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:

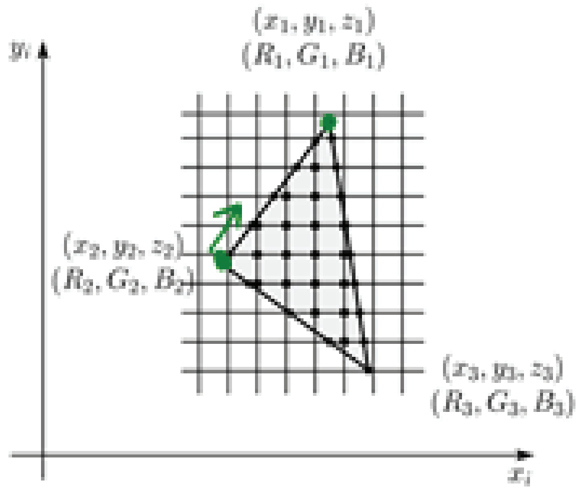
for each pixel *(i,j)* **do**
  Z-buffer [*i,j*] ← *FAR*
  Framebuffer[*i,j*] ← <background color>
end for
for each polygon *A* **do**
  for each pixel in *A* **do**
    Compute depth *z* and shade *s* of *A* at *(i,j)*
    if *z* > *Z-buffer* [*i,j*] **then**
      Z-buffer [*i,j*] ← *z*
      Framebuffer[*i,j*]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

Q: What should FAR be set to? -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:

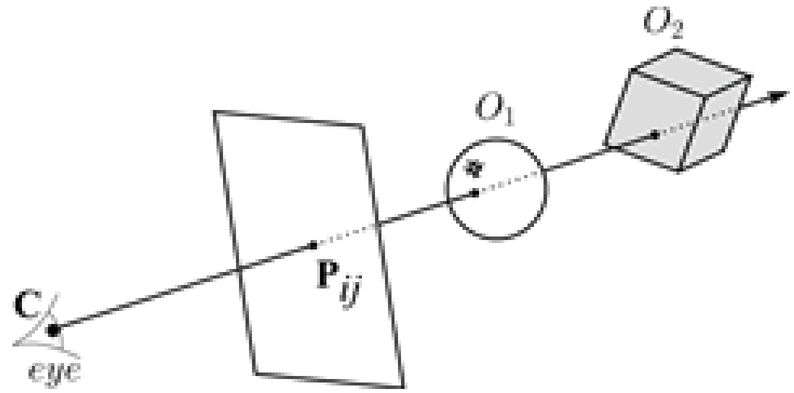
- Described as the "brute-force image space algorithm" by [SSS]
- Mentioned only in Appendix B of [SSS] as a point of comparison for huge memories, but written off as totally impractical.

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?
- On-line (doesn't need all objects before drawing begins)?
- If objects move, does it take more work than normal to draw the frame?
- If the viewer moves, does it take more work than normal to draw the frame?
- Typically polygon-based?
- Efficient shading (doesn't compute colors of hidden surfaces)?
- Handles transparency?
- Handles refraction?

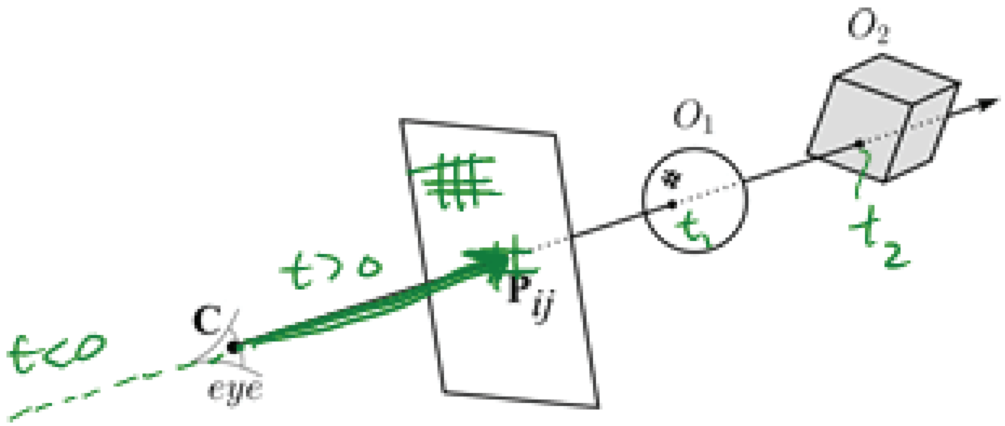
Ray casting



Idea: For each pixel center $\boldsymbol{P}_{ij}$

- Send ray from eye point (COP), **C**, through $\boldsymbol{P}_{ij}$ 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?

$t_n = \text{smallest}\ \{t_i\}$

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

Ray casting: Analysis

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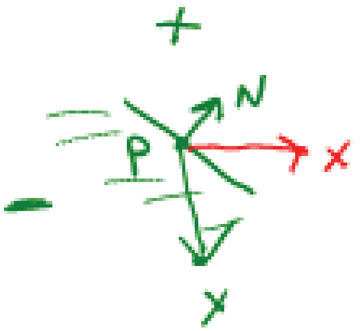
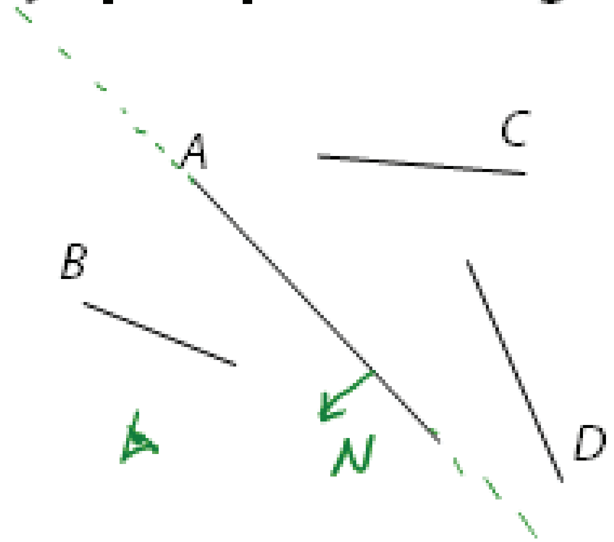
Binary-space partitioning (BSP) trees



