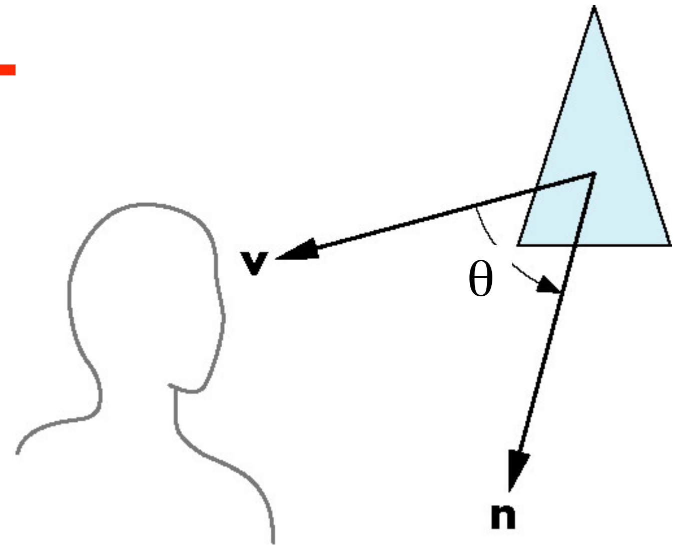


cyclic overlap



penetration

Back-Face Removal (Culling)



- face is visible iff $90 \geq \theta \geq -90$
equivalently $\cos \theta \geq 0$
or $\mathbf{v} \bullet \mathbf{n} \geq 0$

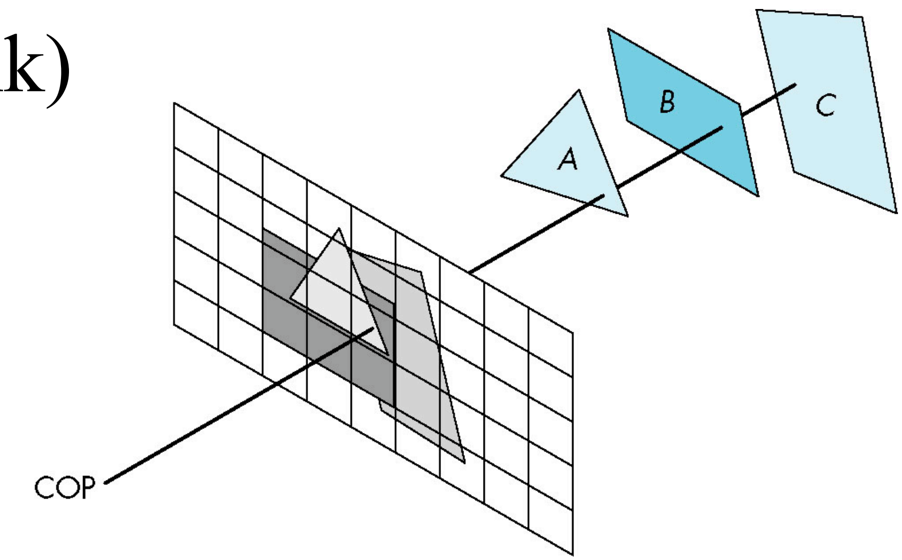
- plane of face has form $ax + by + cz + d = 0$
but after normalization $\mathbf{n} = (\,0\;0\;1\;0)^T$

- need only test the sign of c

- In OpenGL we can simply enable culling
but may not work correctly if we have nonconvex objects

Image Space Approach

- Look at each projector (nm for an $n \times m$ frame buffer) and find closest of k polygons
- Complexity $O(nmk)$
- Ray tracing
- z-buffer



