CS130 : Computer Graphics

Lecture 4: Rasterizing Triangles and Graphics Pipeline (cont.)

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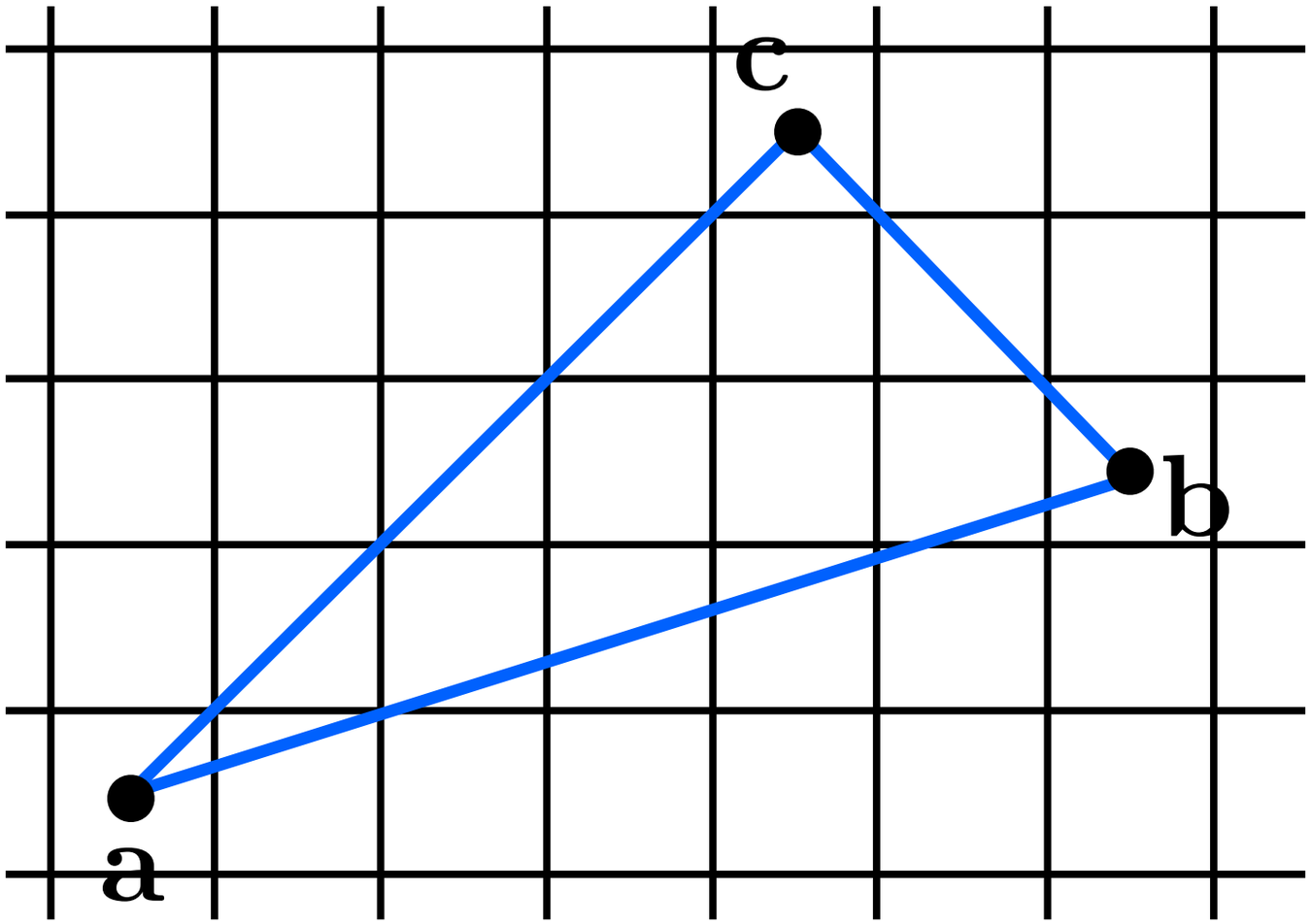
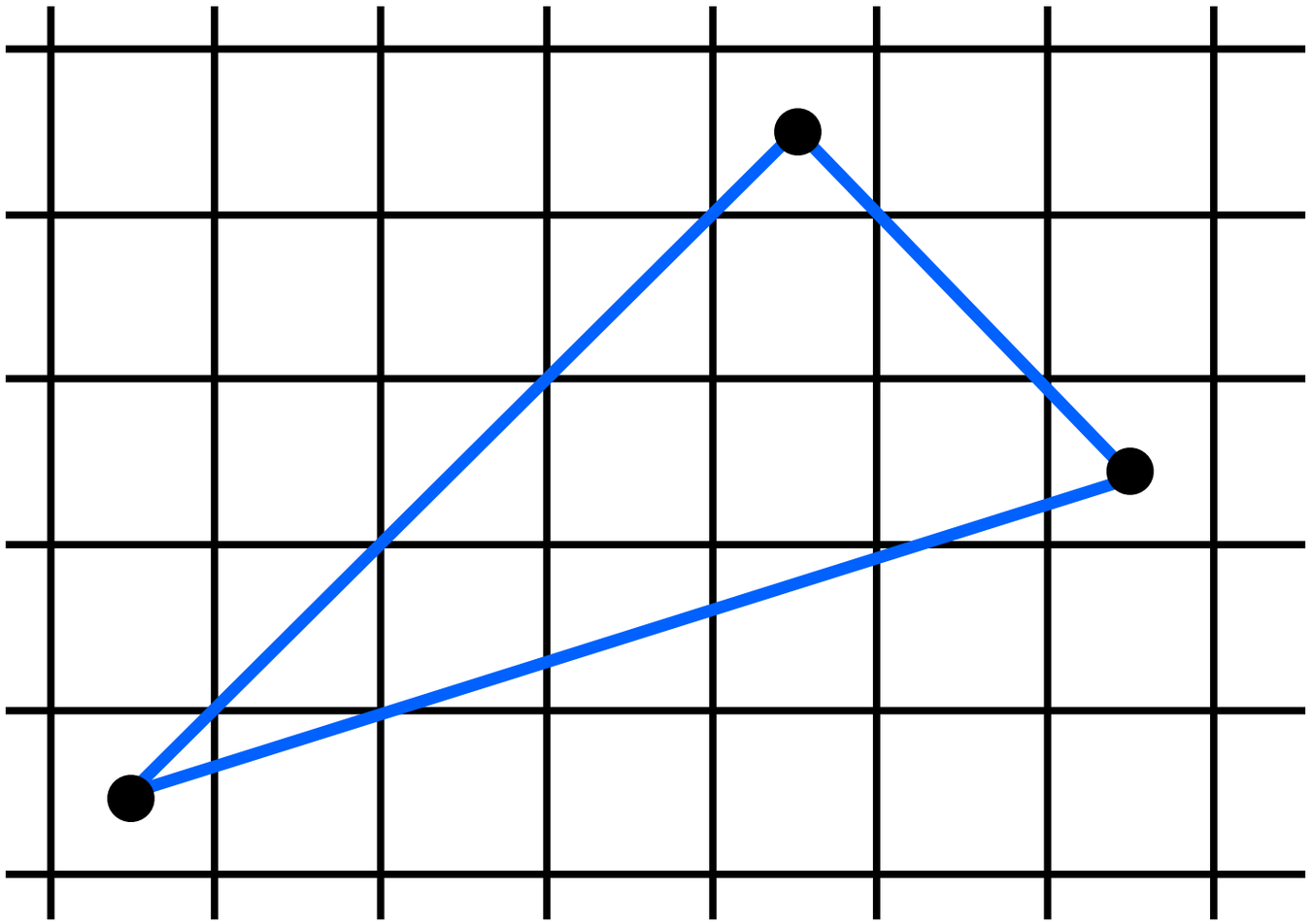
Triangle rasterization

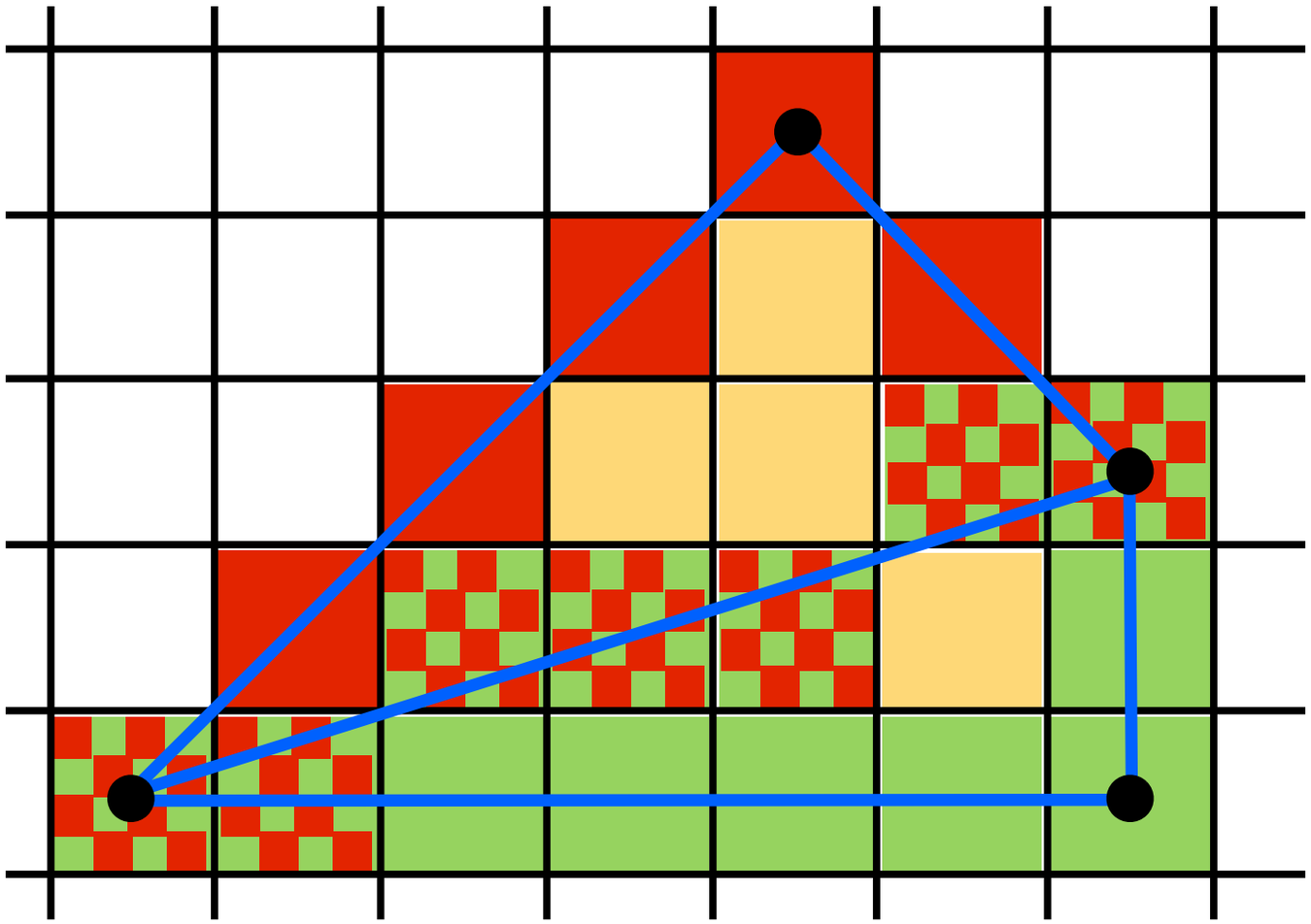
Which pixels should be used to approximate a triangle?