$$\operatorname{sign}[(x-p)\cdot N]$$

$$(x-p)\cdot N = 0$$



Idea:

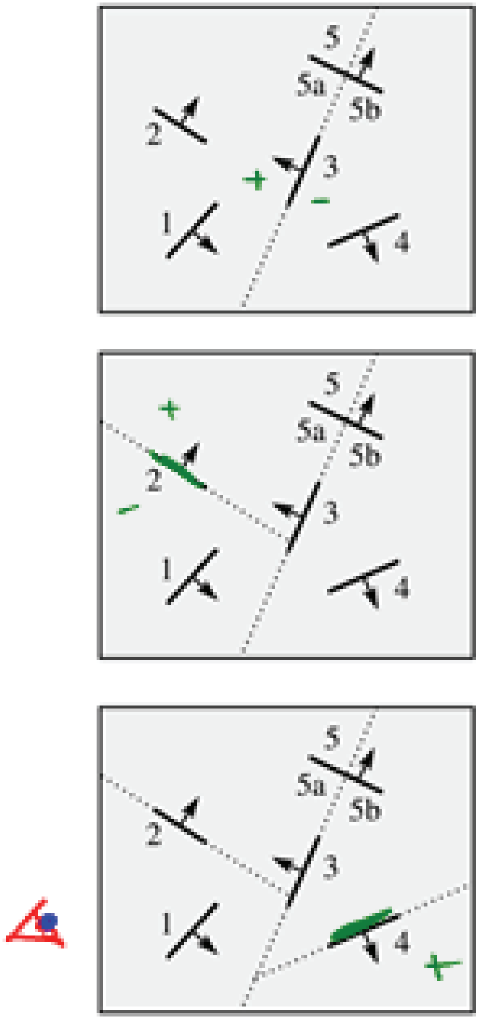
- Do extra preprocessing to allow quick display from <u>any</u> viewpoint.

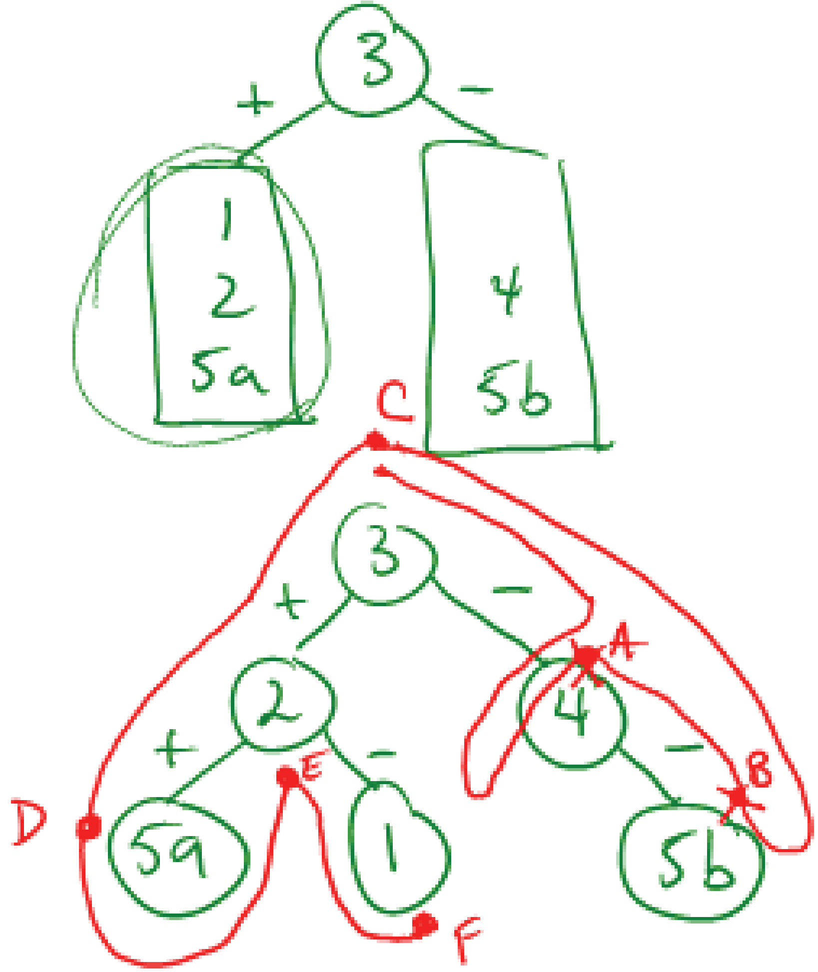
Key observation: A polygon *A* is painted in correct order if

- 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

BSP tree creation





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

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

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. _____)

Draw T.node

DisplayBSPTree(T._____)

else

DisplayBSPTree(T. _____)

Draw T.node

DisplayBSPTree(T. _____)

end if

end procedure

BSP trees: Analysis

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Summary

What to take home from this lecture:

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