CS230 : Computer Graphics

Lecture 5: Perspective Transformations and Hidden Surfaces

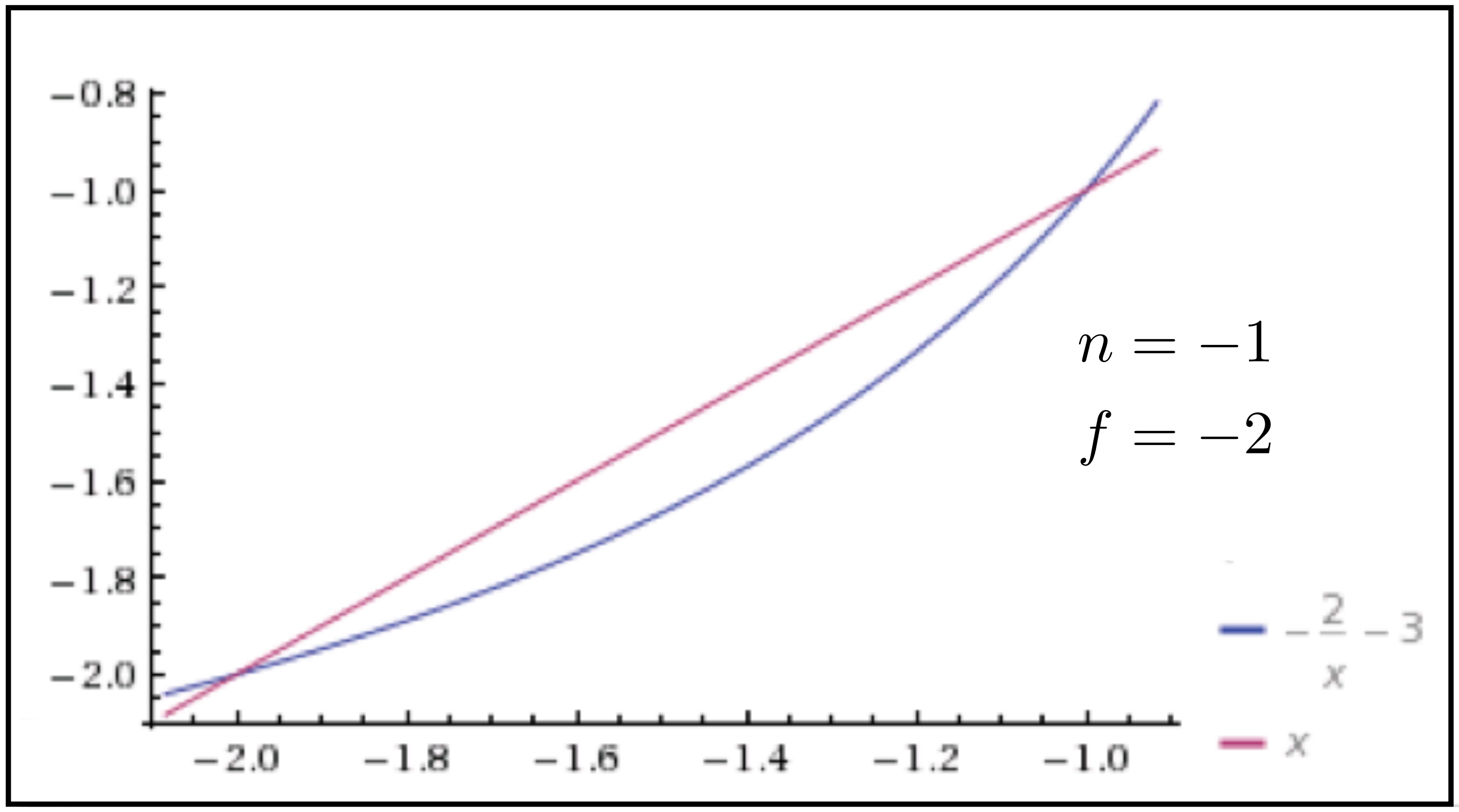
Tamar Shinar
Computer Science & Engineering
UC Riverside

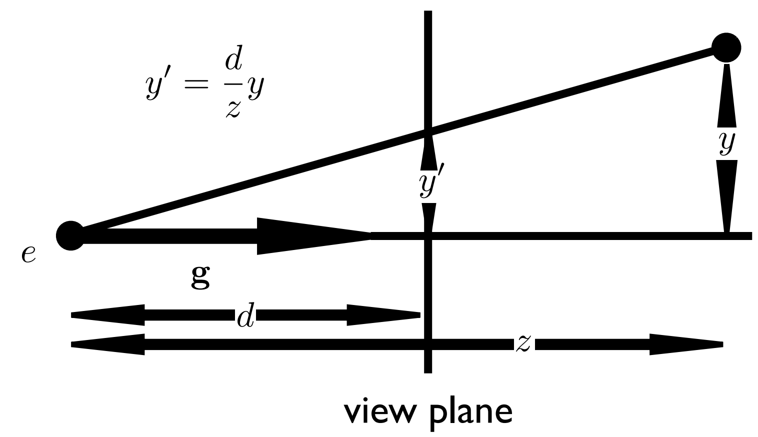
Perspective Projection (continued)

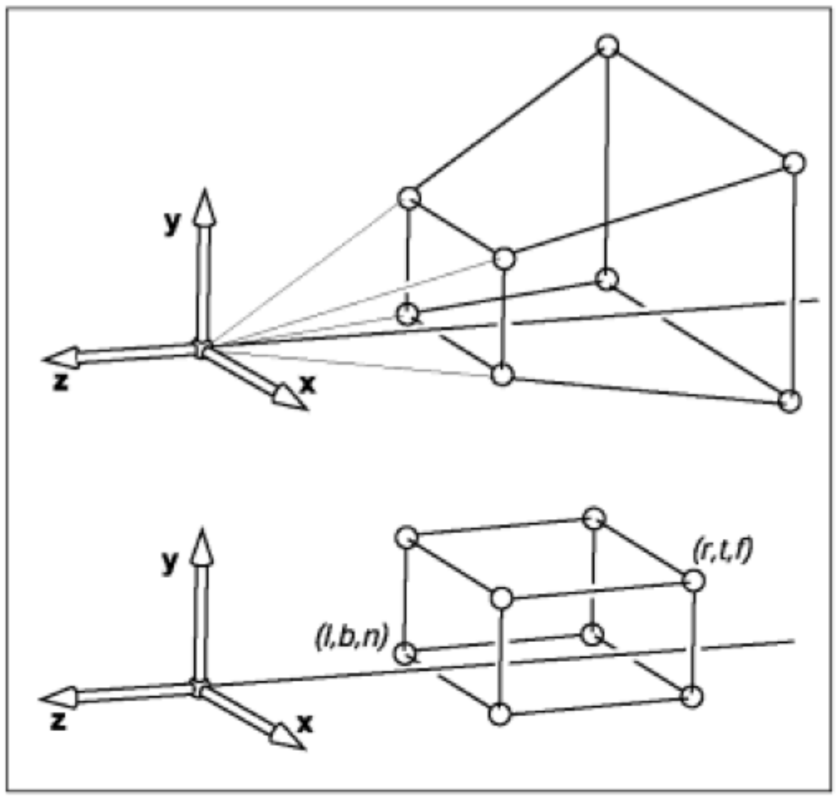
Perspective Projection

$$P = \begin{pmatrix} n & 0 & 0 & 0 \\ 0 & n & 0 & 0 \\ 0 & 0 & n+f & -fn \\ 0 & 0 & 1 & 0 \end{pmatrix}$$

$M_{per} = M_{orth} P$ <whiteboard>





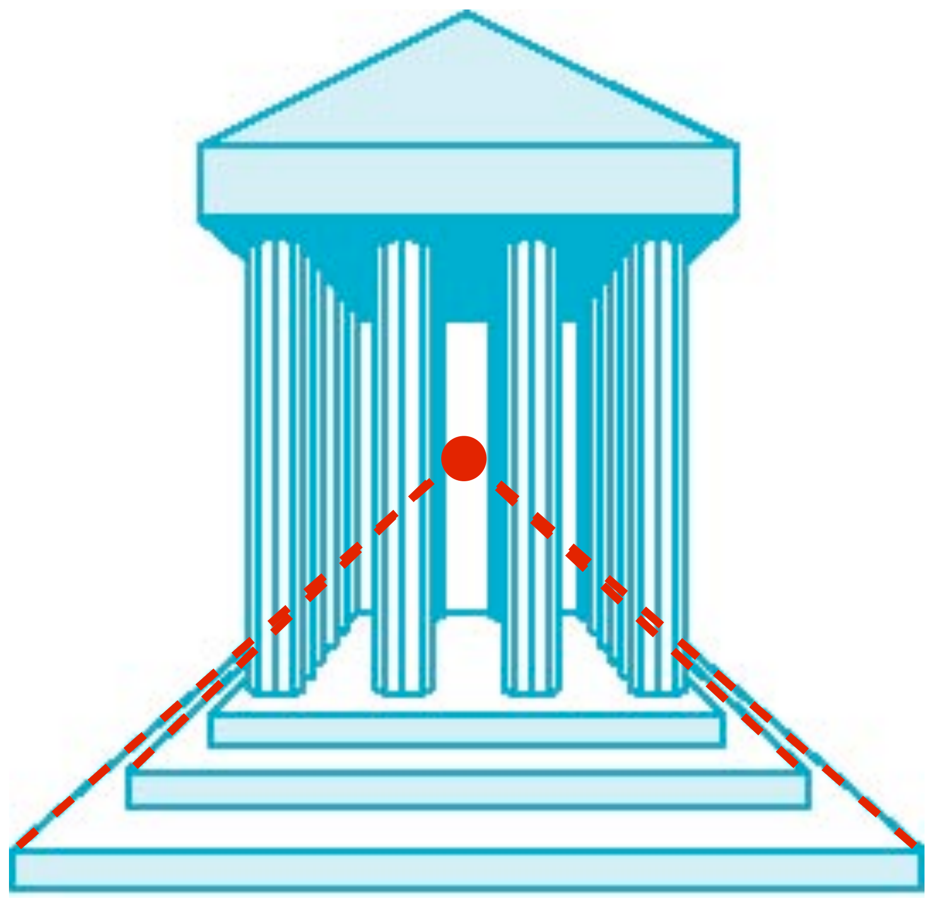


Shirley, Marschner

This does not preserve **z** completely, but it preserves **z = n, f** and is **monotone** (preserves ordering) with respect to z

