Hidden Surface Algorithms

Reading

Reading:

- Angel 5.6, 10.12.2, 13.2 (pp. 654-655)

Optional reading:

- Foley, van Dam, Feiner, Hughes, Chapter 15
- I. E. Sutherland, R. F. Sproull, and R. A. Schumacker, A characterization of ten hidden surface algorithms, *ACM Computing Surveys* 6(1): 1-55, March 1974.

Introduction

In the previous lecture, we figured out how to transform the geometry so that the relative sizes will be correct if we drop the z component.

But, how do we decide which geometry actually gets drawn to a pixel?

Known as the **hidden surface elimination problem** or the **visible surface determination problem**.

There are dozens of hidden surface algorithms.

We look at three prominent ones:

- Z-buffer
- Ray casting
- Binary space partitioning (BSP) trees

Z-buffer

The **Z-buffer** or **depth buffer** algorithm [Catmull, 1974] is probably the simplest and most widely used.

Here is pseudocode for the Z-buffer hidden surface algorithm:

init

```
for each pixel (i,j) do
    Z-buffer [i,j] ← FAR
    Framebuffer[i,j] ← <background color>
end for
for each polygon A do
    for each pixel in A do
        Compute depth z and shade s of A at (i,j)
        if z > Z-buffer [i,j] then
            Z-buffer [i,j] ← z
            Framebuffer[i,j] ← s
        end if
    end for
end for
```

Z's are negative

?

Q: What should FAR be set to?

Z of far clipping plane

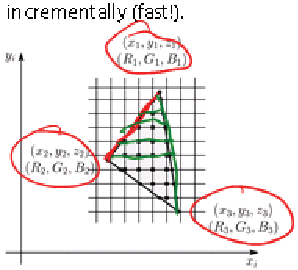
-∞

-big-number

Rasterization

The process of filling in the pixels inside of a polygon is called **rasterization**.

During rasterization, the *z* value and shade *s* can be computed incrementally (fast!).



Curious fact:

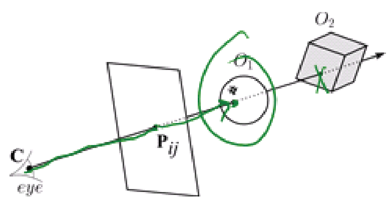
- Described as the "brute-force image space algorithm" by [SSS]
- Mentioned only in Appendix B of [SSS] as a point of comparison for huge memories, but written off as totally impractical.

Today, Z-buffers are commonly implemented in hardware.

Z-buffer: Analysis

- Easy to implement? ✓
- Easy to implement in hardware? ✓
- Incremental drawing calculations (uses coherence)? ✓
- Pre-processing required? no
- On-line (doesn't need all objects before drawing begins)? yes
- If objects move, does it take more work than normal to draw the frame? no
- If the viewer moves, does it take more work than normal to draw the frame? no
- Typically polygon-based? yes
- Efficient shading (doesn't compute colors of hidden surfaces)? could ??
- Handles transparency? → if sorted (from eye view)
- Handles refraction? no

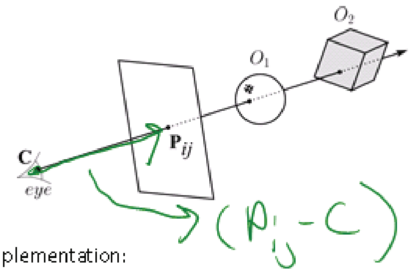
Ray casting



Idea: For each pixel center P_{ij}

- Send ray from eye point (COP), **C**, through P_{ij} into scene.
- Intersect ray with each object.
- Select nearest intersection.

Ray casting, cont.



Implementation:

- Might parameterize each ray:

  $\mathbf{r}(t) = \mathbf{C} + t\,(\mathbf{P}_{ij} - \mathbf{C})$

  where $t > 0$.
- Each object O_k returns $t_k > 0$ such that first intersection with O_k occurs at $\mathbf{r}(t_k)$.

Q: Given the set $\{t_k\}$ what is the first intersection point?

minimum $t > 0$

Note: these calculations generally happen in world coordinates. No projective matrices are applied.