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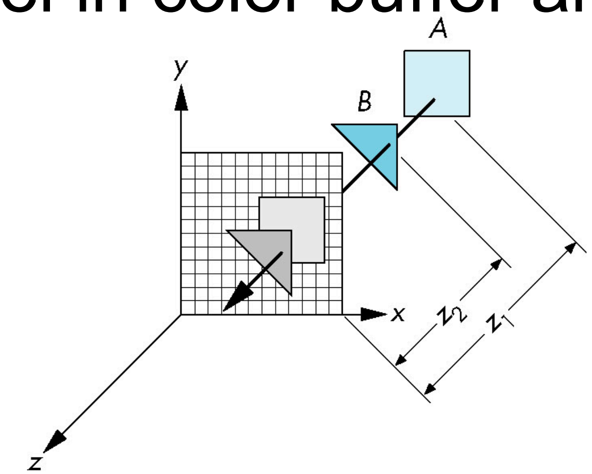
z-Buffer Algorithm

- Use a buffer called the z or depth buffer to store the depth of the closest object at each pixel found so far
- As we render each polygon, compare the depth of each pixel to depth in z buffer
- If less, place shade of pixel in color buffer and update z buffer



Efficiency

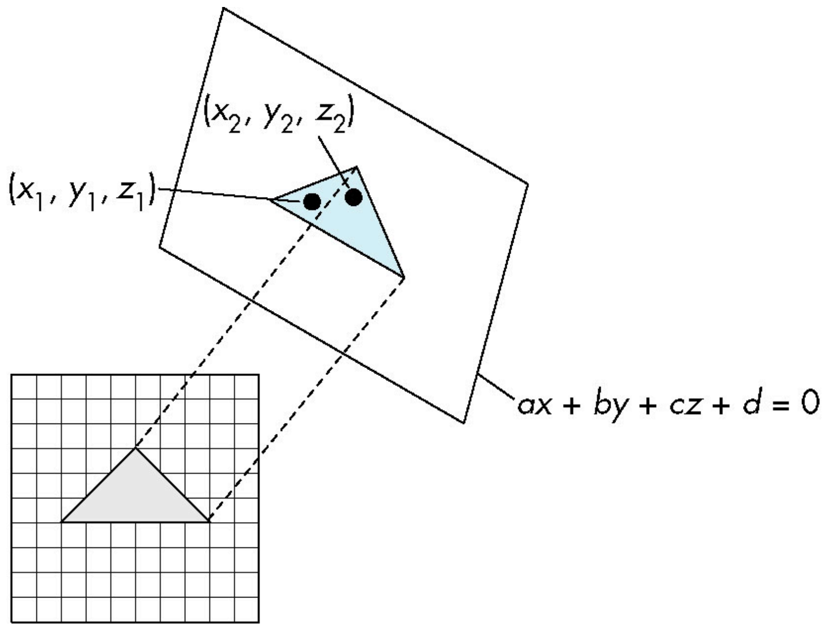
- If we work scan line by scan line as we move across a scan line, the depth changes satisfy $a\Delta x+b\Delta y+c\Delta z=0$