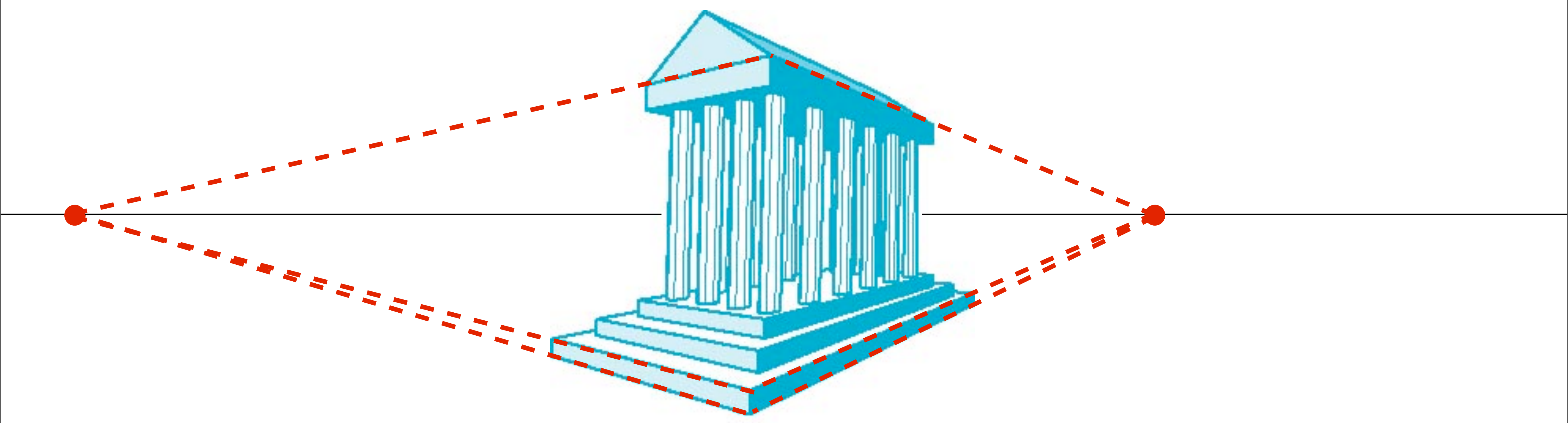
One-Point Perspective

- One principal face parallel to projection plane
- One vanishing point for cube



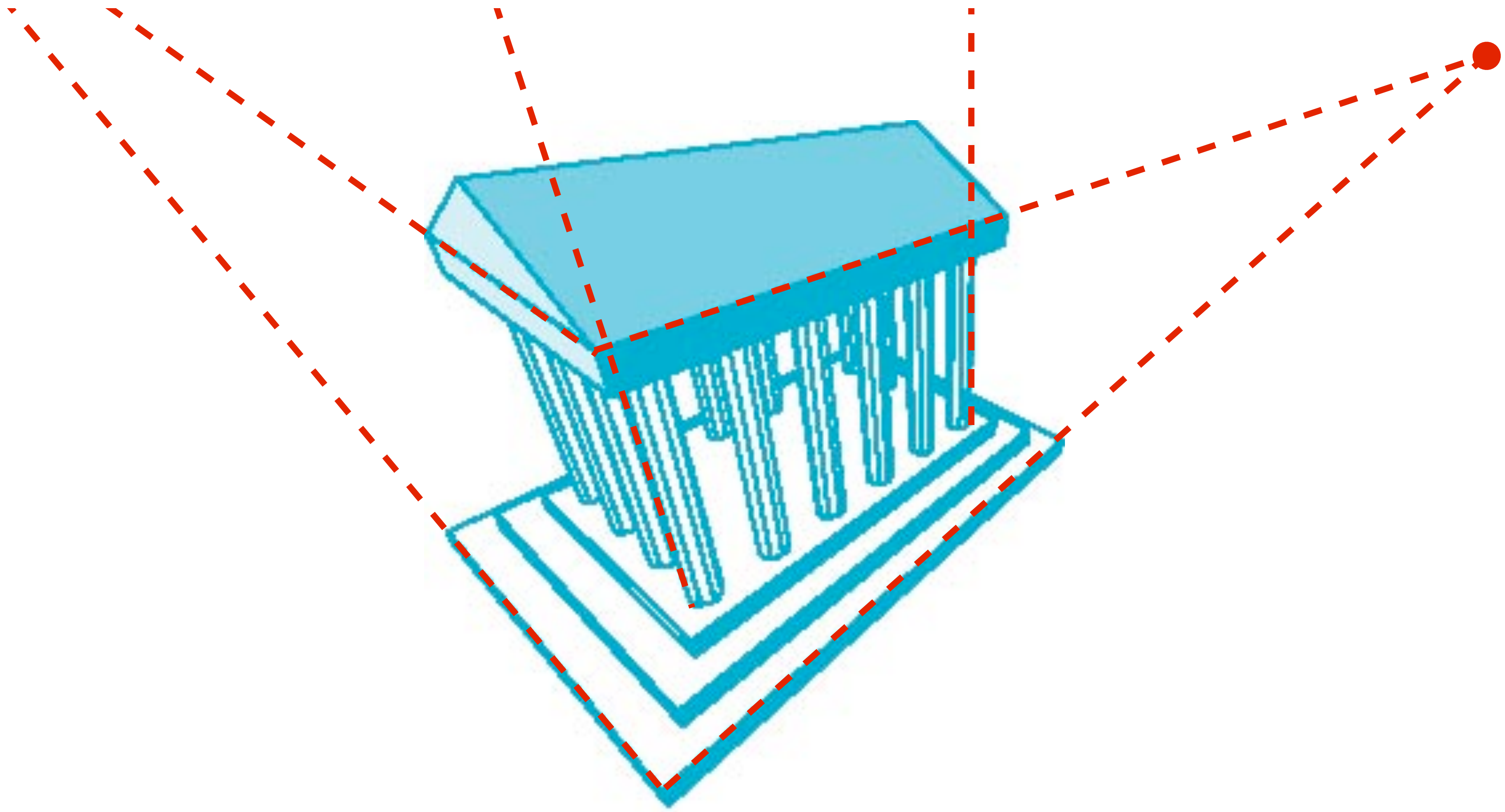
Two-Point Perspective

- On principal direction parallel to projection plane
- Two vanishing points for cube



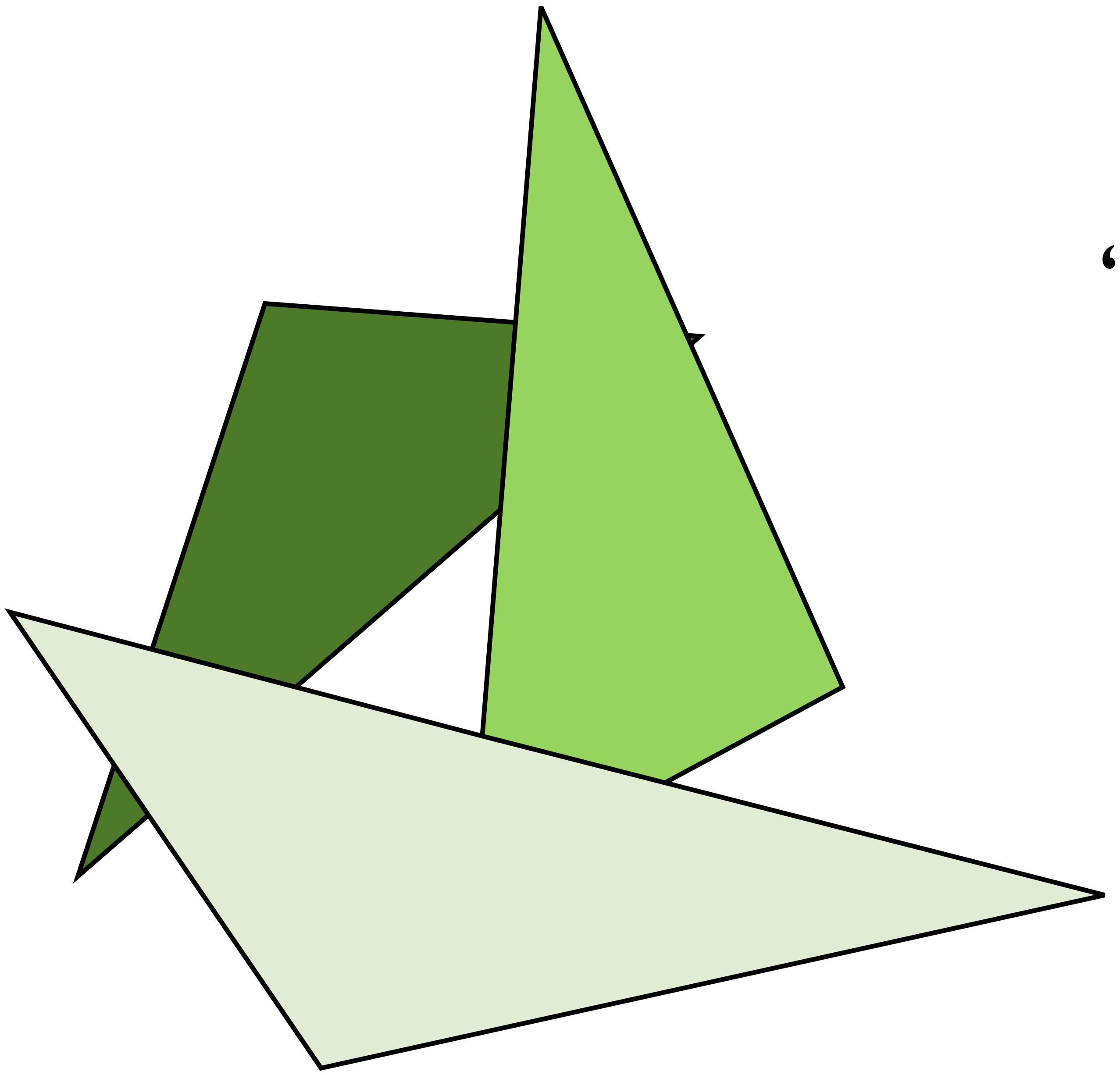
Three-Point Perspective

- No principal face parallel to projection plane
- Three vanishing points for cube



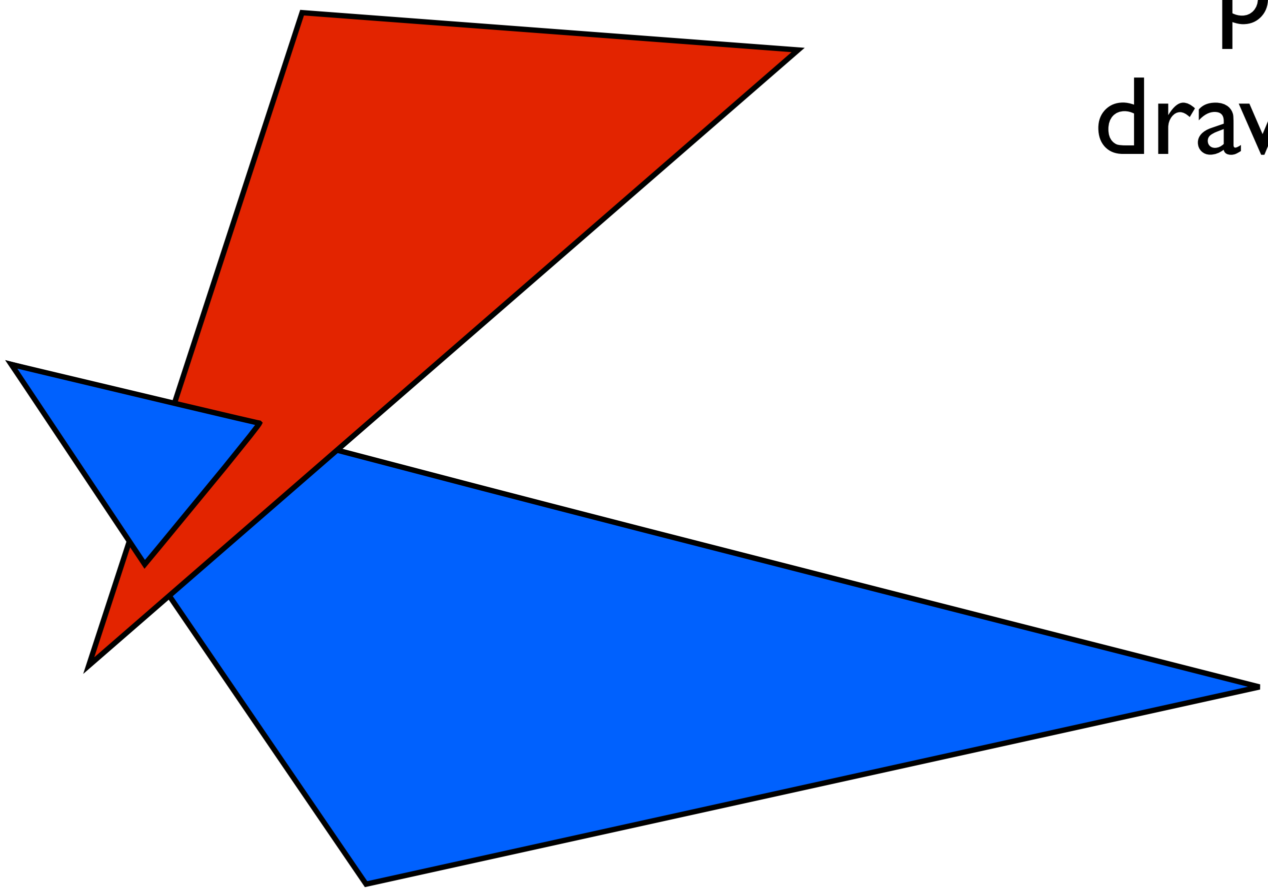
Hidden Surface Removal

Occlusion



“painter’s algorithm”
draw primitives in
back-to-front order

Occlusion

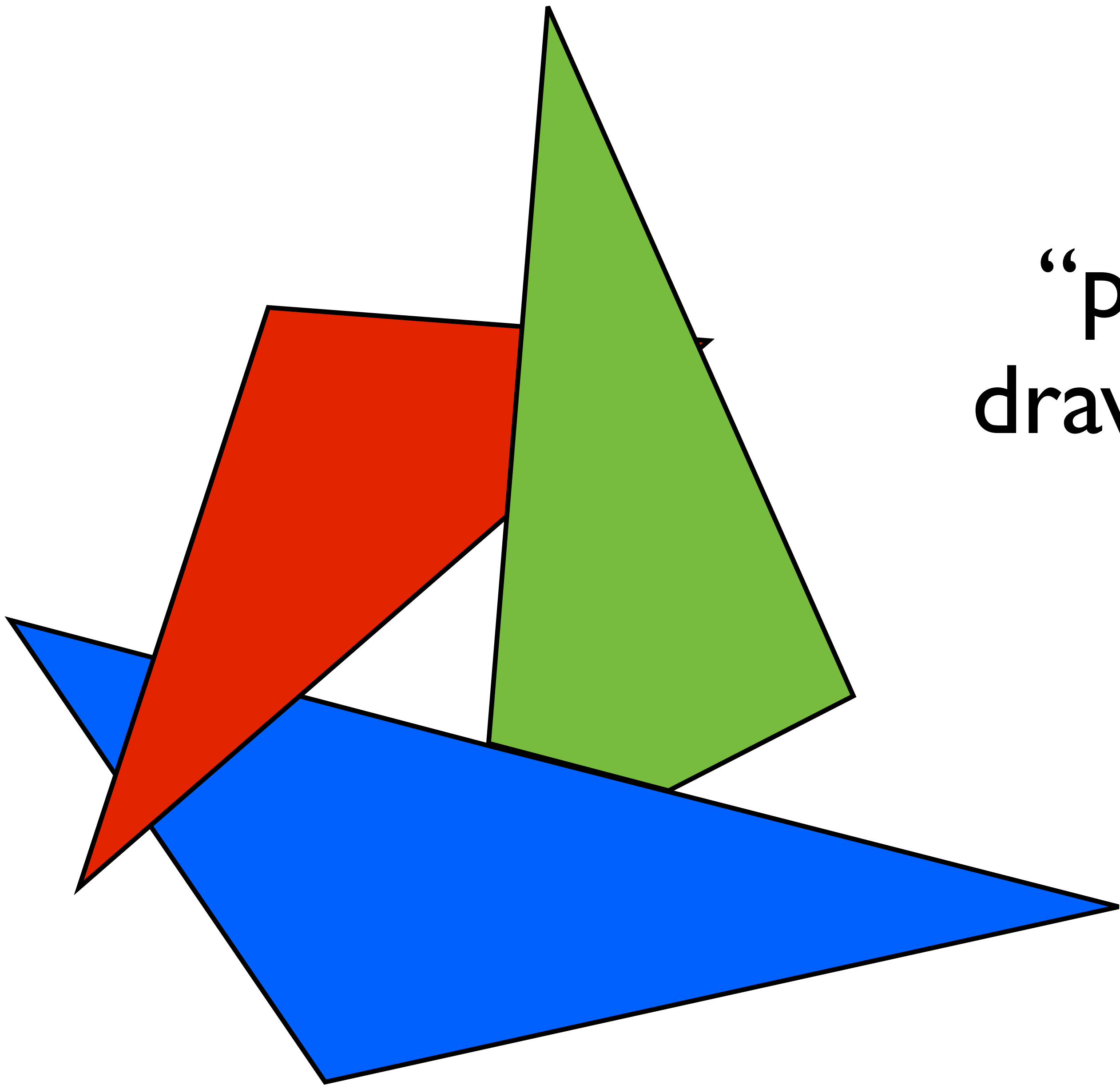


“painter’s algorithm”
draw primitives in back-to-front order

problem:
triangle
intersection

who’s in front of whom?