Triangle rasterization issues

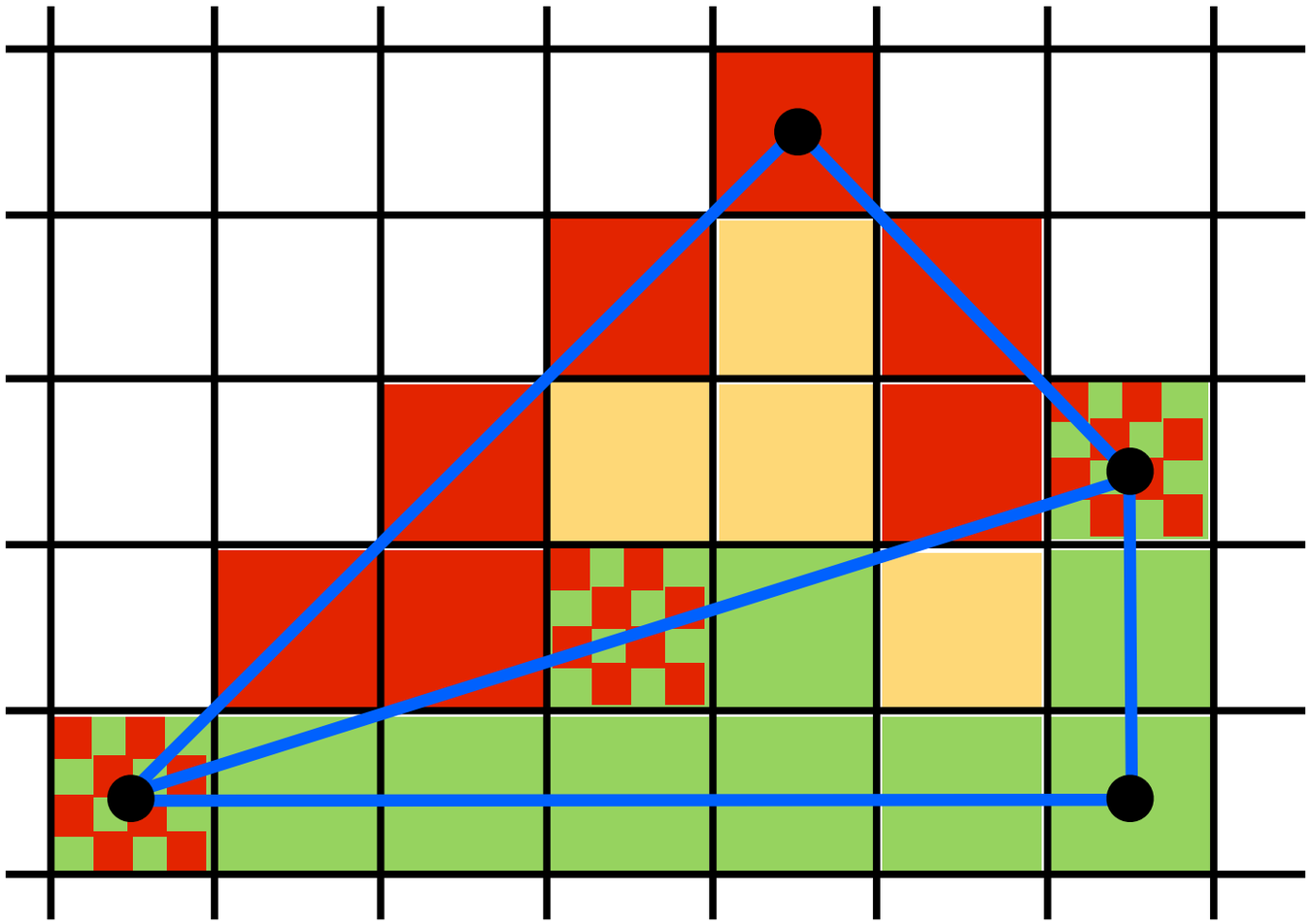


Which pixels should be used to approximate a triangle?



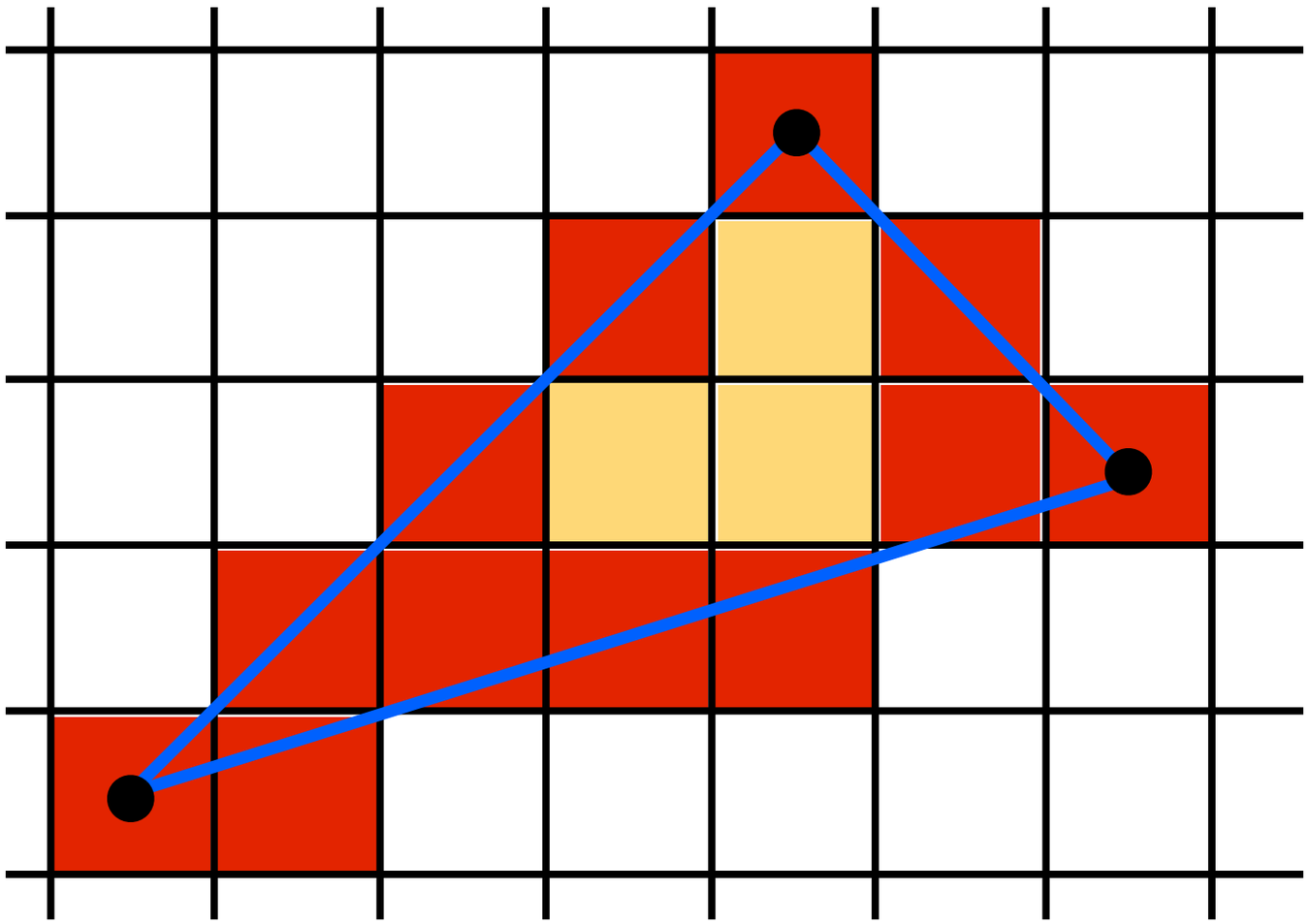
Who should fill in shared edge?

Which pixels should be used to approximate a triangle?