Along scan line

$$\Delta y = 0$$

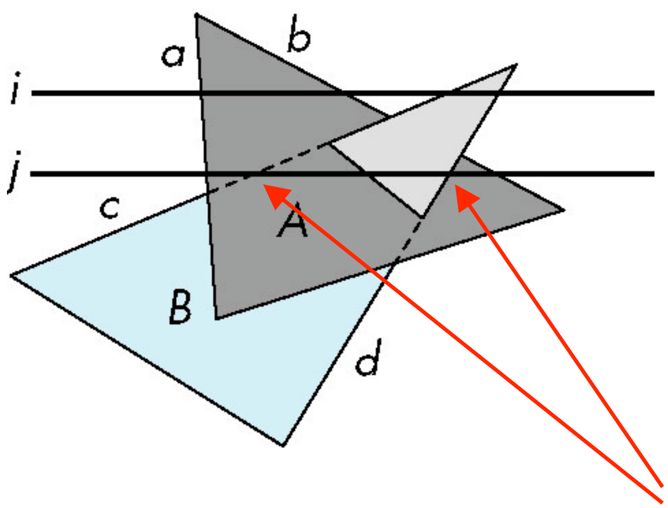
$$\Delta z = -\frac{a}{c}\Delta x$$

In screen space $\Delta x = 1$



Scan-Line Algorithm

- Can combine shading and hsr through scan line algorithm



scan line i: no need for depth information, can only be in no or one polygon

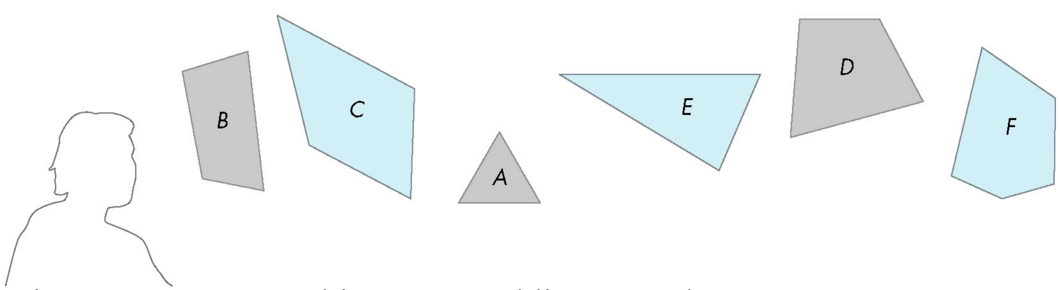
scan line j: need depth information only when in more than one polygon

Implementation

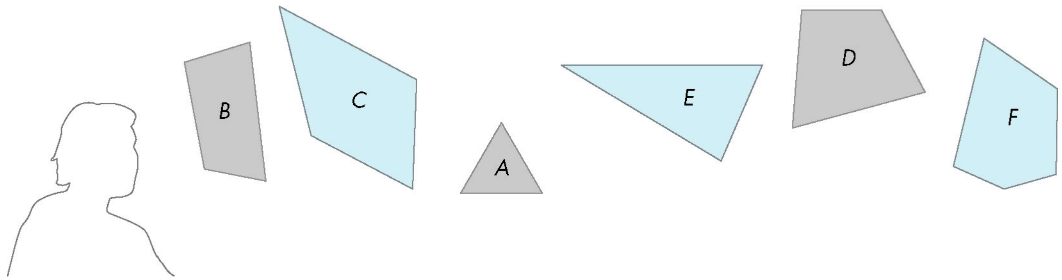
- Need a data structure to store
  - Flag for each polygon (inside/outside)
  - Incremental structure for scan lines that stores which edges are encountered
  - Parameters for planes

Visibility Testing

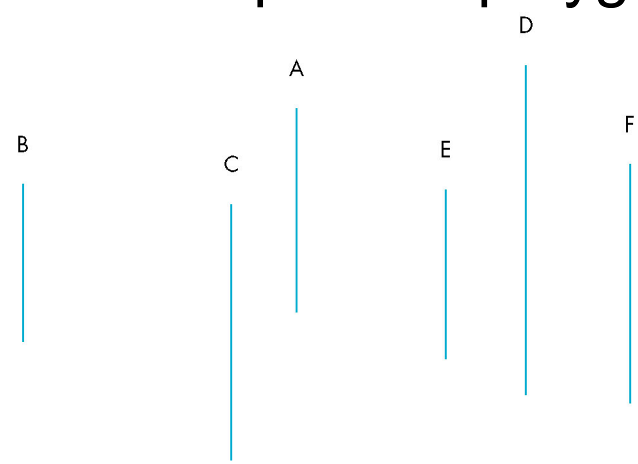
- In many realtime applications, such as games, we want to eliminate as many objects as possible within the application
  - Reduce burden on pipeline
  - Reduce traffic on bus
- Partition space with Binary Spatial Partition (BSP) Tree



Simple Example



consider 6 parallel polygons



top view

The plane of A separates B and C from D, E and F

BSP Tree

- Can continue recursively
  - Plane of C separates B from A
  - Plane of D separates E and F
- Can put this information in a BSP tree
  - Use for visibility and occlusion testing