Occlusion



"painter's algorithm"
draw primitives in back-to-front order

problem:
occlusion cycle

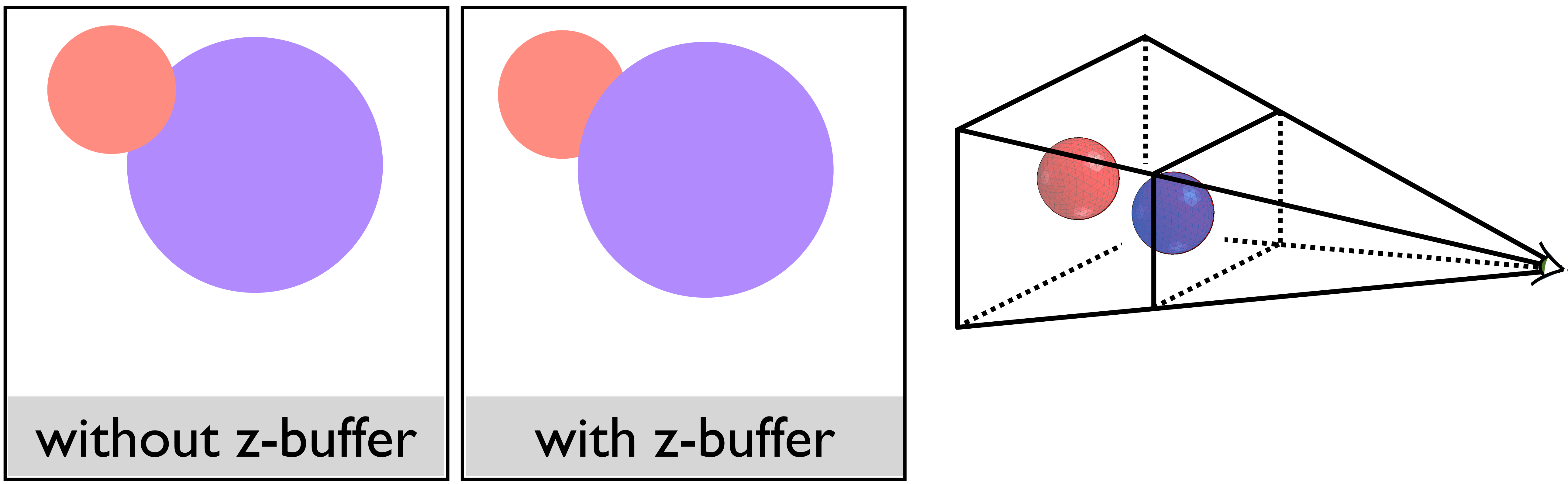
also, sort primitives by depth is **slow**

Use a *z-buffer* for hidden surface removal

at each pixel, record distance to the closest object that has been drawn in a *depth* buffer

Use a *z-buffer* for hidden surface removal

at each pixel, record distance to the closest object that has been drawn in a *depth* buffer



- assume both spheres of the same size, red drawn last

Use a *z-buffer* for hidden surface removal

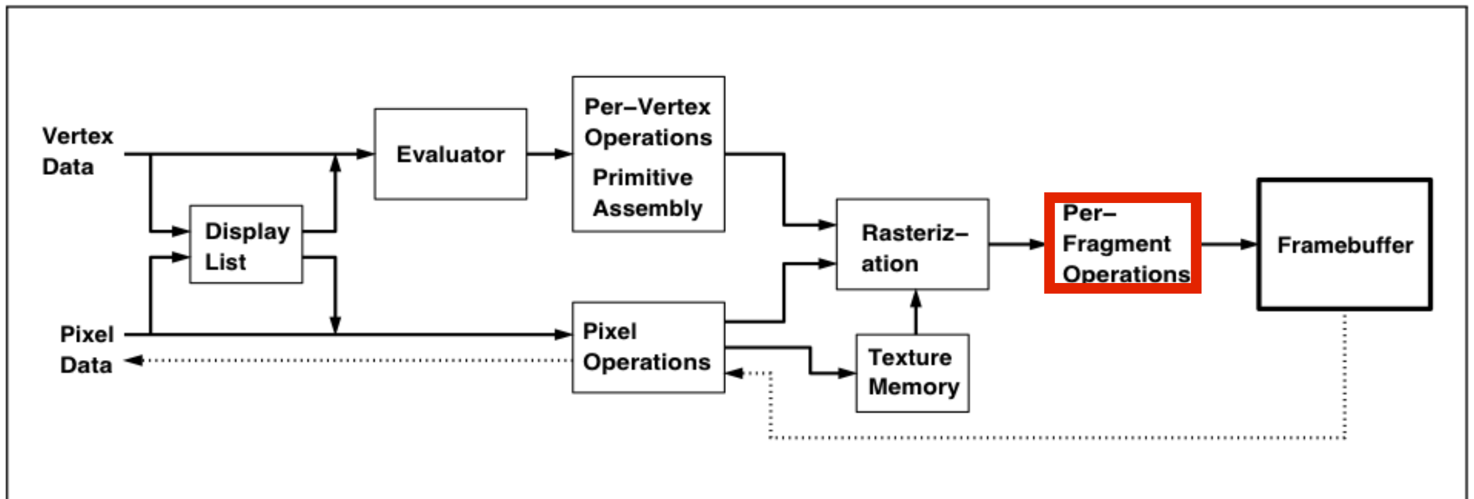
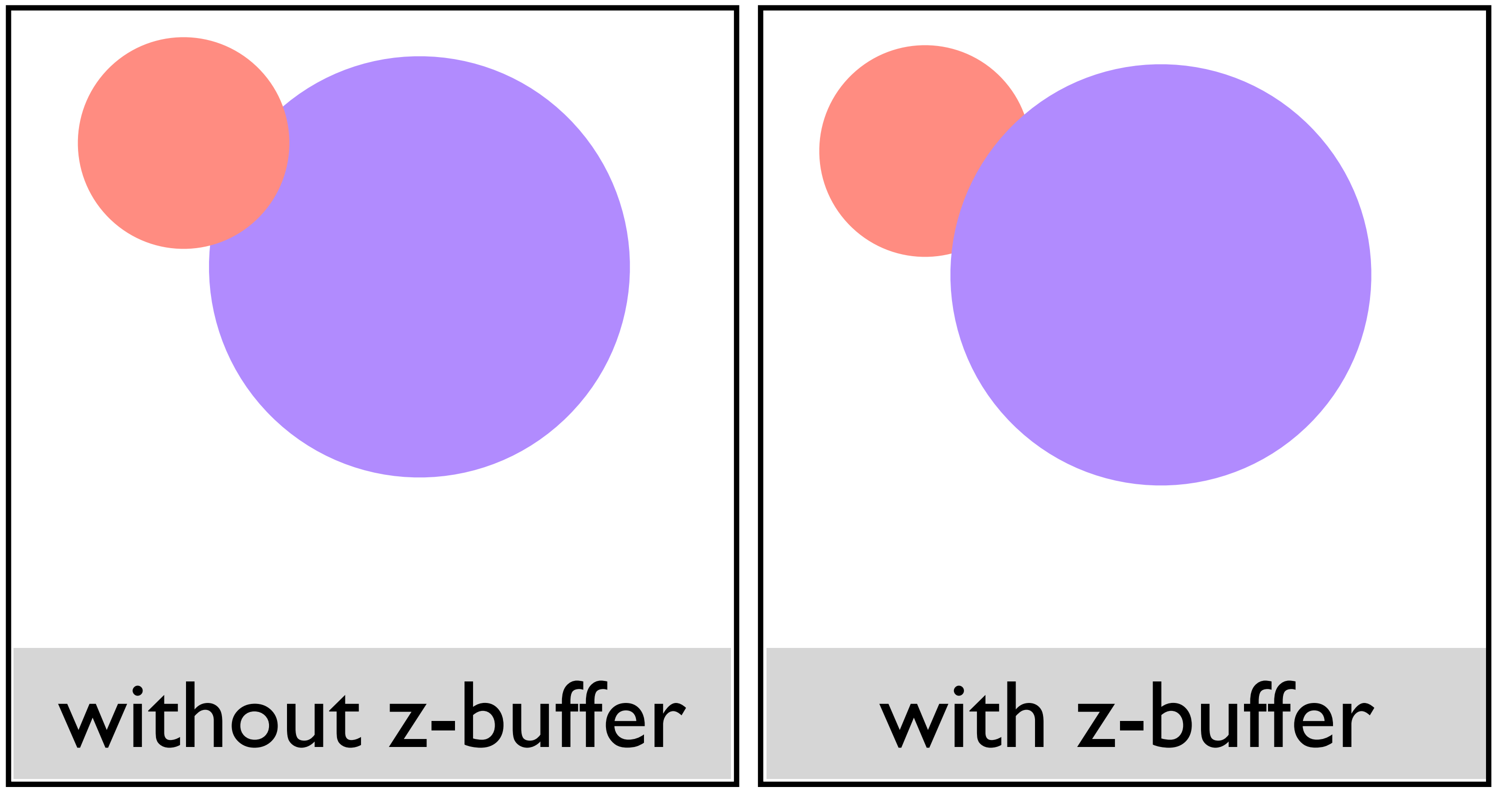
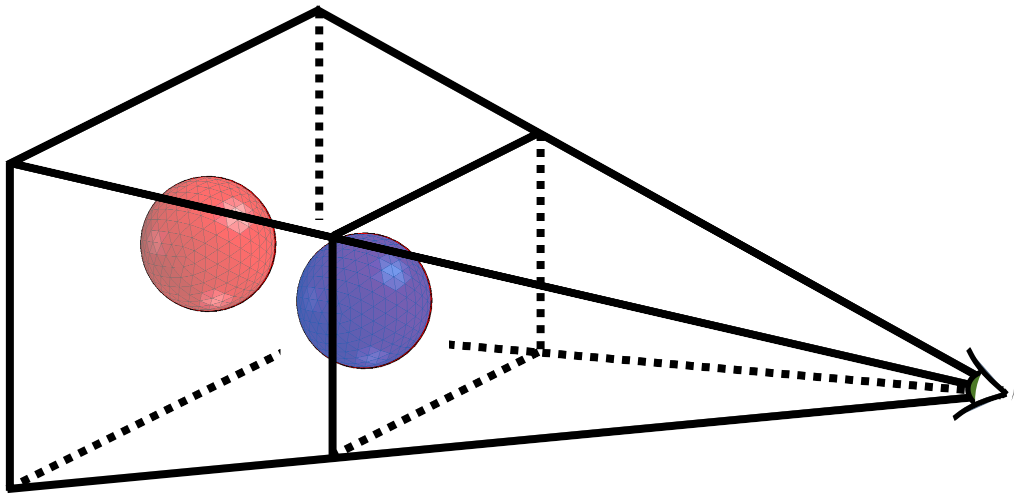


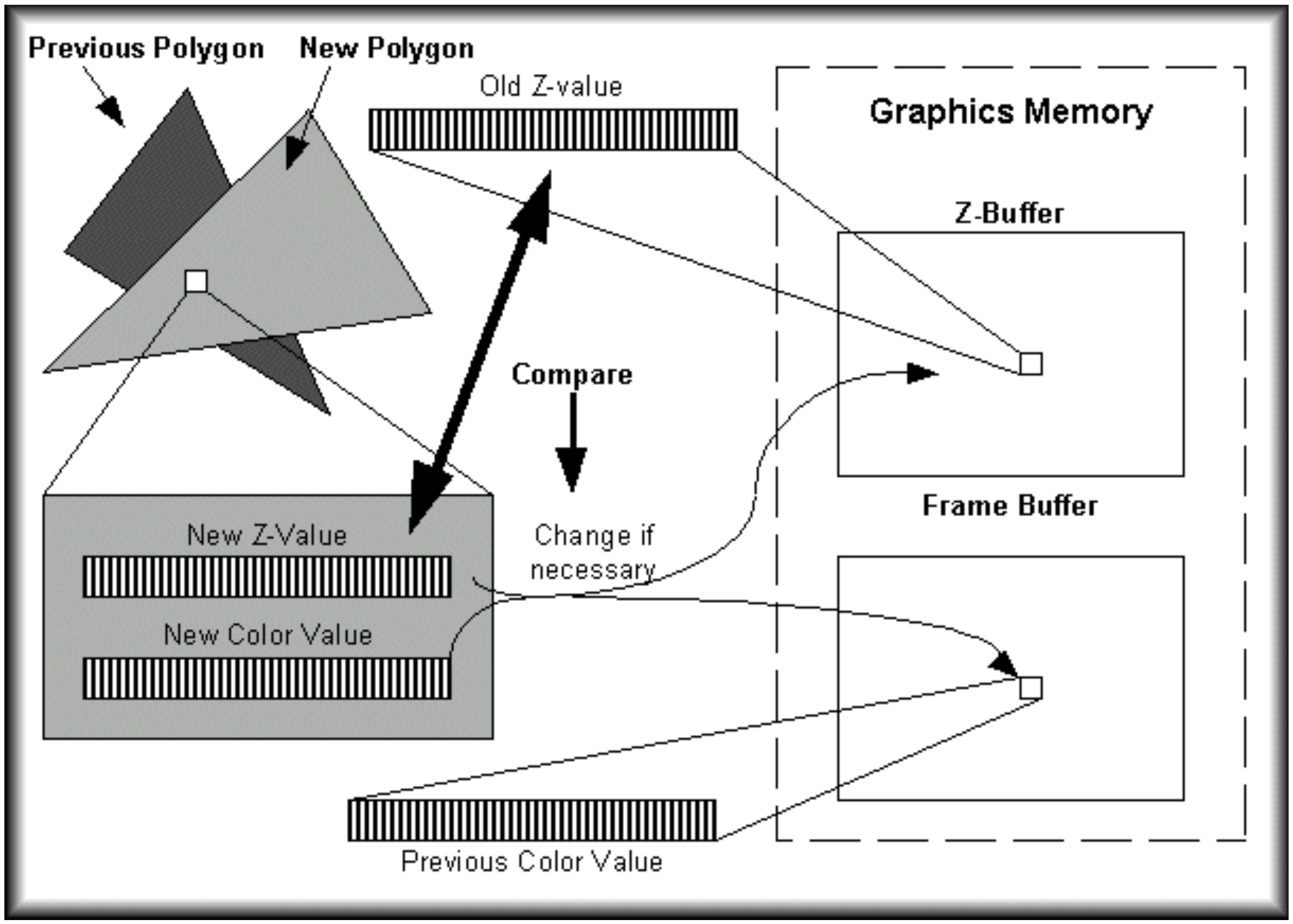
Figure 1. Block diagram of OpenGL.