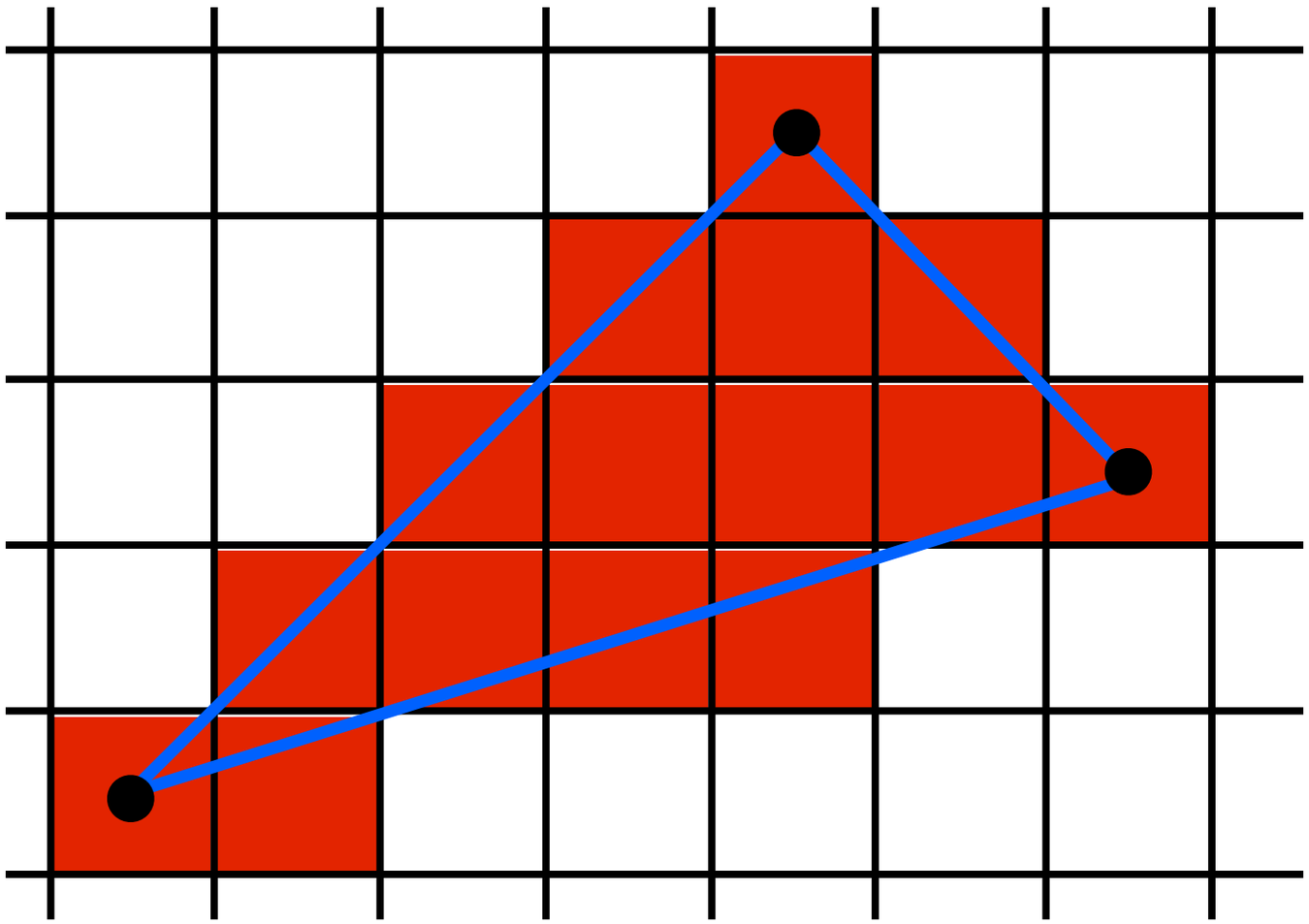
Who should fill in shared edge?

Which pixels should be used to approximate a triangle?



Use Midpoint Algorithm for edges and fill in?

Which pixels should be used to approximate a triangle?



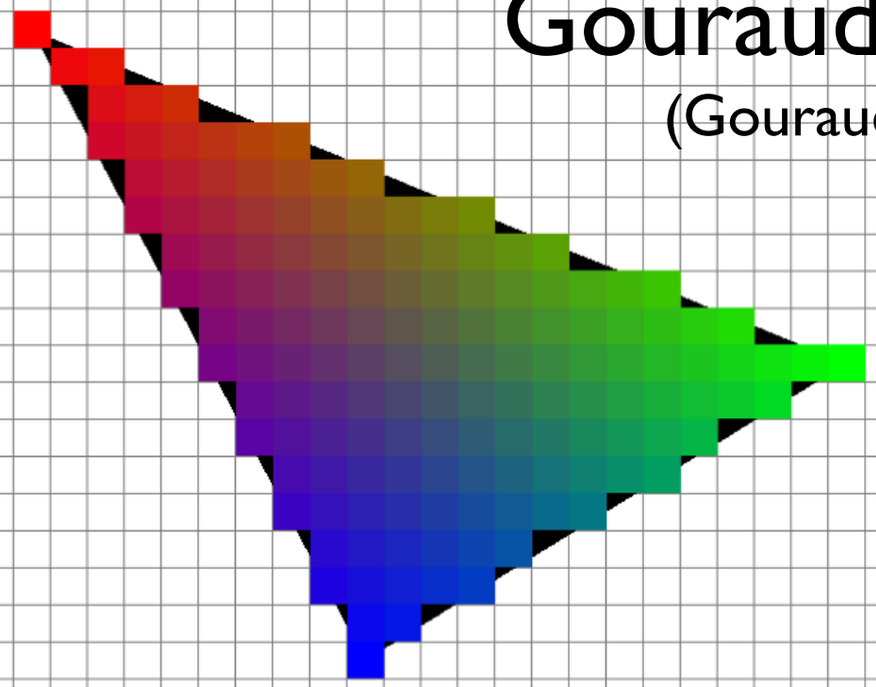
Use an approach based on barycentric coordinates

We can interpolate attributes using barycentric coordinates

$$\mathbf{c} = \alpha\mathbf{c}_0 + \beta\mathbf{c}_1 + \gamma\mathbf{c}_2$$

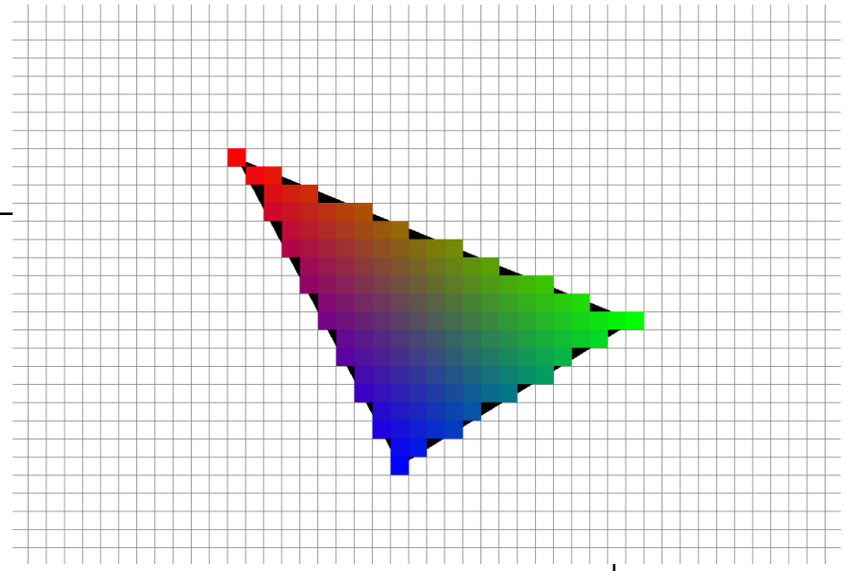
Gouraud shading

(Gouraud, 1971)



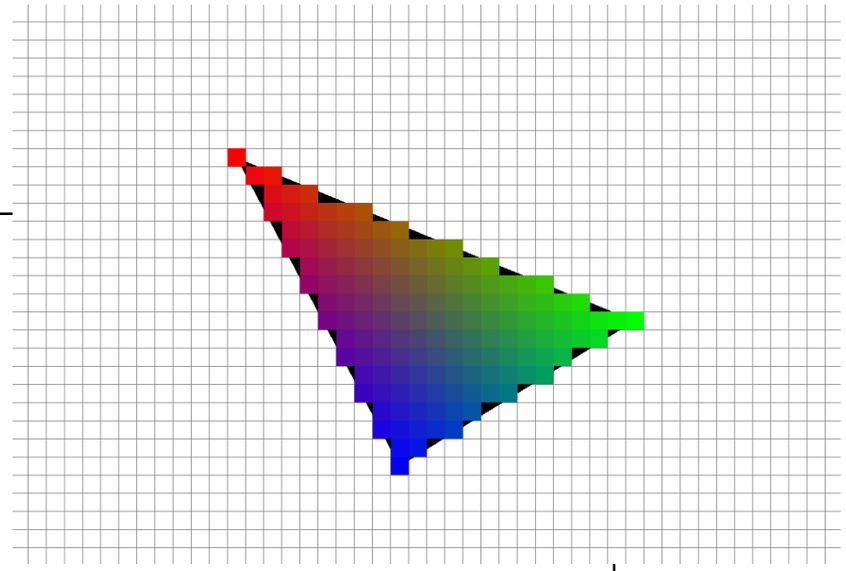
http://jtibble.dyndns.org/graphics/eecs487/eecs487.html

Triangle rasterization algorithm



```
for all x do
    for all y do
        compute (α, β, γ) for (x,y)
        if (α ∈ [0, 1] and β ∈ [0, 1] and γ ∈ [0, 1]) then
            c = αc0 + βc1 + γc2
            drawpixel(x,y) with color c
```

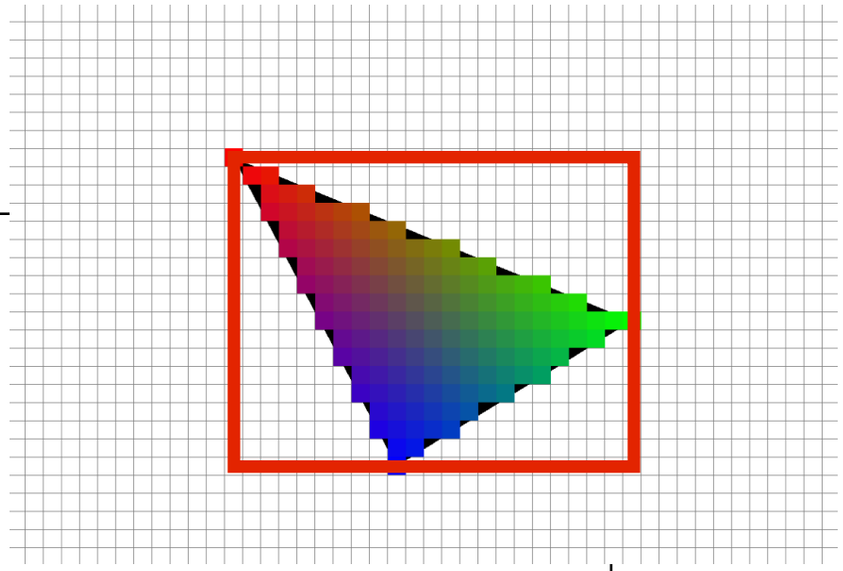
Triangle rasterization algorithm



for all x do
  for all y do
    compute (α, β, γ) for (x,y)
    if $(\alpha \in [0,1]$ and $\beta \in [0,1]$ and $\gamma \in [0,1])$ then
      $\mathbf{c} = \alpha\mathbf{c}_0 + \beta\mathbf{c}_1 + \gamma\mathbf{c}_2$
      drawpixel(x,y) with color c