Ray casting: Analysis

- Easy to implement?
- Easy to implement in hardware?
- Incremental drawing calculations (uses coherence)? no
- Pre-processing required? no
- On-line (doesn't need all objects before drawing begins)? no
- If objects move, does it take more work than normal to draw the frame? no
- If the viewer moves, does it take more work than normal to draw the frame? no
- Typically polygon-based? no (spheres, etc.)
- Efficient shading (doesn't compute colors of hidden surfaces)? yes
- Handles transparency? } with more rays
- Handles refraction?

z-buffer = every polygon, then pixel

ray-casting = " pixel, then poly

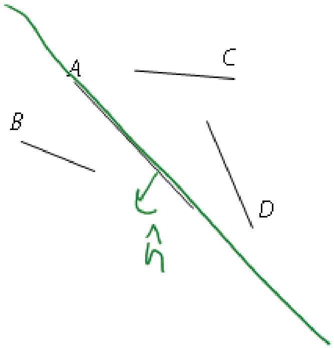
Binary-space partitioning (BSP) trees

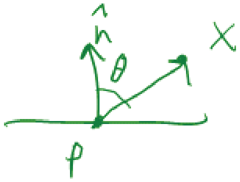
$\vec{v}\cdot\vec{w}$

$= \|\vec{v}\|\cdot\|\vec{w}\|\cdot\cos\theta$

if unit length

$\hat{v}\cdot\hat{w} = \cos\theta$





$0 \le \theta < 90°$ "+" side

$90° < \theta \le 180°$ "−" side

$(x-p)\cdot\vec{n}$

"+" or "−"

Idea:

- Do extra preprocessing to allow quick display from any viewpoint.

Key observation: A polygon *A* is painted in correct order if

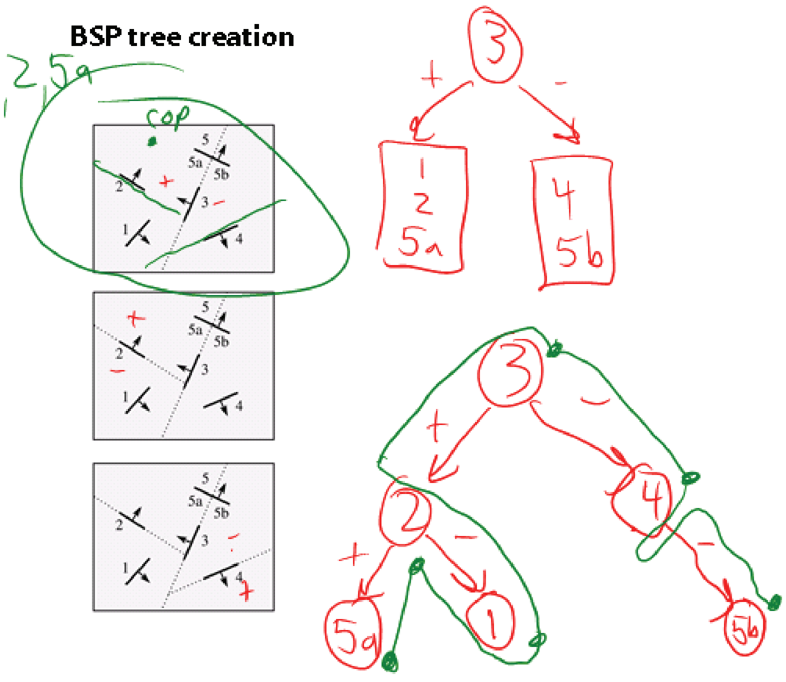
- Polygons on far side of *A* are painted first
- *A* is painted next
- Polygons on near side of *A* are painted last.

"painter's algorithm"

back-to-front

BSP tree creation

4, 5b, 3, 1, 2, 5a



BSP tree creation (cont'd)

```
procedure MakeBSPTree:
takes PolygonList L
returns BSPTree
    Choose polygon A from L to serve as root
    Split all polygons in L according to A
    node ← A
    node.neg ← MakeBSPTree(Polygons on neg. side of A)
    node.pos ← MakeBSPTree(Polygons on pos. side of A)
    return node
end procedure
```

) recursion

Note: Performance is improved when fewer polygons are split --- in practice, best of ~ 5 random splitting polygons are chosen.

Note: BSP is created in *world* coordinates. No projective matrices are applied before building tree.

BSP tree display

```
procedure DisplayBSPTree:
Takes BSPTree T, Point COP
    if T is empty then return
    if COP is in front (on pos. side) of T.node
        DisplayBSPTree(T.negative)
        Draw T.node
        DisplayBSPTree(T.positive)
    else
        DisplayBSPTree(T.+)
        Draw T.node
        DisplayBSPTree(T.−)
    end if
end procedure
```

BSP trees: Analysis

- Easy to implement?
- Easy to implement in hardware?
- Incremental drawing calculations (uses coherence)?
- Pre-processing required? yes
- On-line (doesn't need all objects before drawing begins)?
- If objects move, does it take more work than normal to draw the frame? yes
- If the viewer moves, does it take more work than normal to draw the frame? no
- Typically polygon-based?
- Efficient shading (doesn't compute colors of hidden surfaces)?
- Handles transparency?
- Handles refraction?

Summary

What to take home from this lecture:

- Understanding of three hidden surface algorithms:
    - Z-buffering
    - Ray casting
    - BSP tree creation and traversal