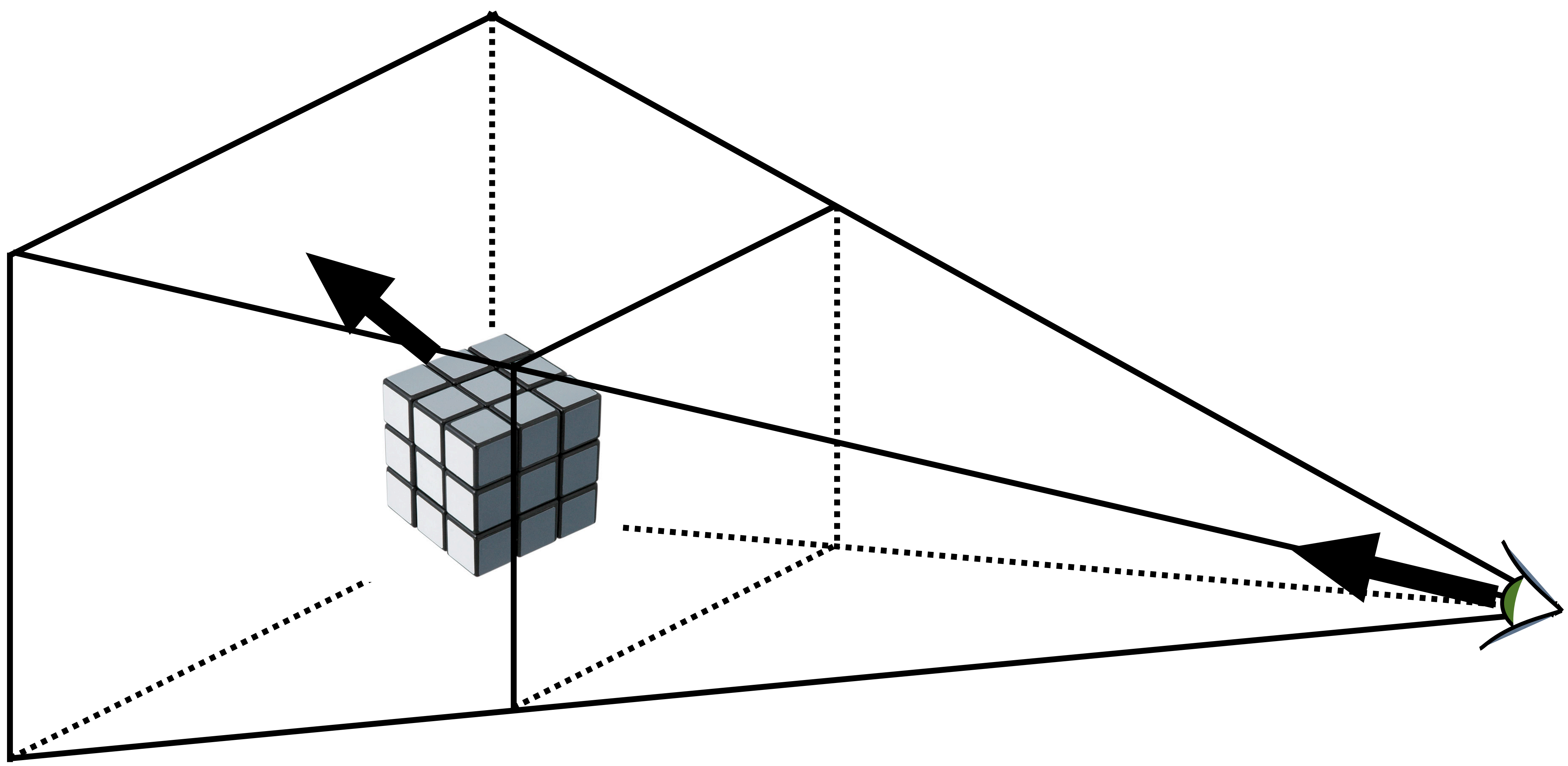
done in the **fragment blending** phase
– each fragment must carry a depth

Use a *z-buffer* for hidden surface removal



http://www.beyond3d.com/content/articles/41/

Backface culling: another way to eliminate hidden geometry



Hidden Surface Removal in OpenGL

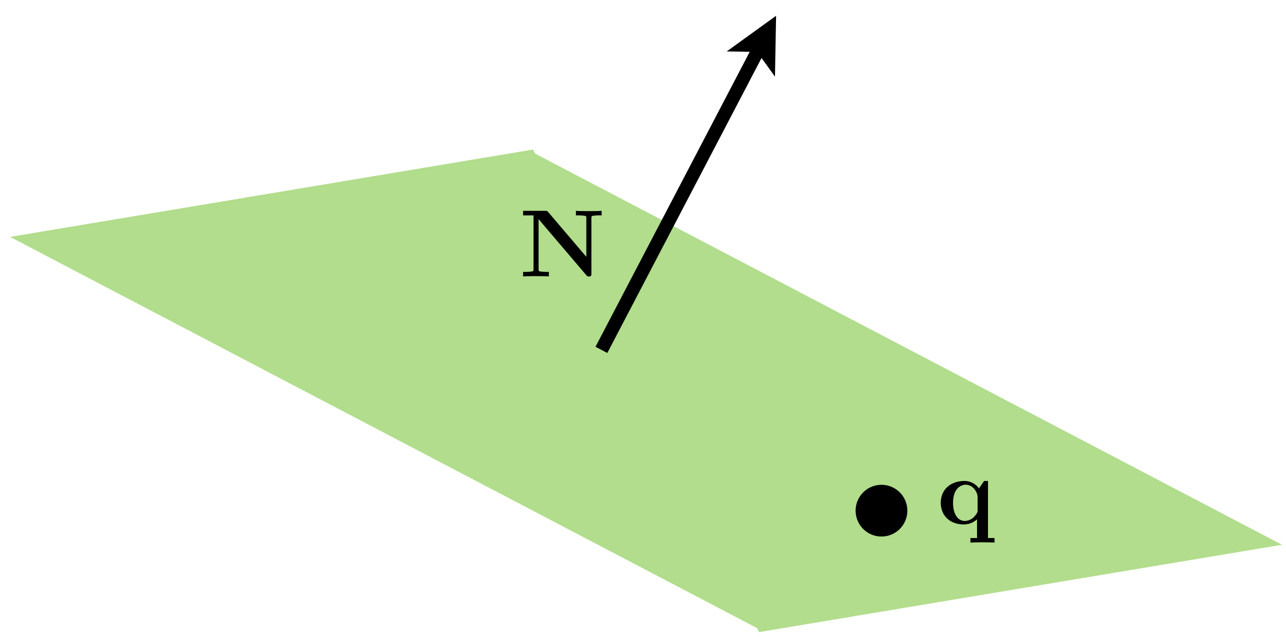
```
glutInitDisplayMode(GLUT_DOUBLE | GLUT_RGB | GLUT_DEPTH);

glEnable(GL_DEPTH_TEST);

glEnable(GL_CULL_FACE);
```

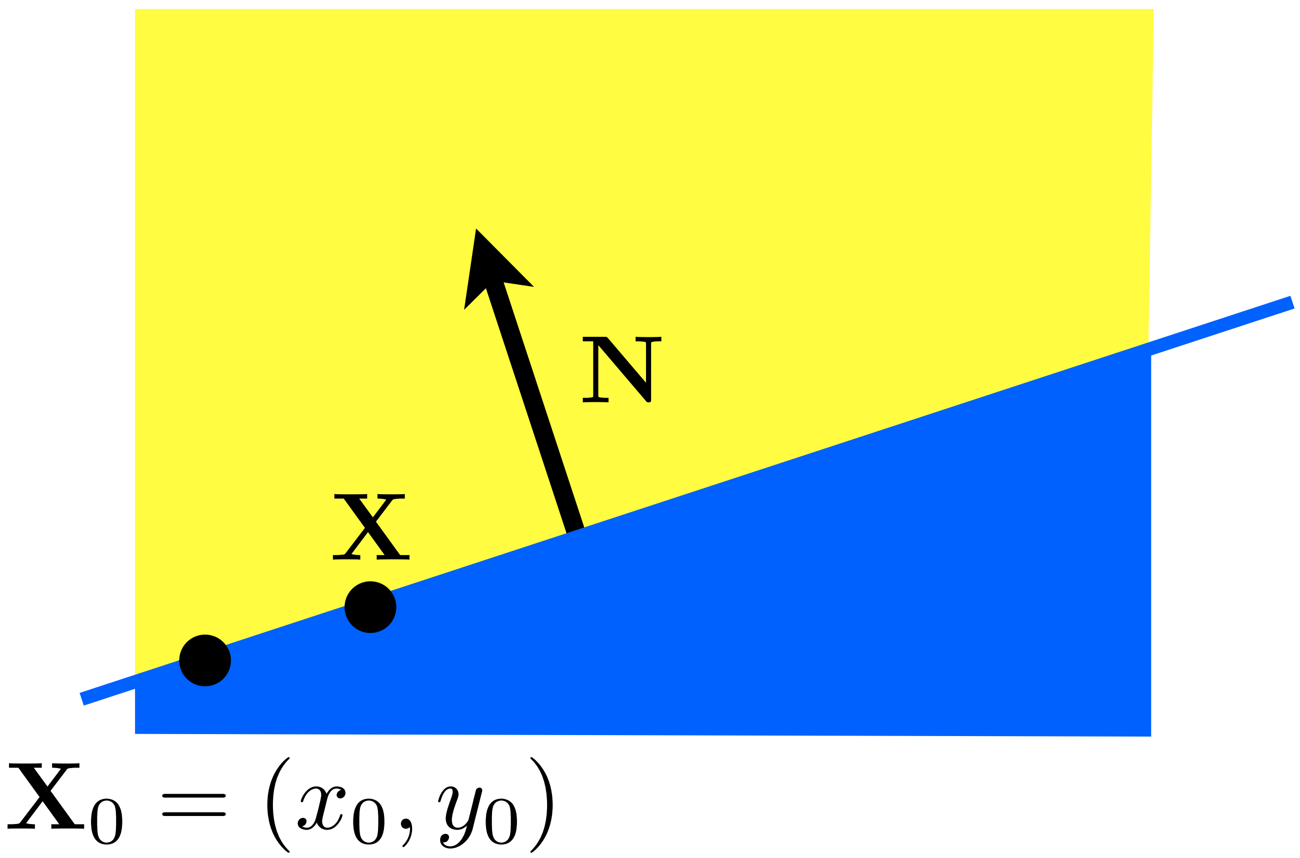
Note: For a perspective transformation, there is more in the depth buffer for z-values closer to the near plane

Clipping

Clipping against a plane

What's the equation for the plane through **q** with normal **N**?





implicit line equation:

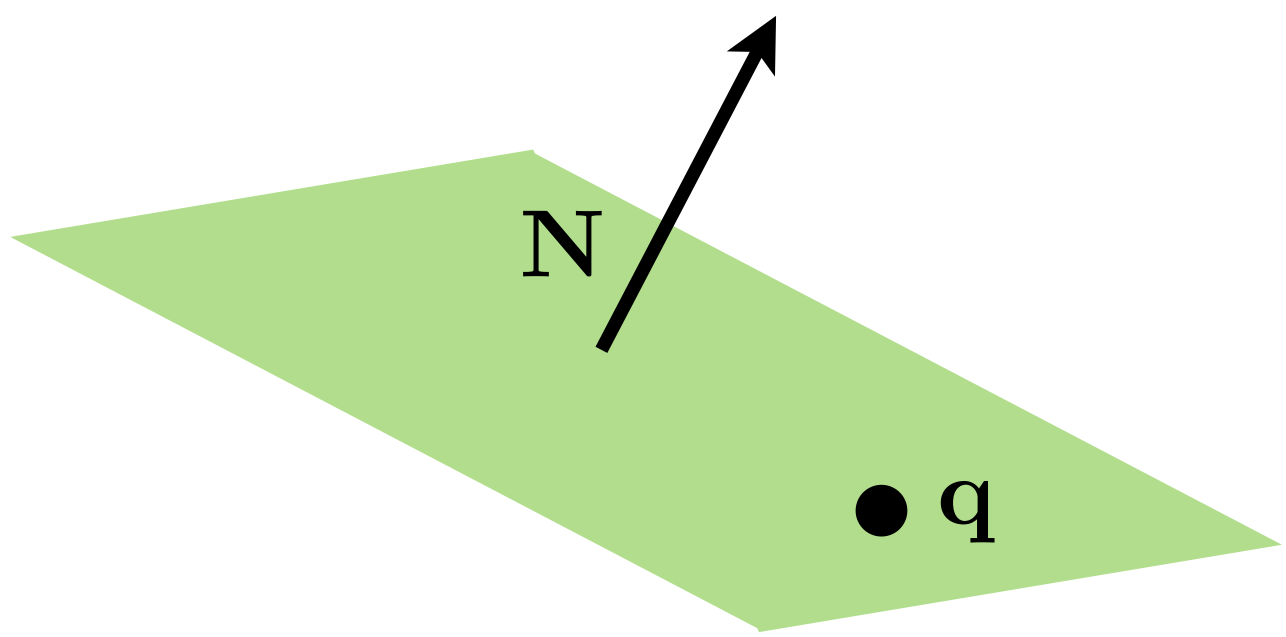
$$f(\mathbf{X}) = \mathbf{N} \cdot (\mathbf{X} - \mathbf{X}_0) = 0$$

Clipping against a plane

What's the equation for the plane through **q** with normal **N**?