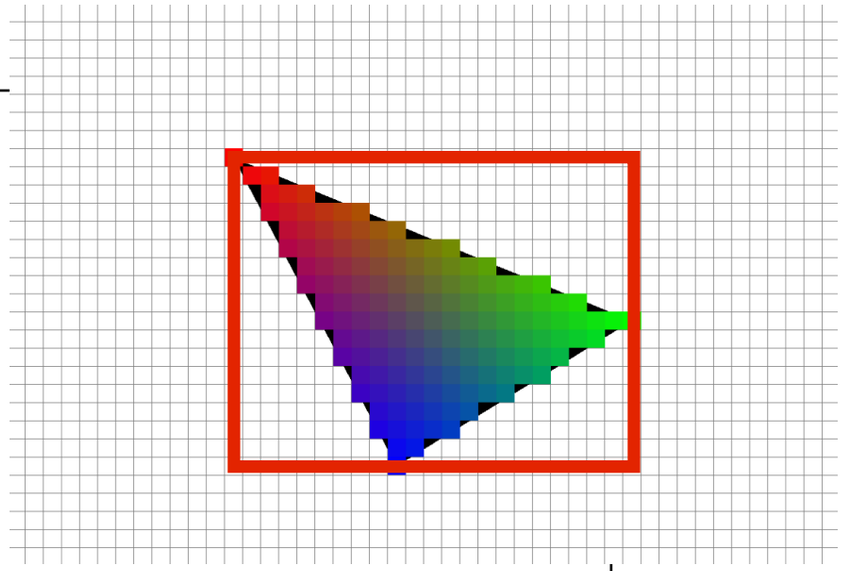
Triangle rasterization algorithm

use a bounding rectangle



for x in [x_min, x_max]
  for y in [y_min, y_max]
    compute (α, β, γ) for (x,y)
    if $(\alpha \in [0,1]$ and $\beta \in [0,1]$ and $\gamma \in [0,1])$ then
      $\mathbf{c} = \alpha\mathbf{c}_0 + \beta\mathbf{c}_1 + \gamma\mathbf{c}_2$
      drawpixel(x,y) with color c

Triangle rasterization algorithm



for x in [x_min, x_max]
  for y in [y_min, y_max]

$$\alpha = f_{bc}(x, y)/f_{bc}(x_a, y_a)$$

$$\beta = f_{ca}(x, y)/f_{ca}(x_b, y_b)$$

$$\gamma = f_{ab}(x, y)/f_{ab}(x_c, y_c)$$

if $(\alpha \in [0, 1]$ and $\beta \in [0, 1]$ and $\gamma \in [0, 1])$ then

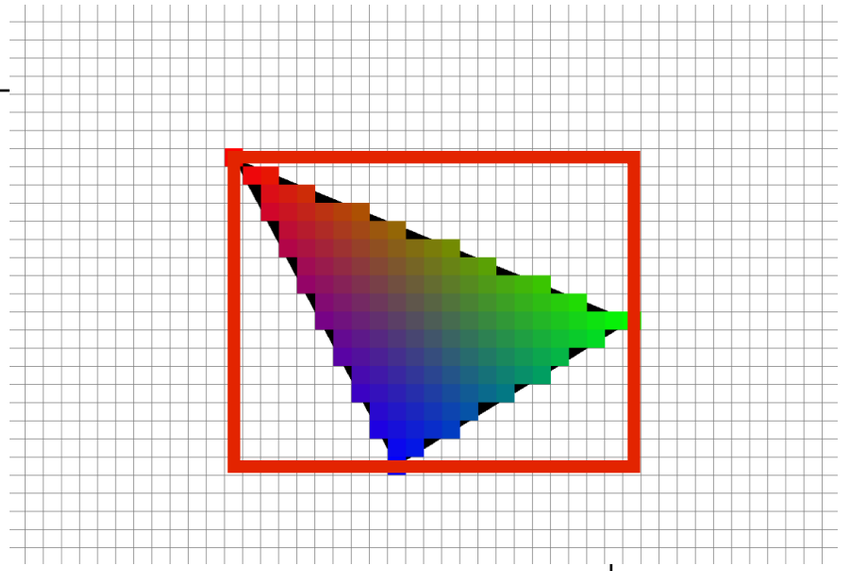
$$\mathbf{c} = \alpha\mathbf{c}_0 + \beta\mathbf{c}_1 + \gamma\mathbf{c}_2$$

drawpixel(x,y) with color c

<whiteboard>

Triangle rasterization algorithm

Optimizations?



for x in [x_min, x_max]
  for y in [y_min, y_max]

$$\alpha = f_{bc}(x, y) / f_{bc}(x_a, y_a)$$

$$\beta = f_{ca}(x, y) / f_{ca}(x_b, y_b)$$

$$\gamma = f_{ab}(x, y) / f_{ab}(x_c, y_c)$$

if $(\alpha \in [0, 1]$ and $\beta \in [0, 1]$ and $\gamma \in [0, 1])$ then

$$\mathbf{c} = \alpha \mathbf{c}_0 + \beta \mathbf{c}_1 + \gamma \mathbf{c}_2$$

drawpixel(x,y) with color c

Triangle rasterization algorithm

Optimizations?

for x in [x_min, x_max]
  for y in [y_min, y_max]

$$\alpha = f_{bc}(x,y)/f_{bc}(x_a,y_a)$$

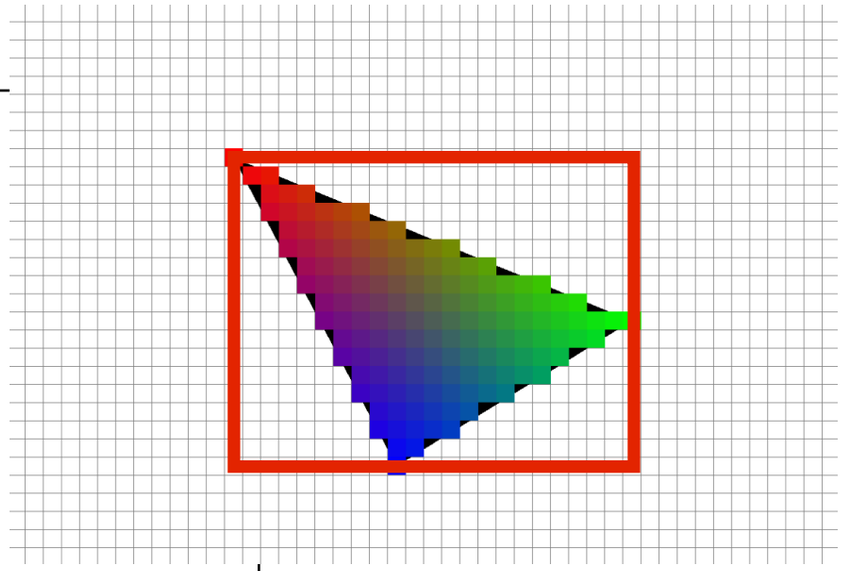
$$\beta = f_{ca}(x,y)/f_{ca}(x_b,y_b)$$

$$\gamma = f_{ab}(x,y)/f_{ab}(x_c,y_c)$$

if $(\alpha \geq 0 \text{ and } \beta \geq 0 \text{ and } \gamma \geq 0)$ then

$$\mathbf{c} = \alpha\mathbf{c}_0 + \beta\mathbf{c}_1 + \gamma\mathbf{c}_2$$

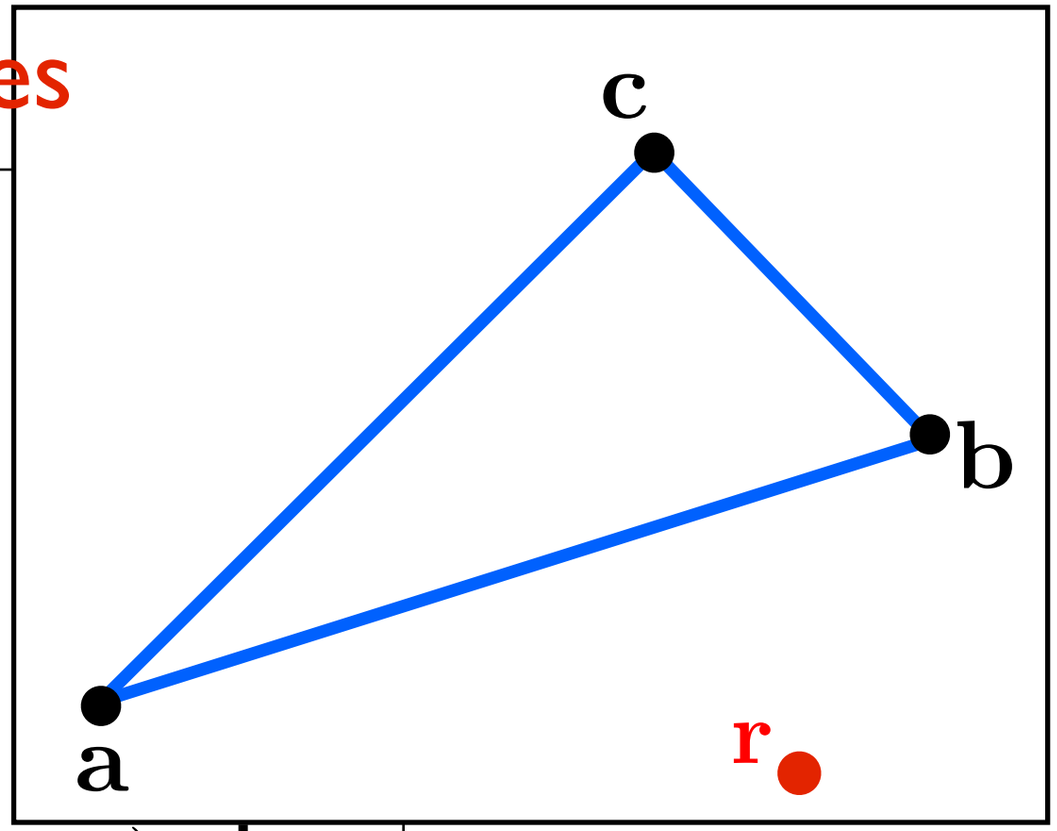
drawpixel(x,y) with color c



make computation of bary. coords. incremental
color can also be computed incrementally
don't need to check upper bound