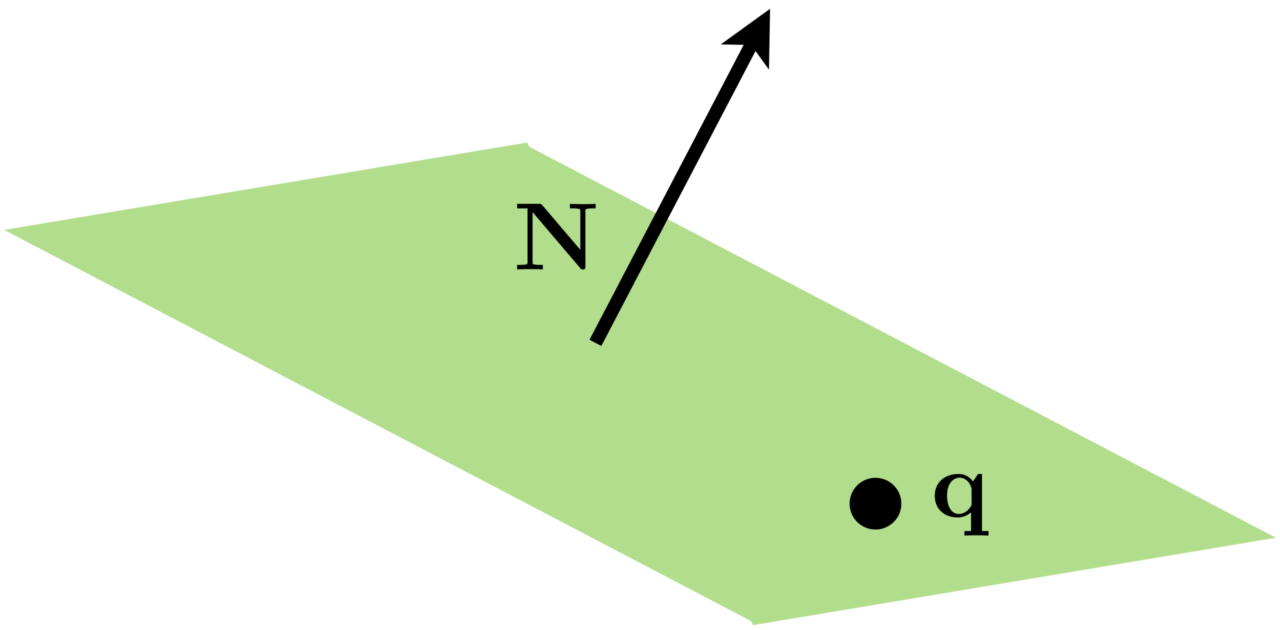
$$f(\mathbf{p}) = ? = 0$$

<whiteboard>



Clipping against a plane

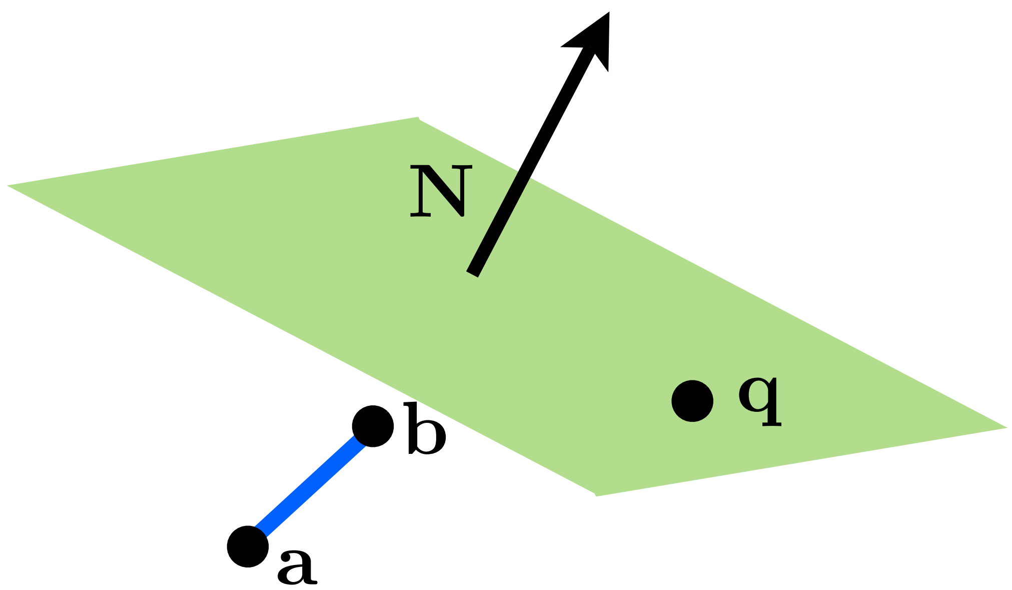
What's the equation for the plane through **q** with normal **N**?

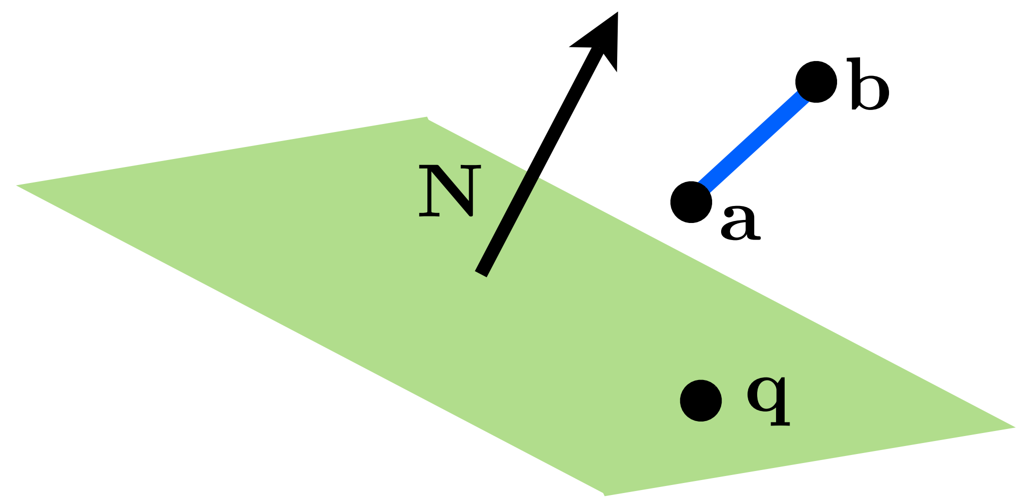


$$f(\mathbf{p}) = \mathbf{N} \cdot (\mathbf{p} - \mathbf{q}) = 0$$

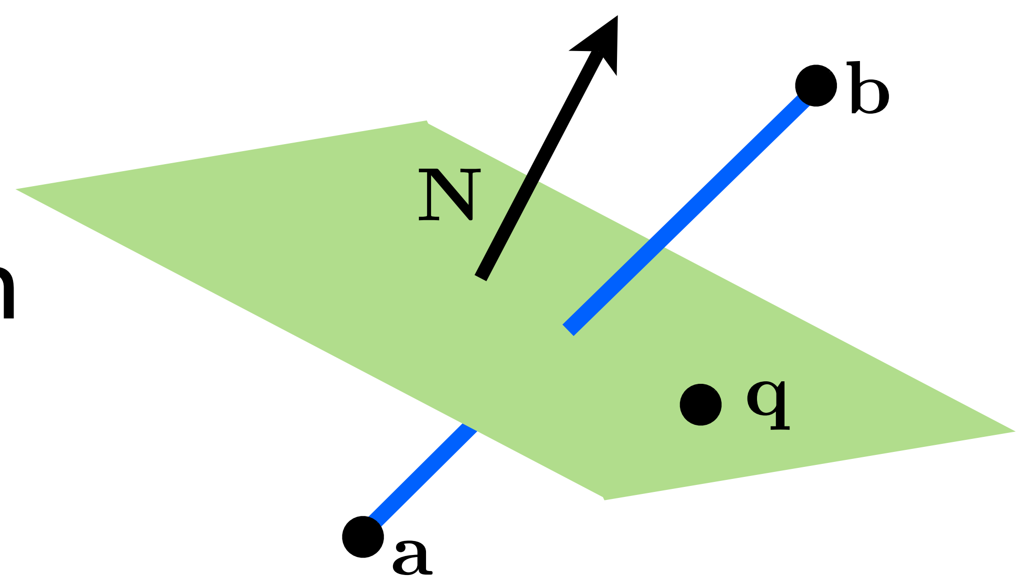
$$f(\mathbf{p}) = \mathbf{N} \cdot \mathbf{p} + D = 0$$

Intersection of line and plane



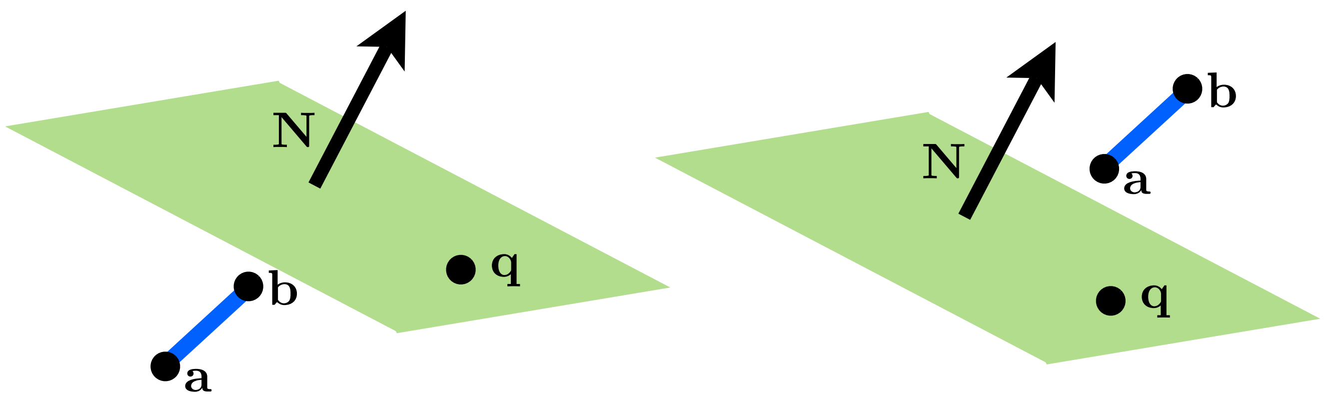


How can we distinguish between these cases?

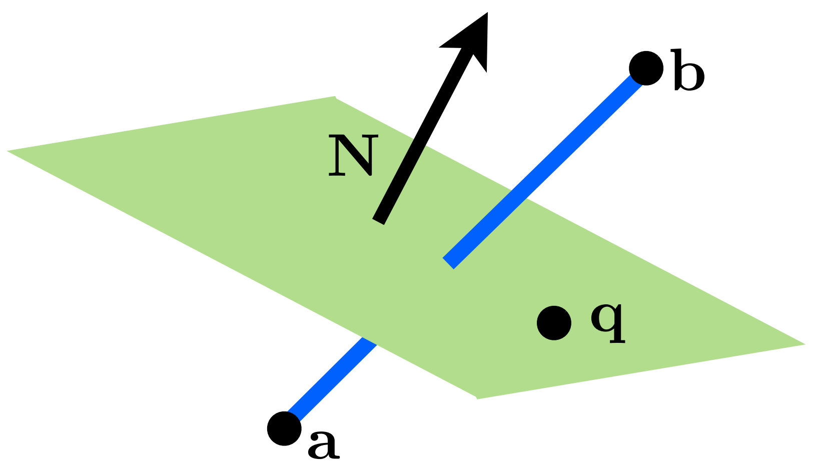


Intersection of line and plane

$$f(\mathbf{a})f(\mathbf{b}) \geq 0$$

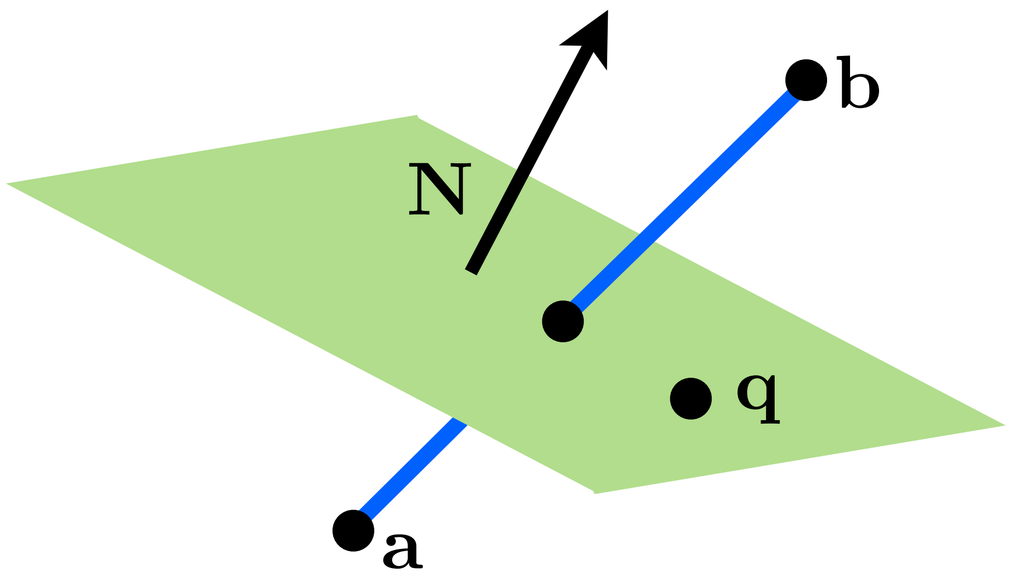


$$f(\mathbf{a})f(\mathbf{b}) < 0$$



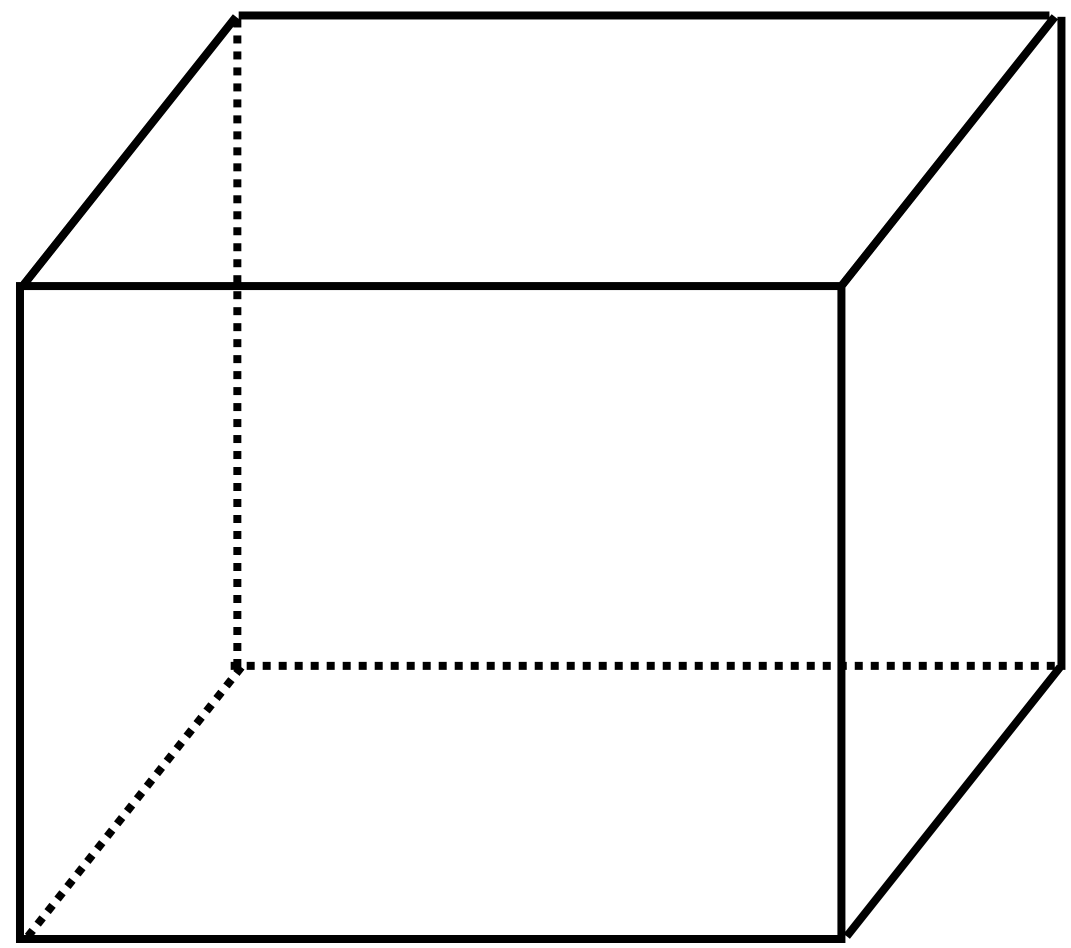
Intersection of line and plane

How can we find the intersection point?