Triangle rasterization algorithm

dealing with shared triangle edges



for x in [x_min, x_max]

for y in [y_min, y_max]

$$\alpha = f_{bc}(x,y)/f_{bc}(x_a,y_a)$$

$$\beta = f_{ac}(x,y)/f_{ac}(x_b,y_b)$$

$$\gamma = f_{ab}(x,y)/f_{ab}(x_c,y_c)$$

if $(\alpha \geq 0$ and $\beta \geq 0$ and $\gamma \geq 0)$ then

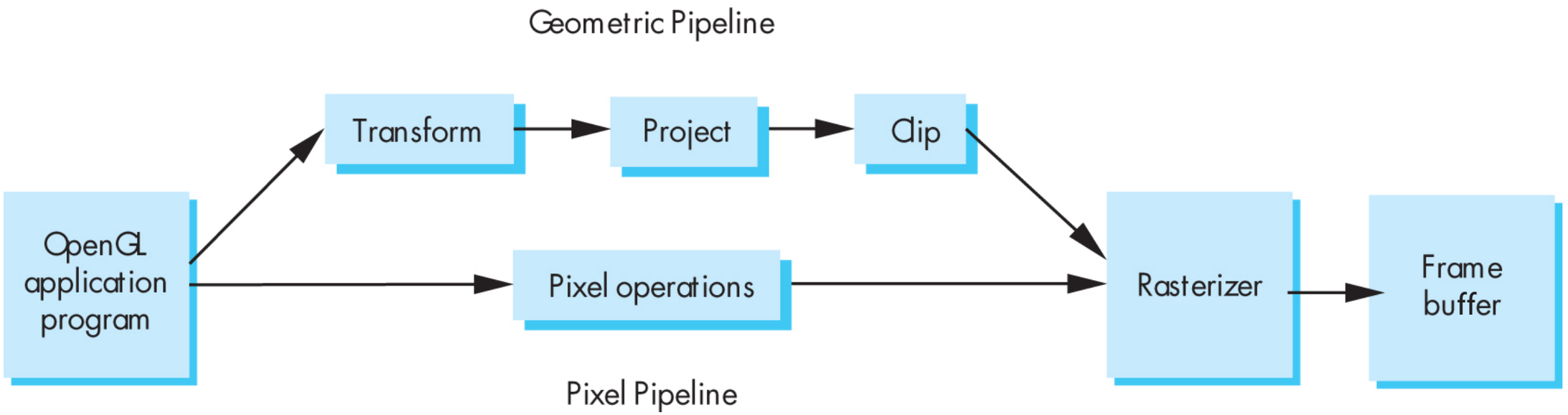
if $(\alpha > 0$ or $f_{bc}(\mathbf{a})f_{bc}(\mathbf{r}) > 0)$ and
$(\beta > 0$ or $f_{ca}(\mathbf{b})f_{ca}(\mathbf{r}) > 0)$ and
$(\gamma > 0$ or $f_{ab}(\mathbf{c})f_{ab}(\mathbf{r}) > 0)$ then

$$\mathbf{c} = \alpha\mathbf{c}_0 + \beta\mathbf{c}_1 + \gamma\mathbf{c}_2$$

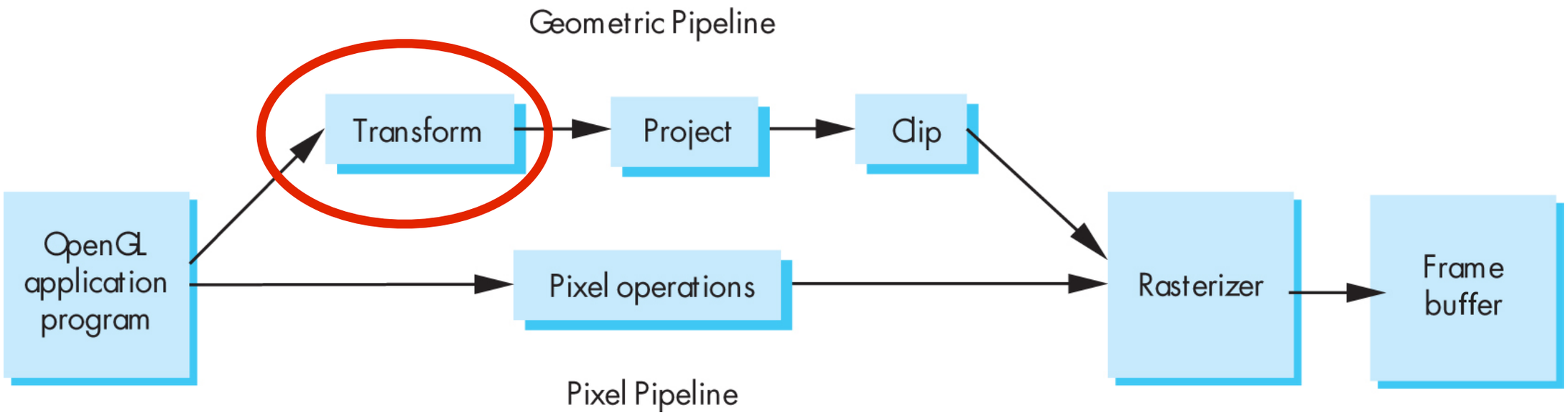
drawpixel(x,y) with color c

Graphics Pipeline (cont.)

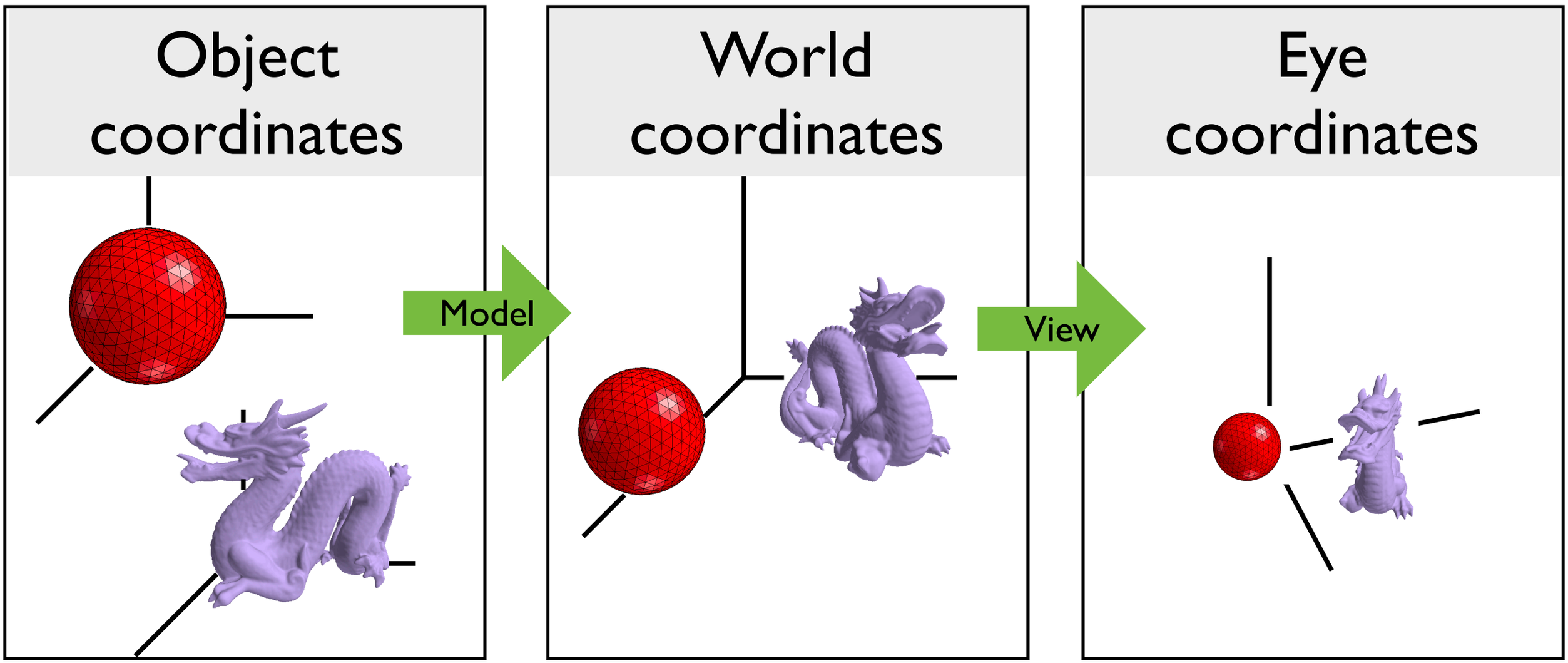
Graphics Pipeline



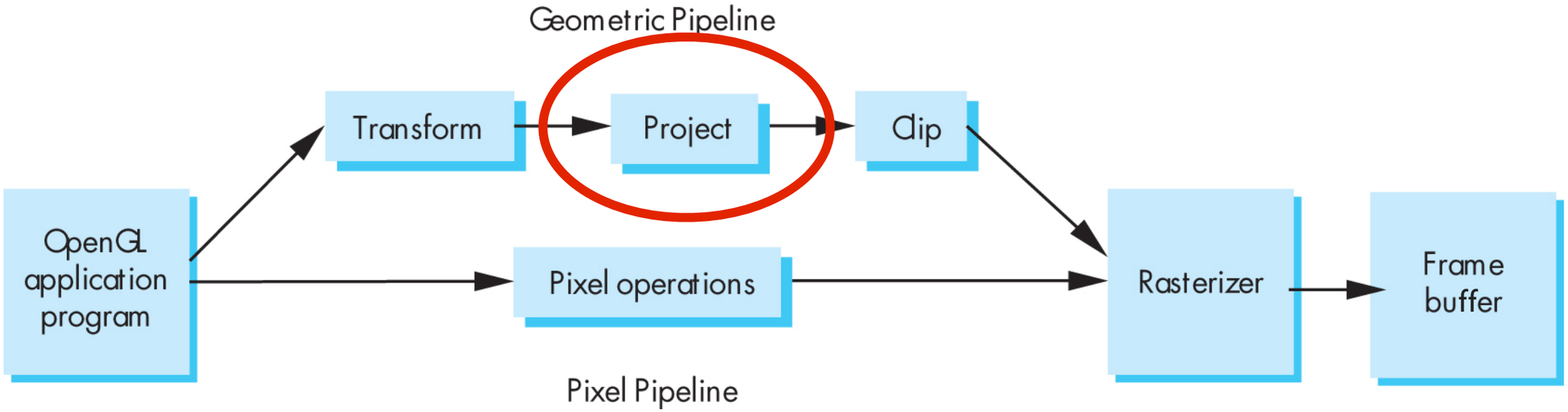
Transform


Geometric Pipeline
Transform
Project
Clip
OpenGL application program
Pixel operations
Rasterizer
Frame buffer
Pixel Pipeline

"Modelview" Transformation



Project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Pixel operations
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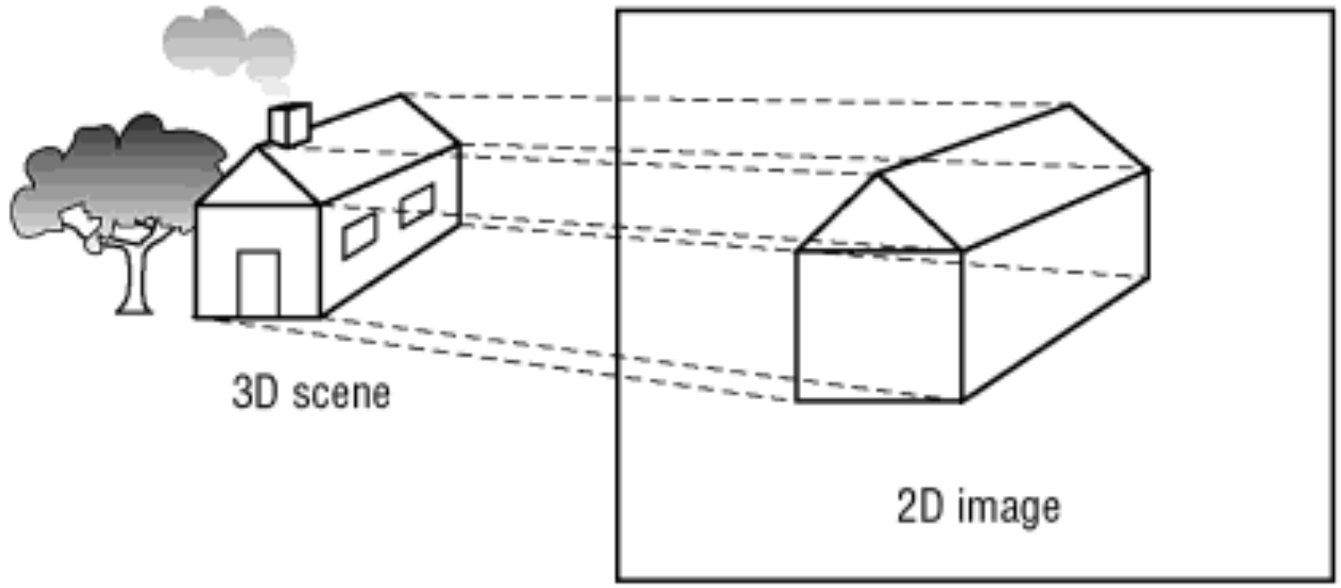
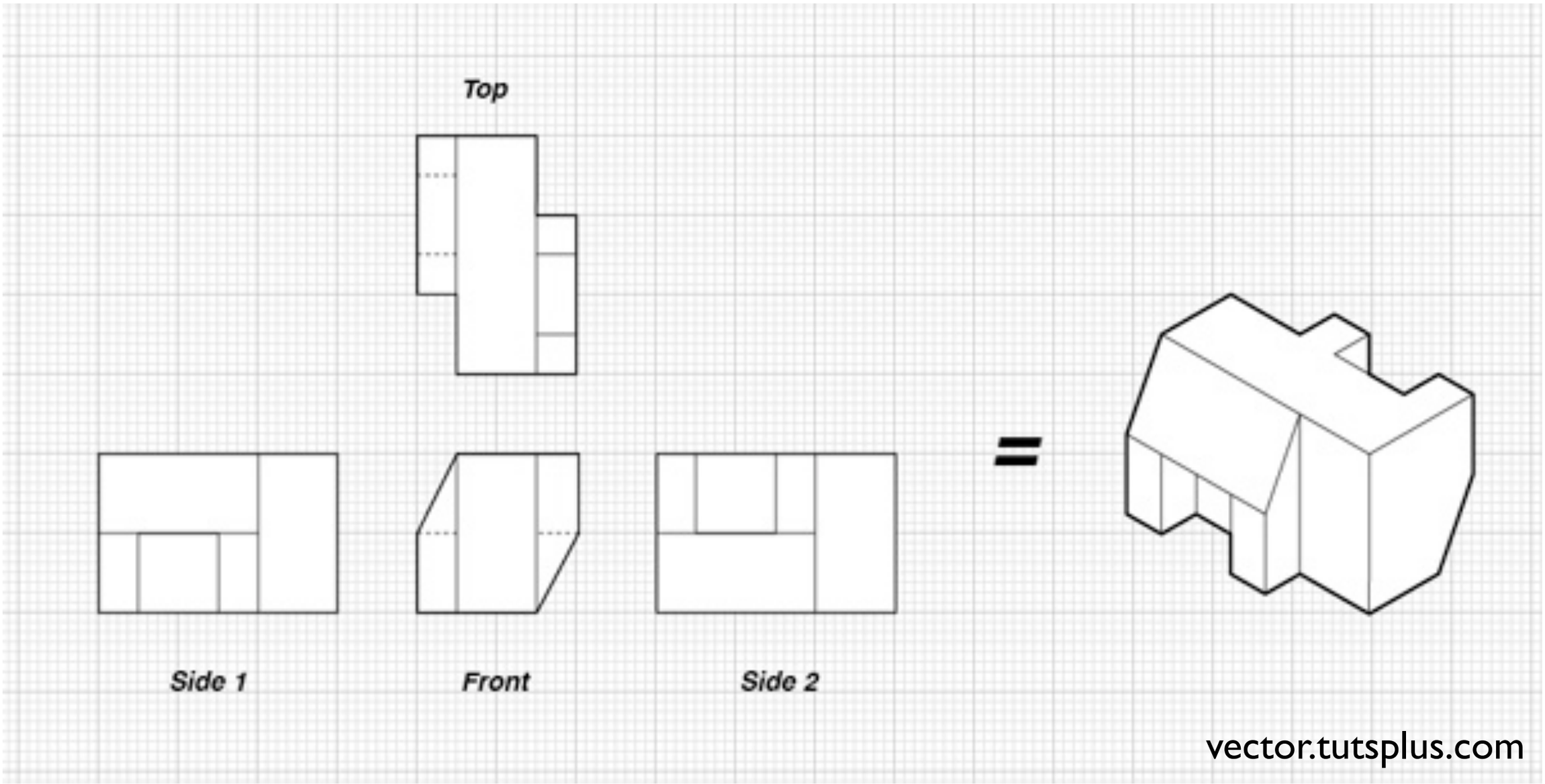
Frame buffer
Pixel Pipeline

Projection: map 3D scene to 2D image



OpenGL Super Bible, 5th Ed.