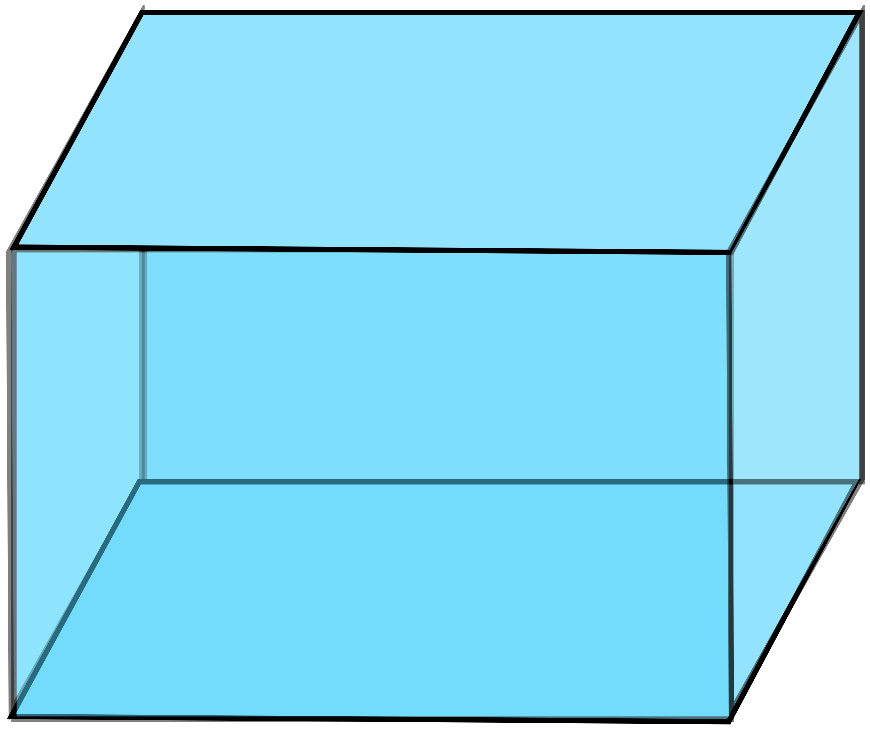


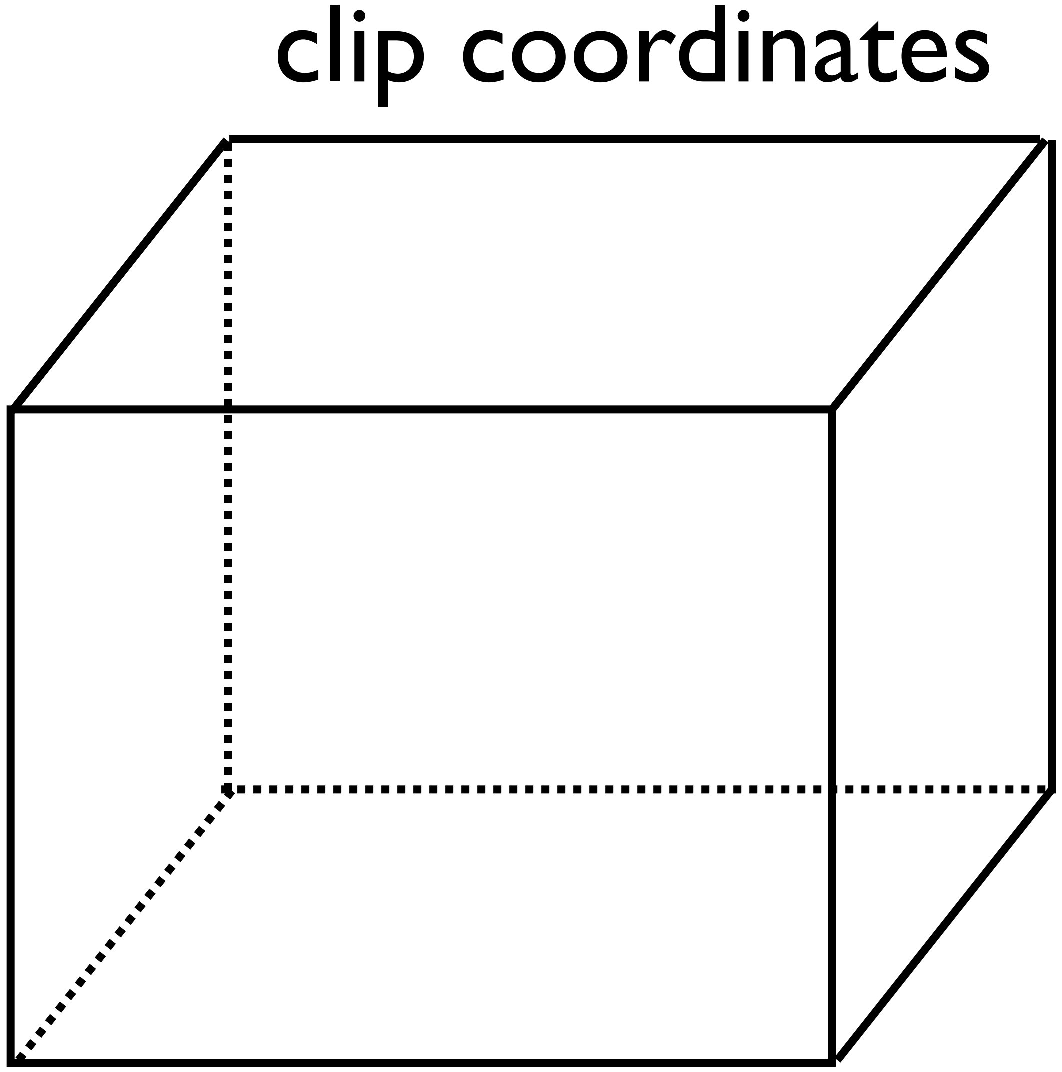
<whiteboard>

Clipping against the viewing volume

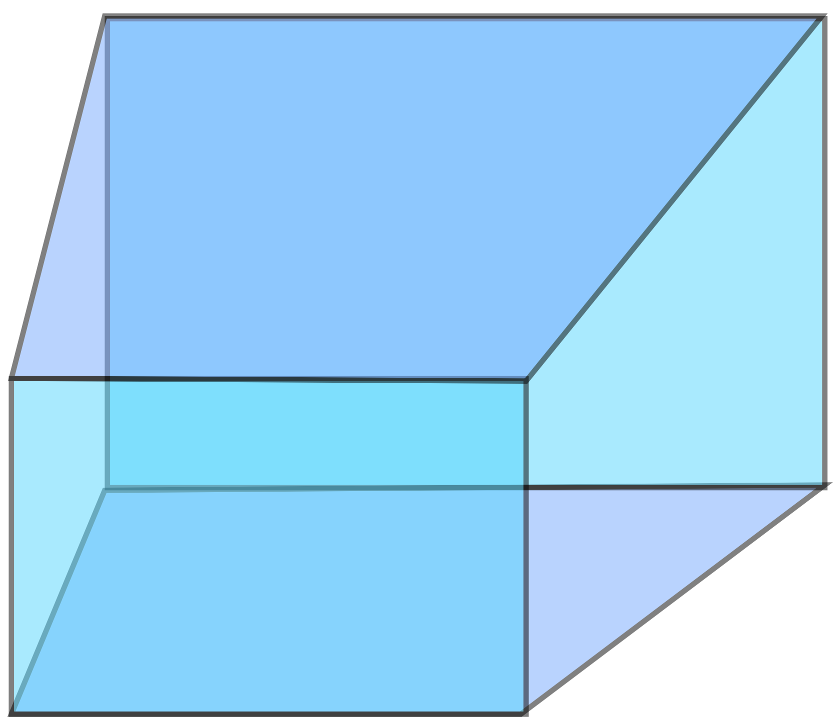


Orthographic projection viewing volume

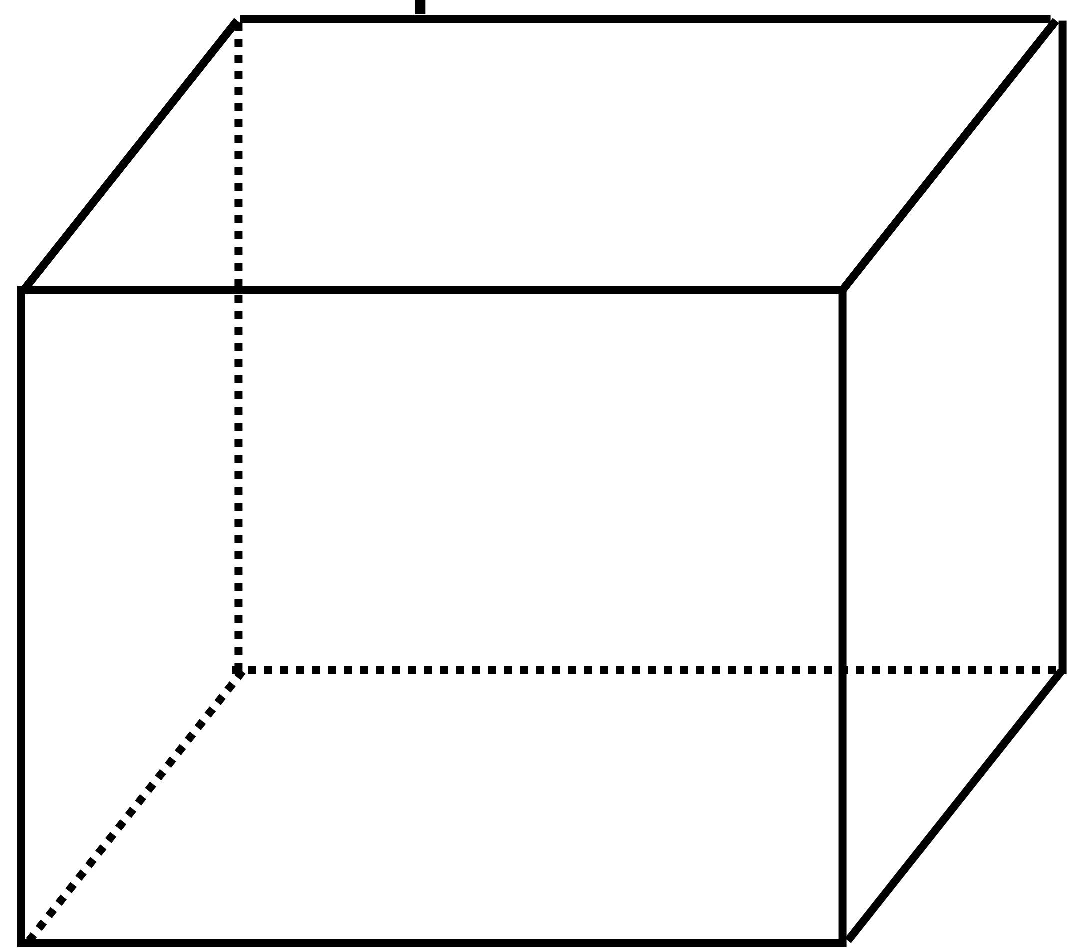




Perspective projection viewing volume



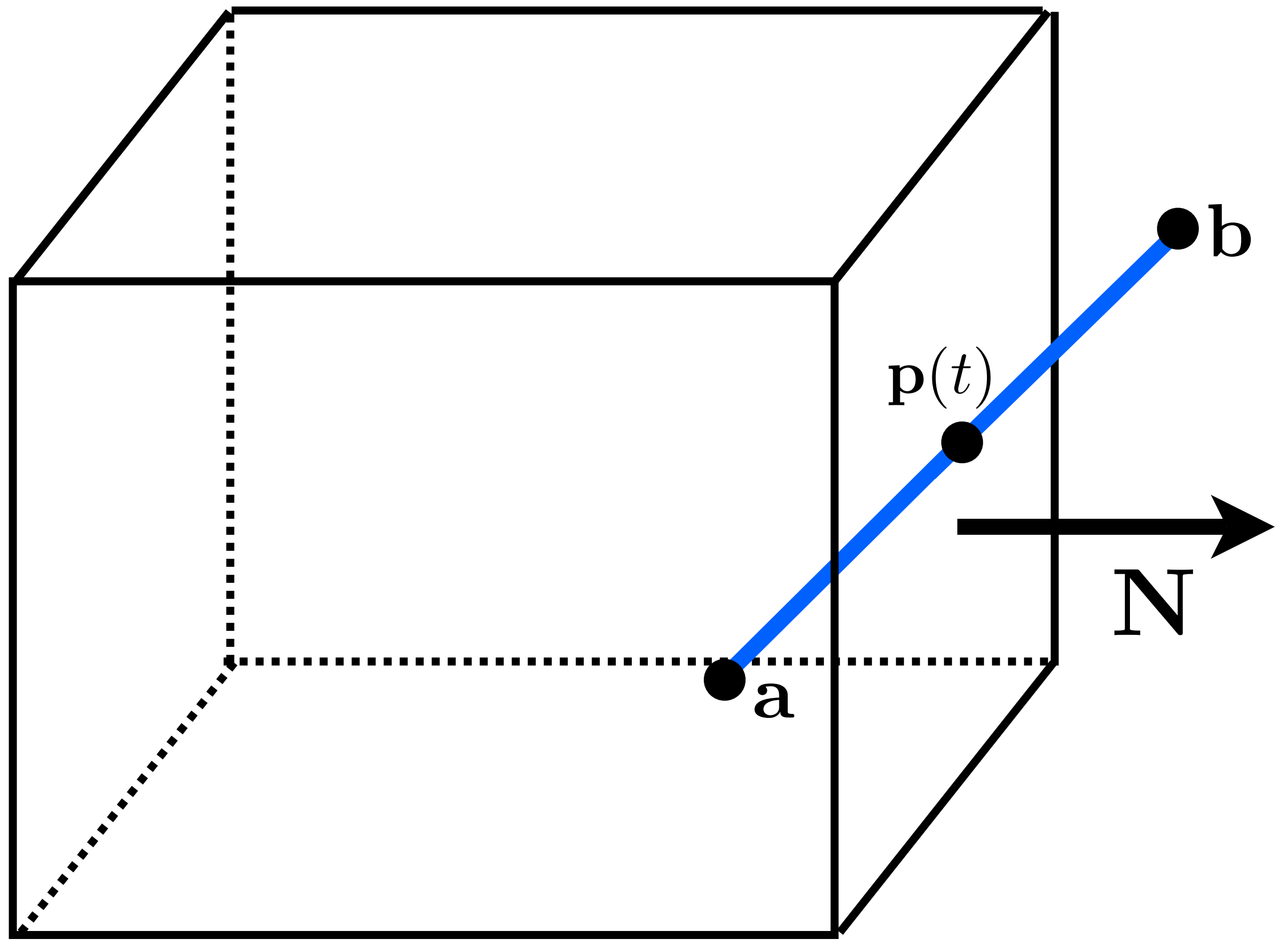
clip coordinates



Clipping against the viewing volume

$$\mathbf{p}(t)$$

$$t = \frac{\mathbf{N}\cdot\mathbf{a} + D}{\mathbf{N}\cdot(\mathbf{a}-\mathbf{b})}$$