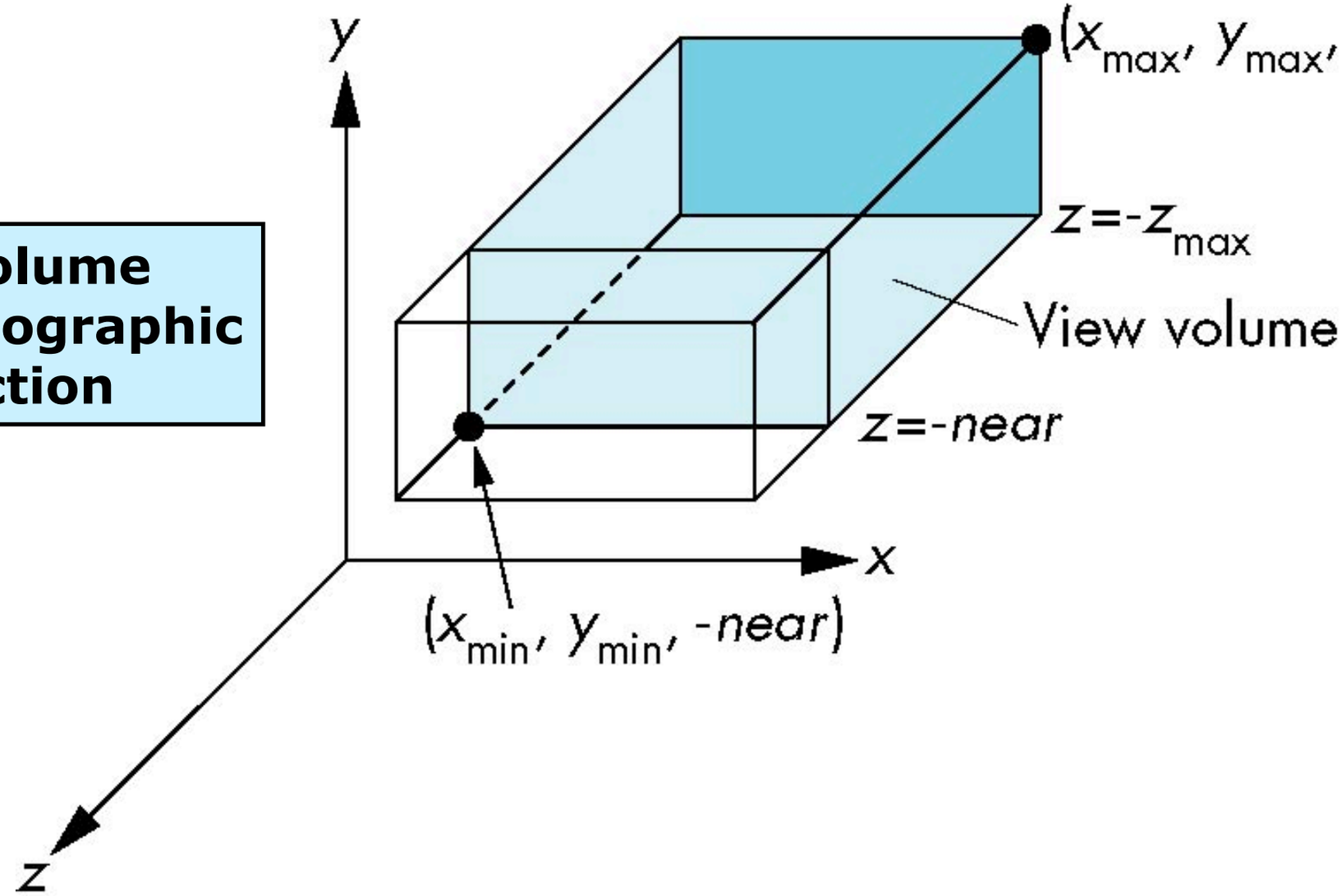
Orthographic projection



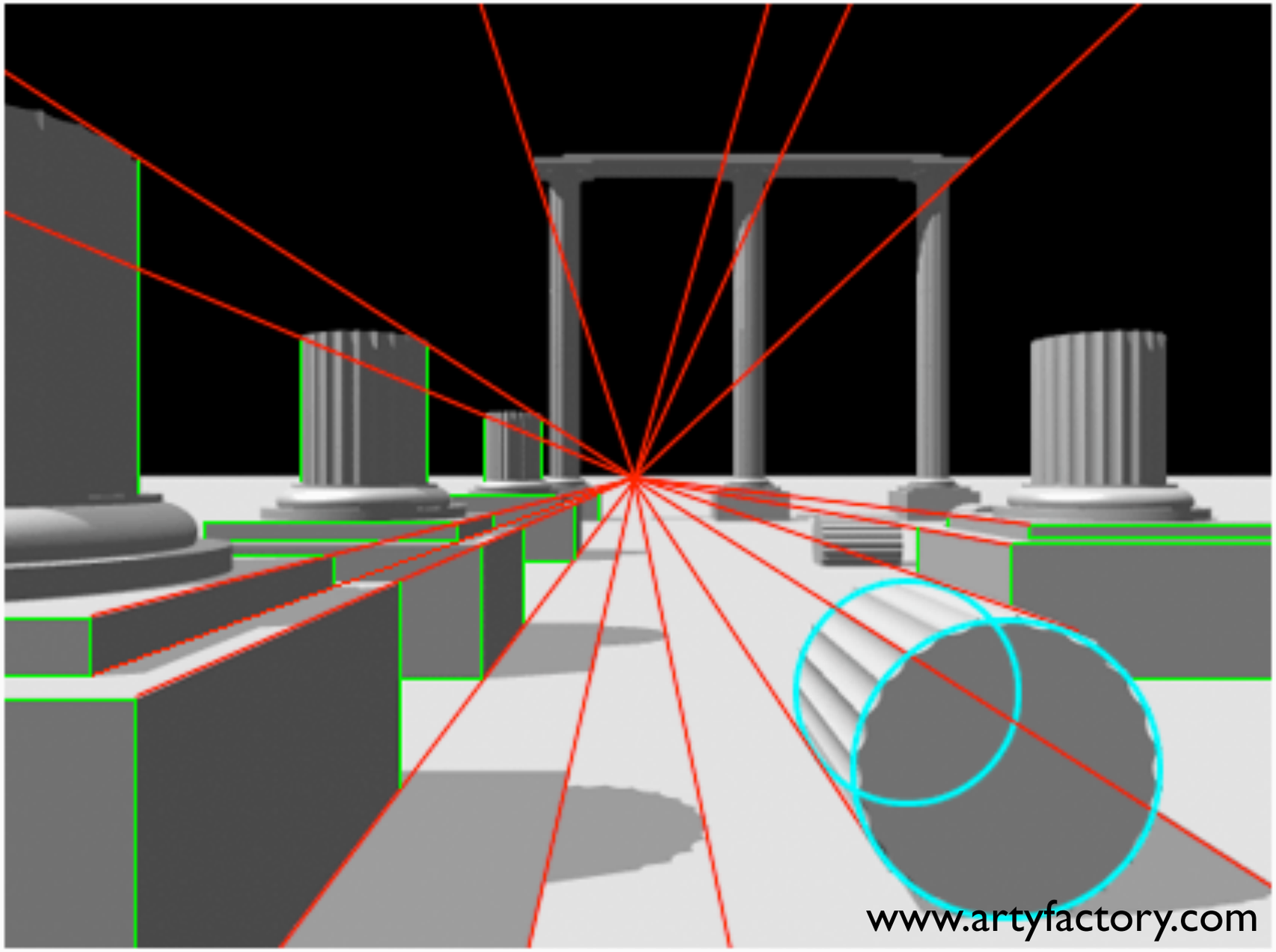
OpenGL Orthogonal Viewing

```
glOrtho(left,right,bottom,top,near,far)
```