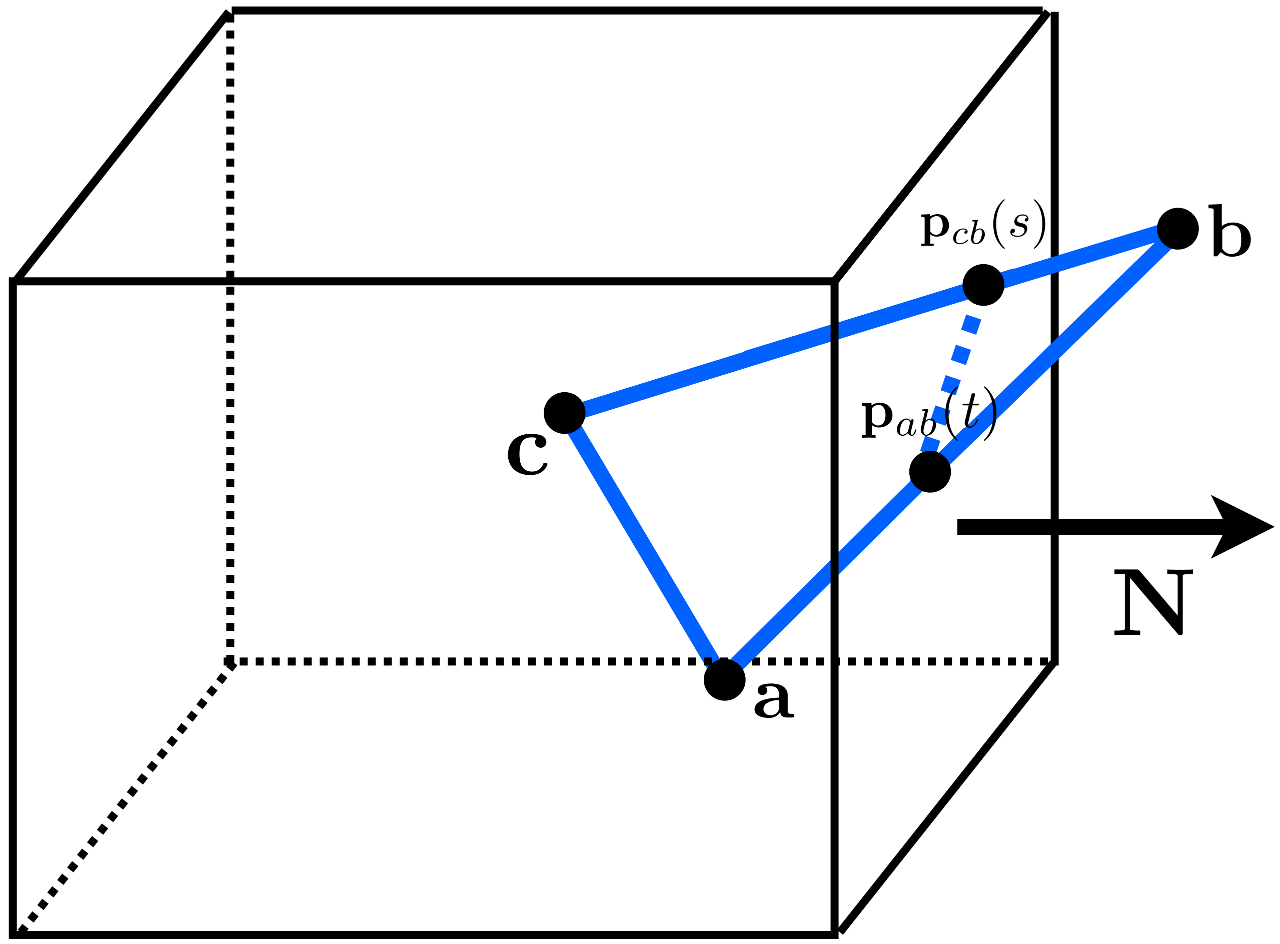


N is particularly simple for the orthographic viewing volume in NDC

Clipping against the viewing volume

$$s = \frac{\mathbf{N} \cdot \mathbf{c} + d}{\mathbf{N} \cdot (\mathbf{c} - \mathbf{b})}$$

$$t = \frac{\mathbf{N} \cdot \mathbf{a} + D}{\mathbf{N} \cdot (\mathbf{a} - \mathbf{b})}$$



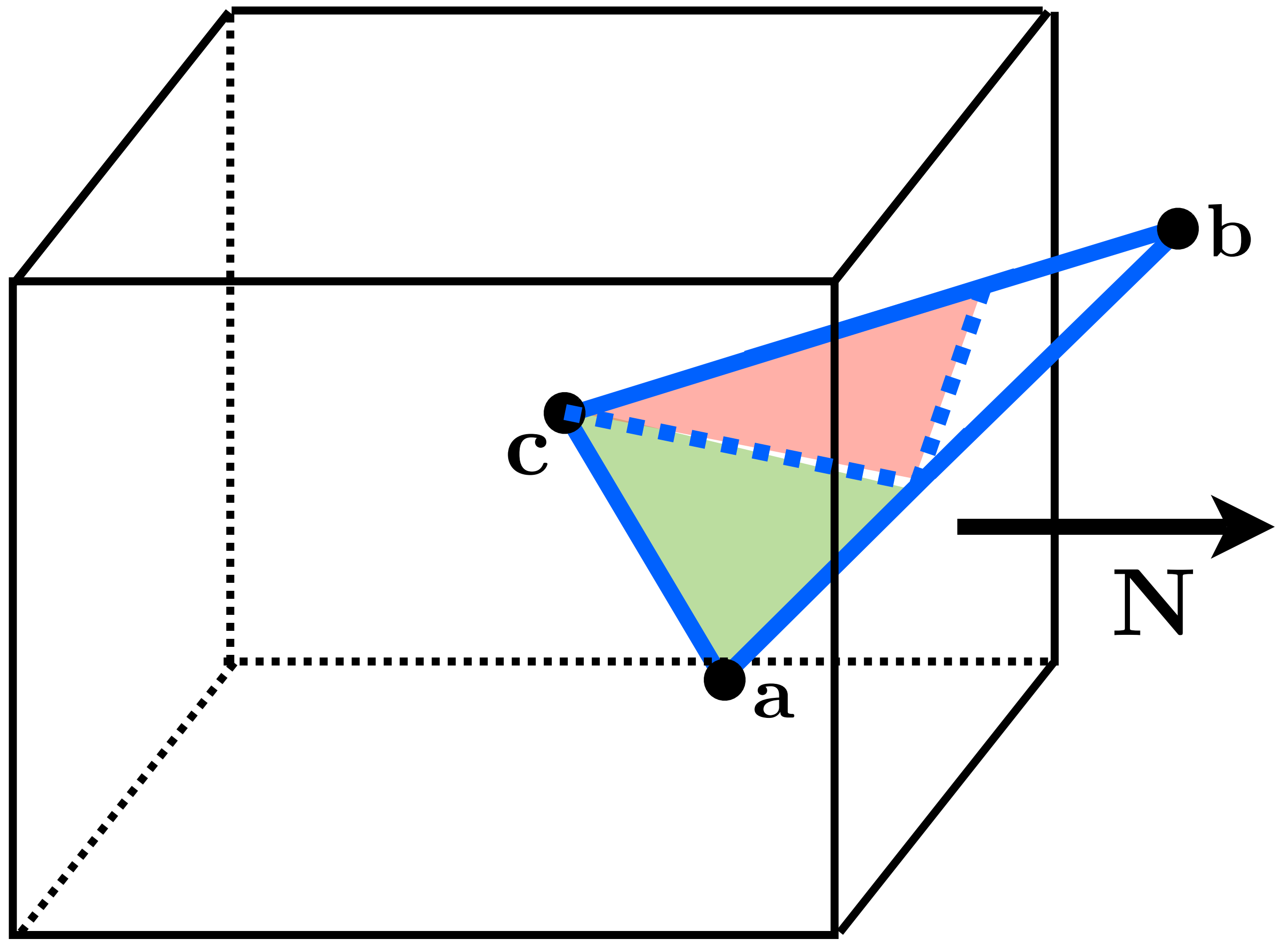
N is particularly simple for the orthographic viewing volume in NDC

Clipping against the viewing volume

$$s = \frac{\mathbf{N} \cdot \mathbf{c} + d}{\mathbf{N} \cdot (\mathbf{c} - \mathbf{b})}$$

$$t = \frac{\mathbf{N} \cdot \mathbf{a} + D}{\mathbf{N} \cdot (\mathbf{a} - \mathbf{b})}$$

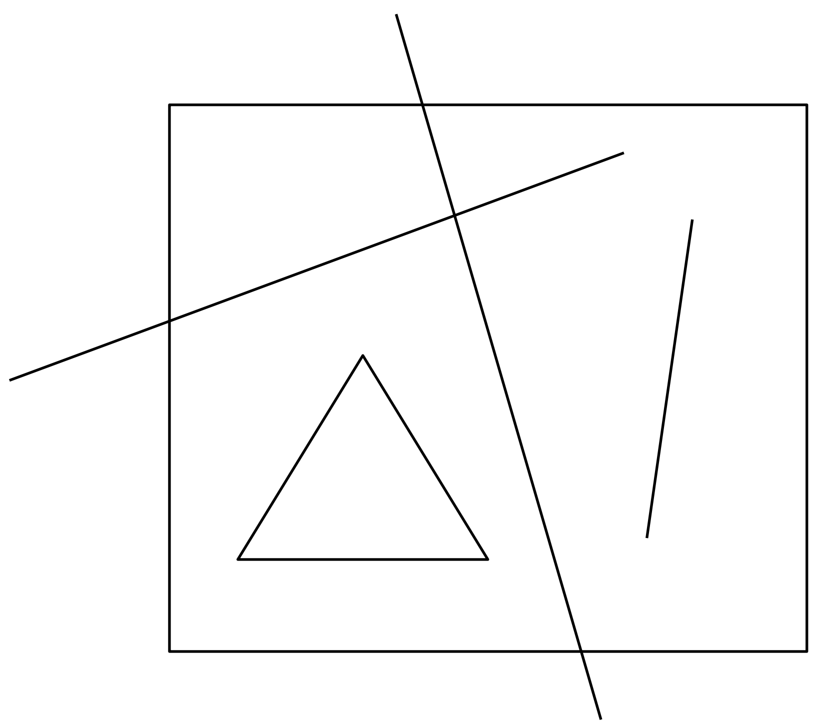
need to generate new triangles



N is particularly simple for the orthographic viewing volume in NDC

Clipping

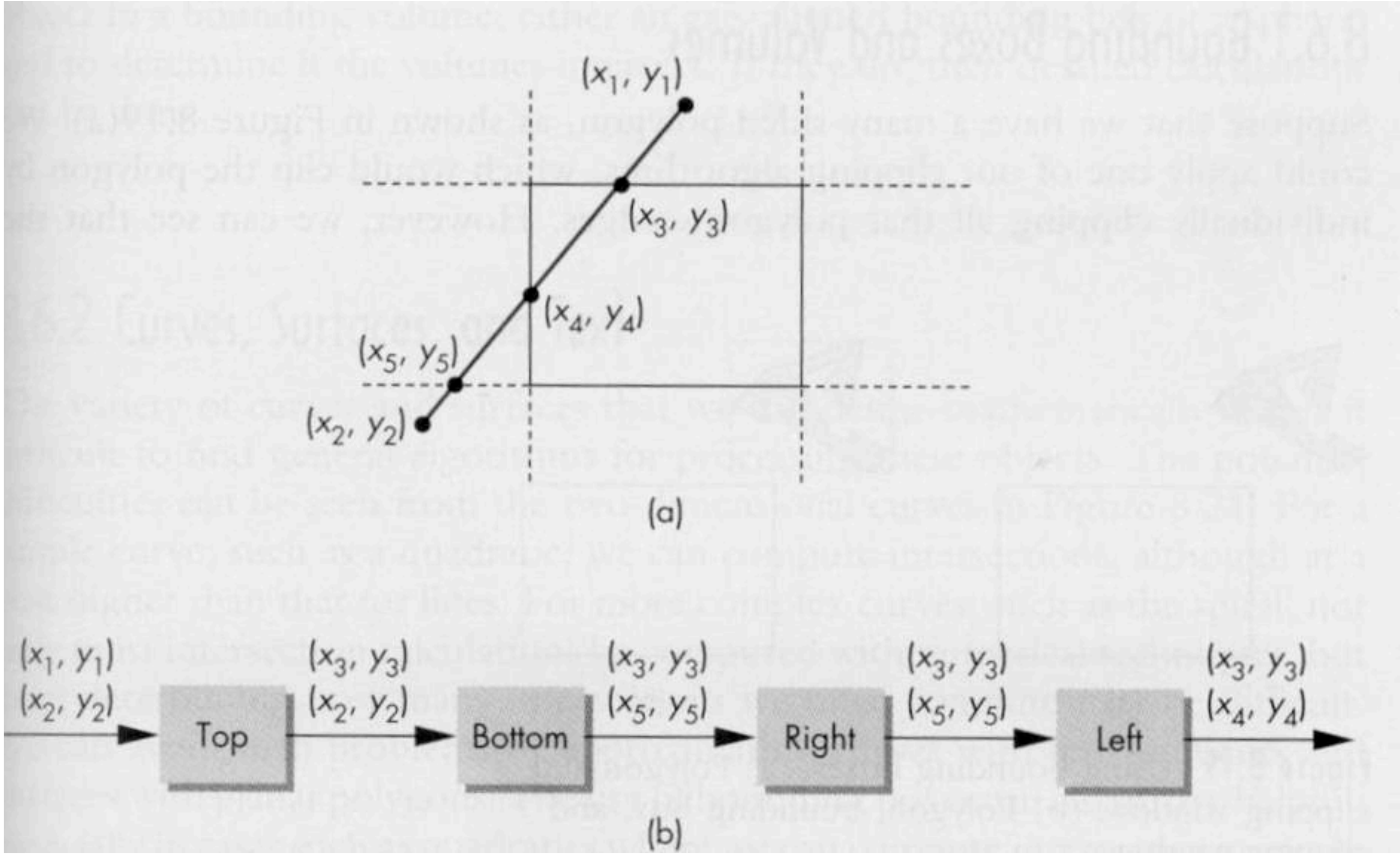
- Removing the unseen geometry
- Direct (brute-force) solution - solve silmultaneous equations for intersections of lines/edges at window edges



A point or vertex is visible if
$xleft < x < xright$
and
$ybot < y < ytop$

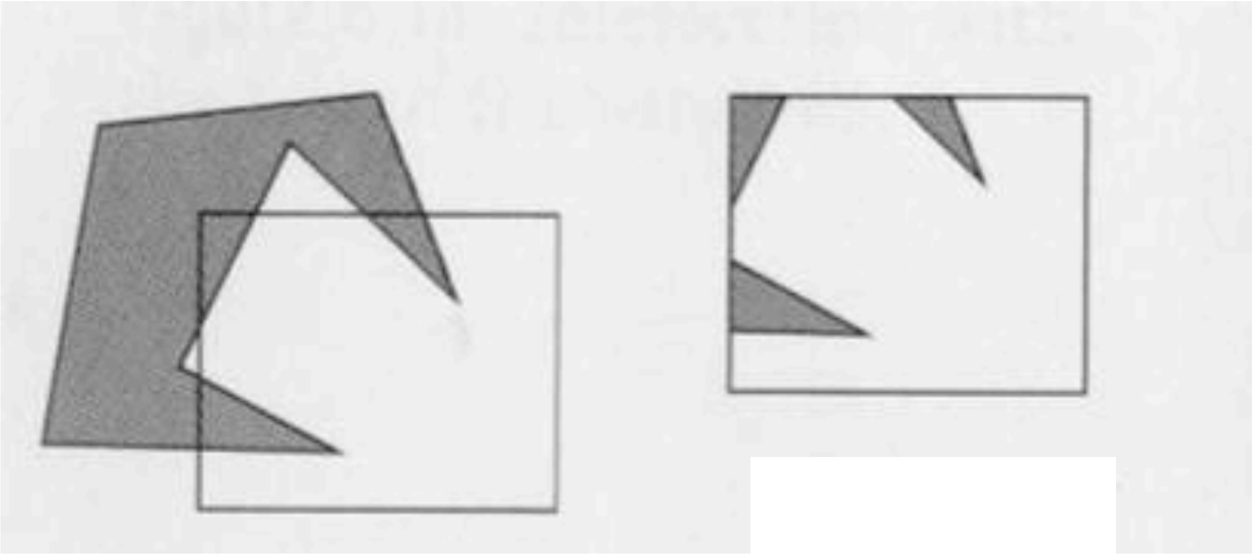
Clipping lines

Pipeline, clip each edge of the window separately:

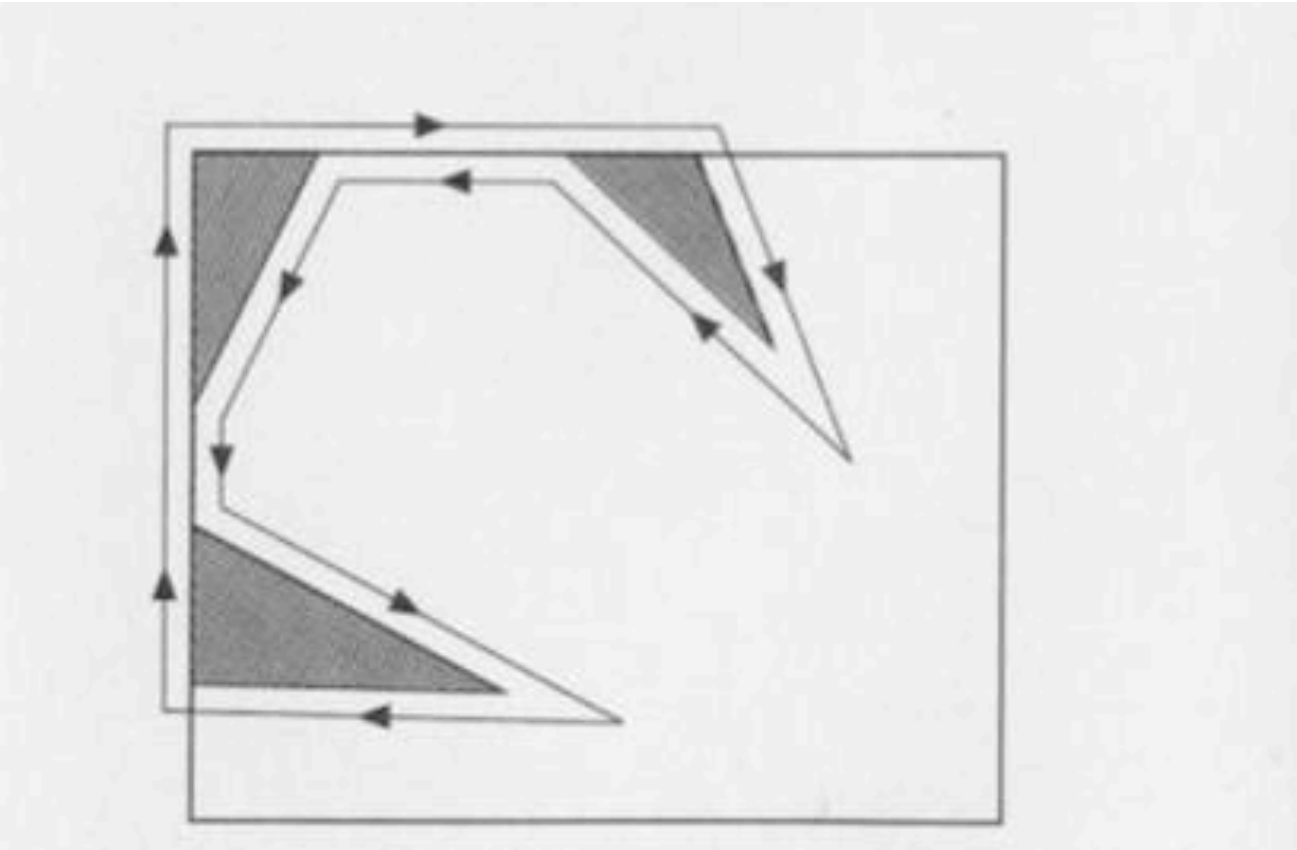


Clipping polygons

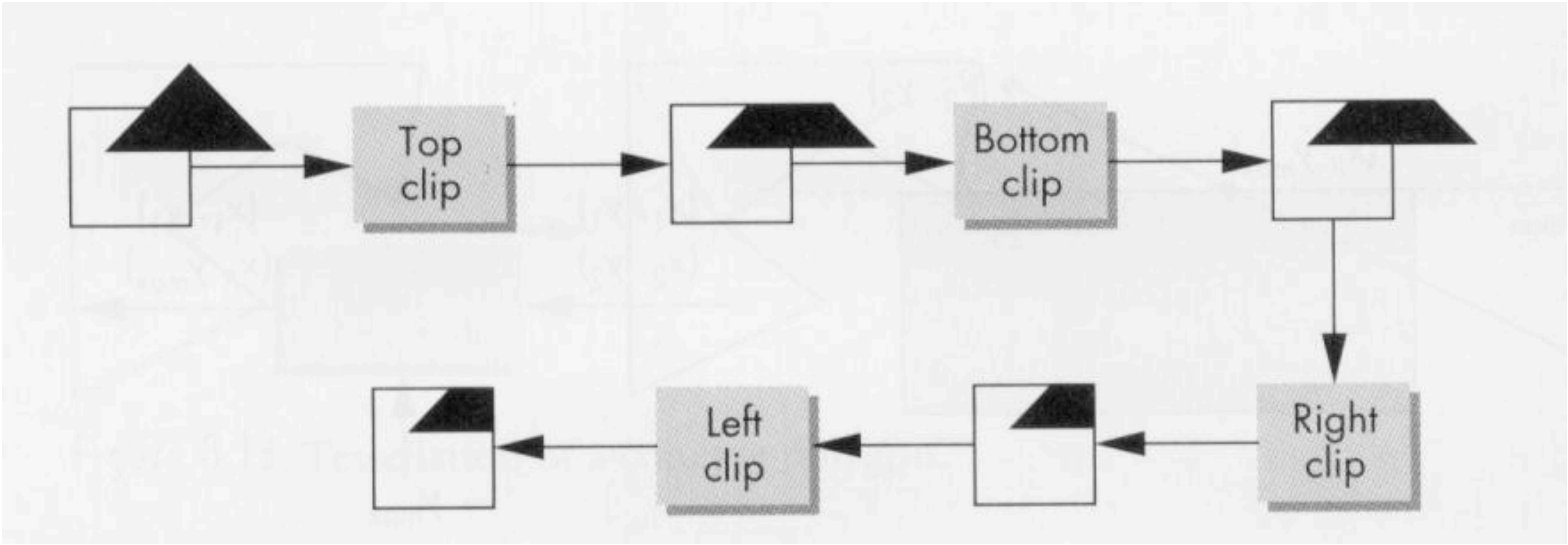
Clip the vertices that are outside of the window and create new vertices at window border



Result is still a single polygon but may have more vertices and an odd shape

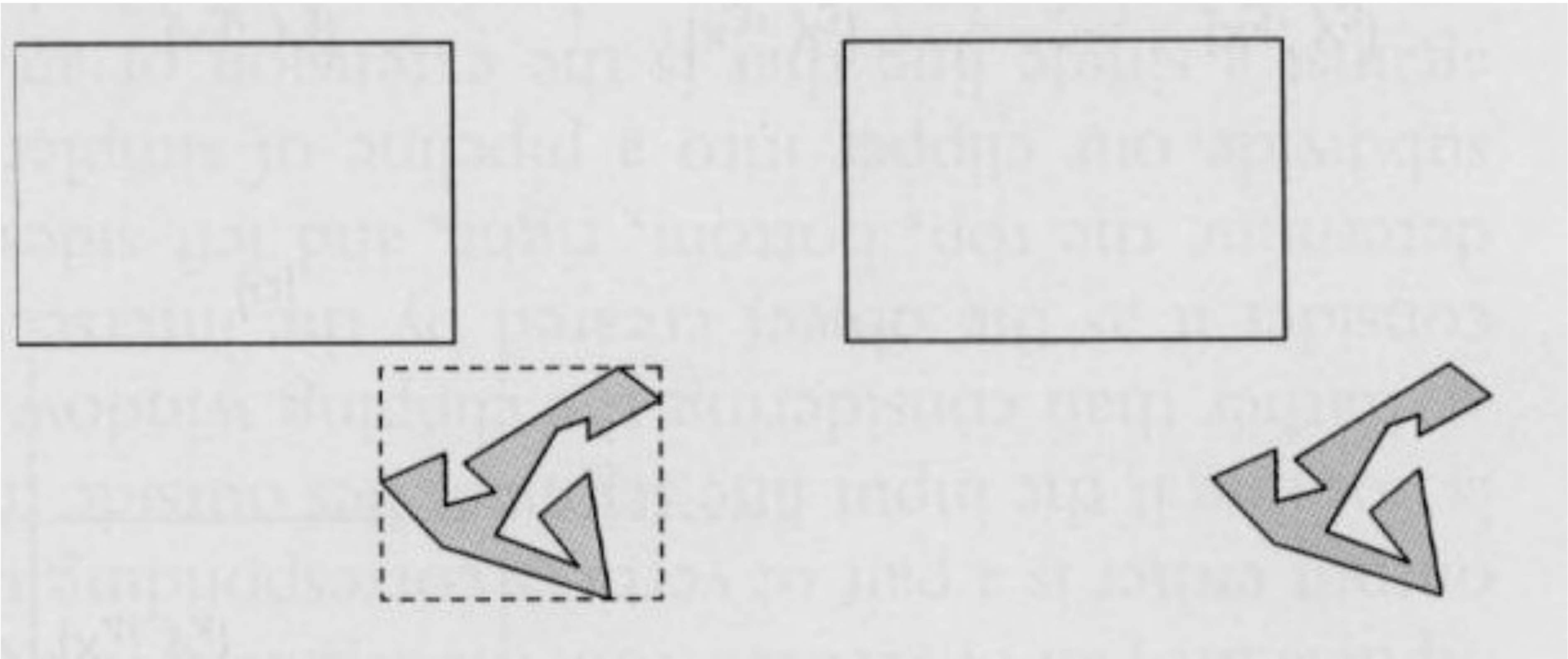


Clipping polygons



Clipping polygons

Bounding box - surrounds each polygon



Cohen-Sutherland Algorithm

- Region Checks: Trivially reject or accept for clipping
- Good for large or small windows (all is in or out of window, respectively)
- Each vertex is assigned an 4-bit outcode

1001	1000	1010
0001	0000	0010
0101	0100	0110

A line can be **trivially accepted** if both endpoints have an outcode of 0000.
A line can be **trivially rejected** if any of the same two bits in the outcodes are both equal to 1 (both endpoints are left, right, above, below the window)

Clipping 3D

Adds far and near clipping planes for 3D viewing volume