View volume for an orthographic projection



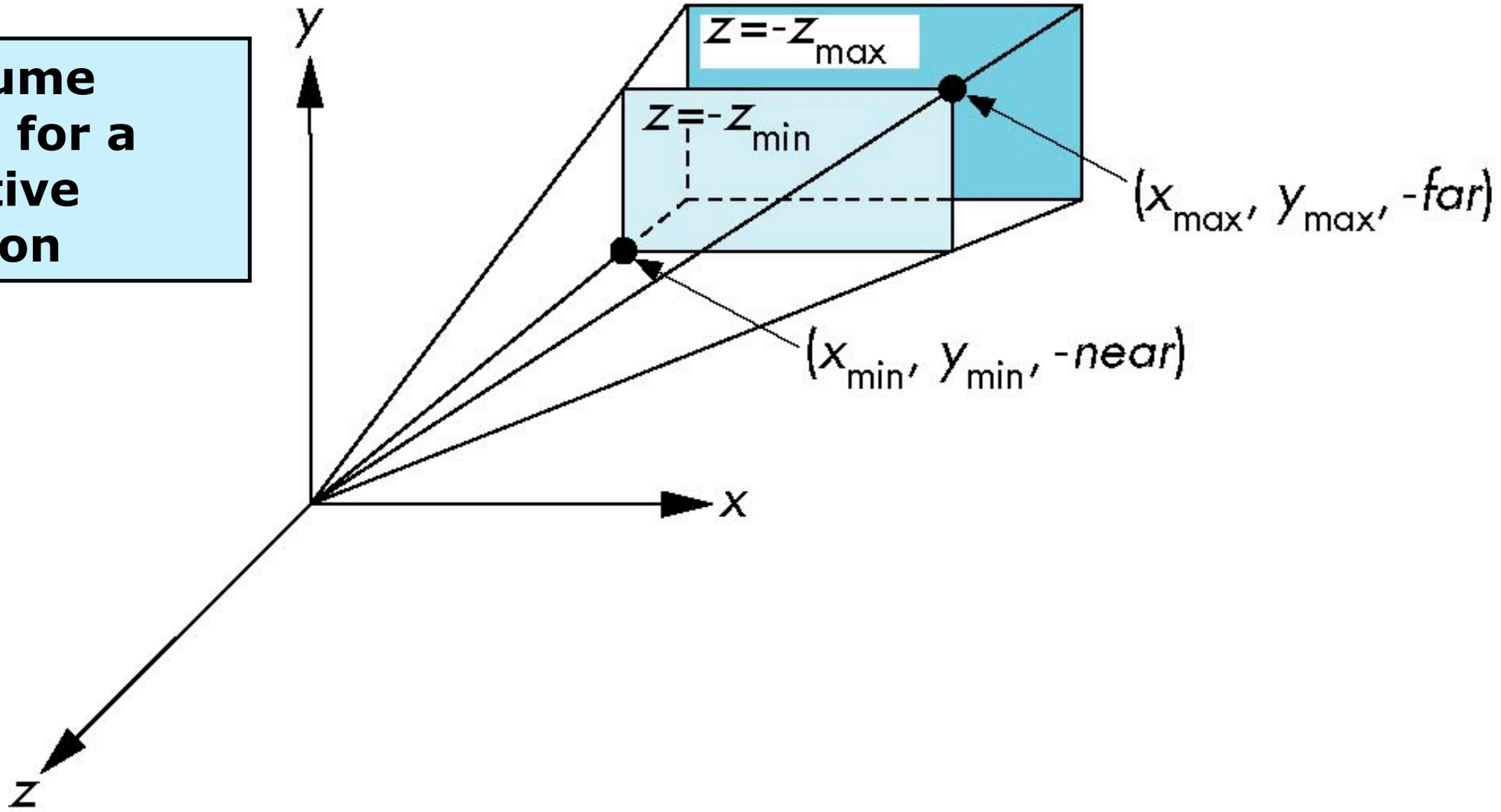
Perspective projection



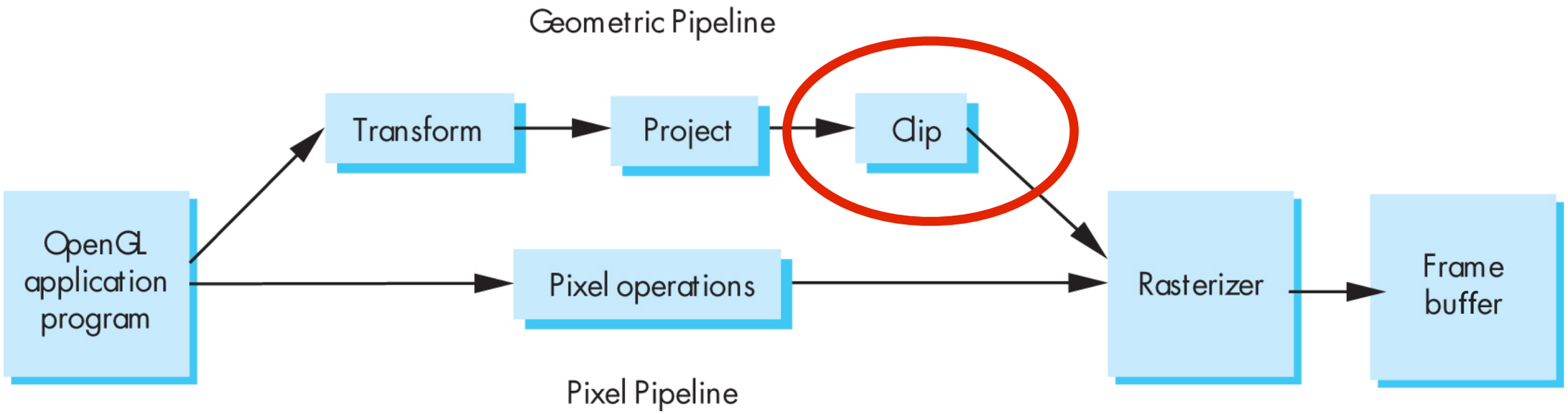
OpenGL Perspective Viewing

`glFrustum(xmin,xmax,ymin,ymax,near,far)`

View volume (frustrum) for a perspective projection



Clip


Geometric Pipeline
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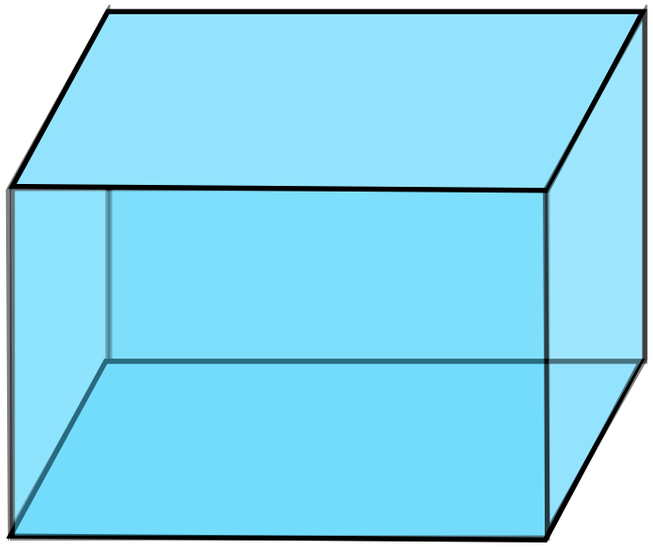
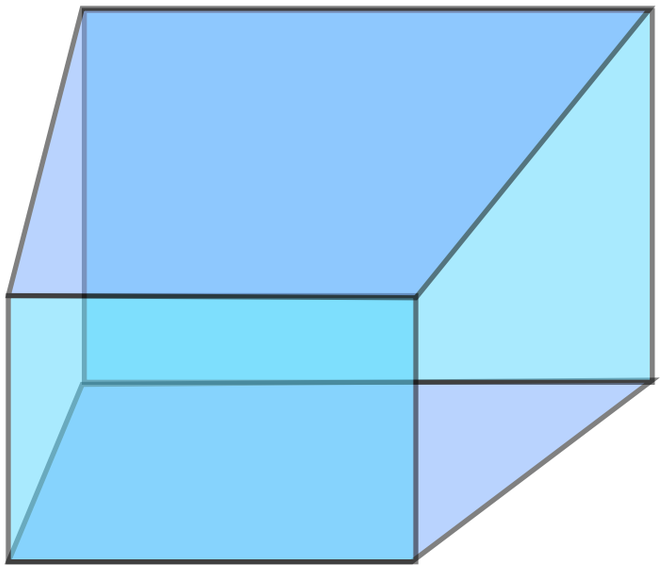
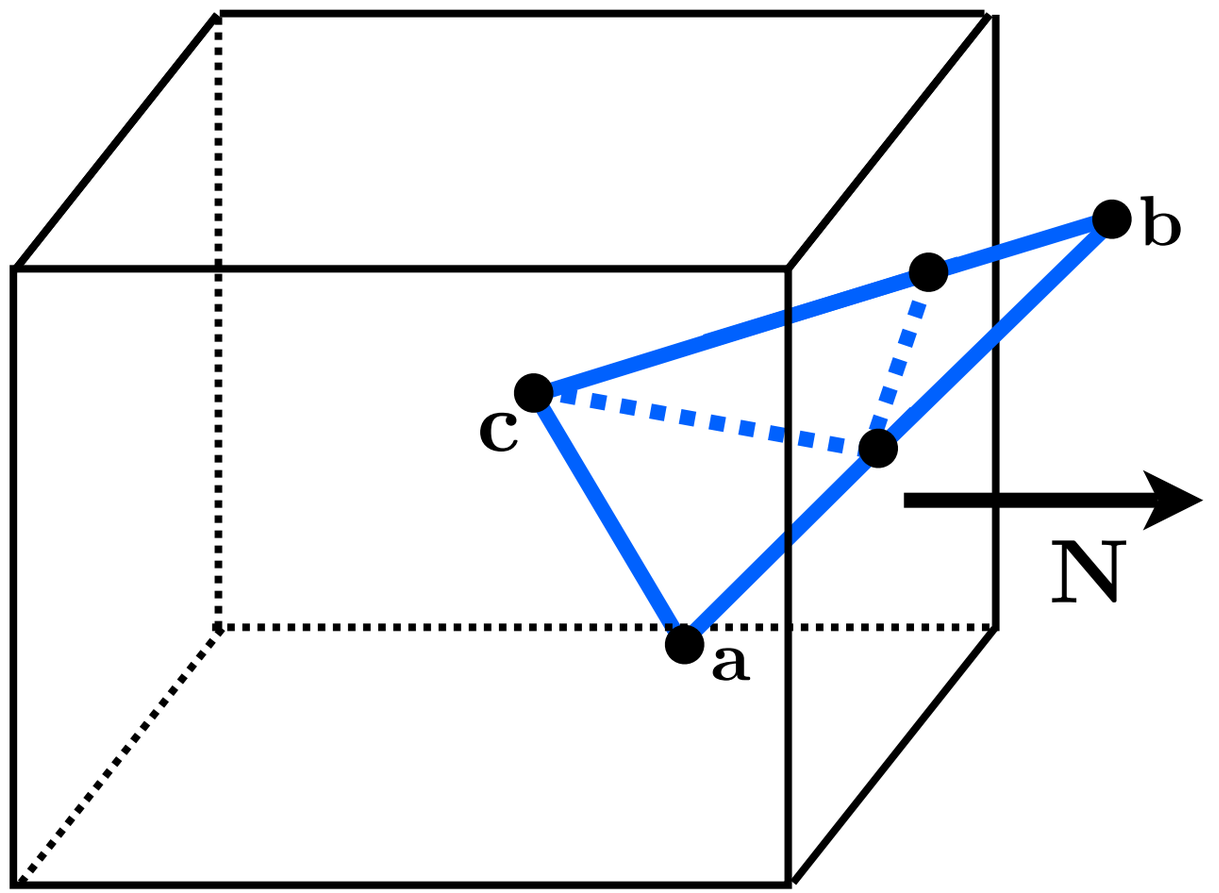
Clip against view volume

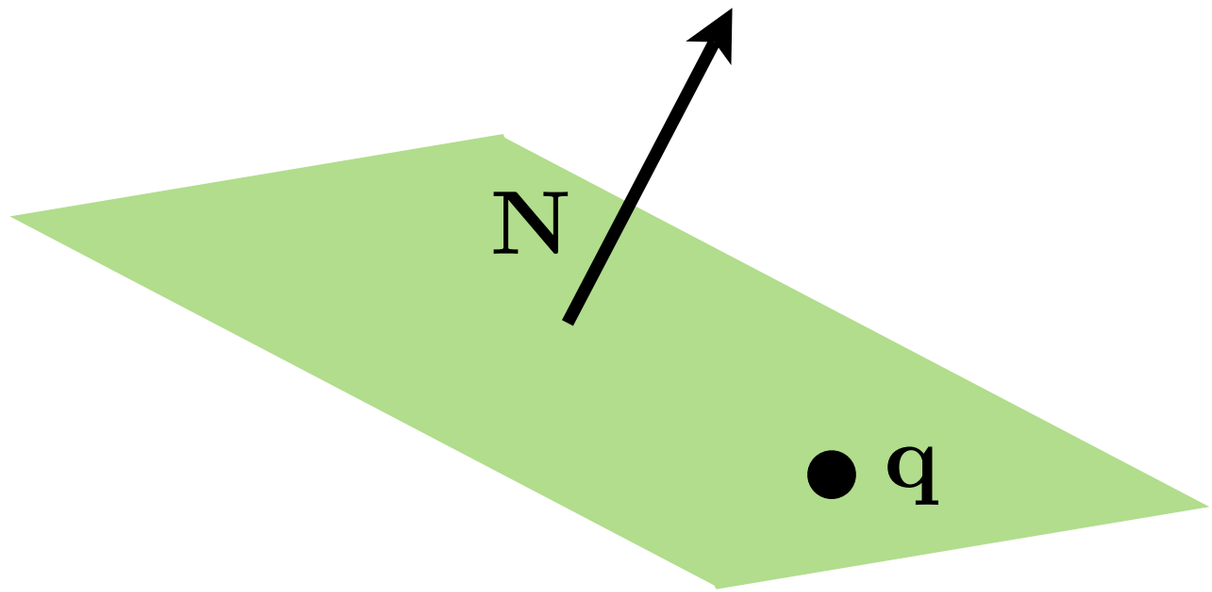


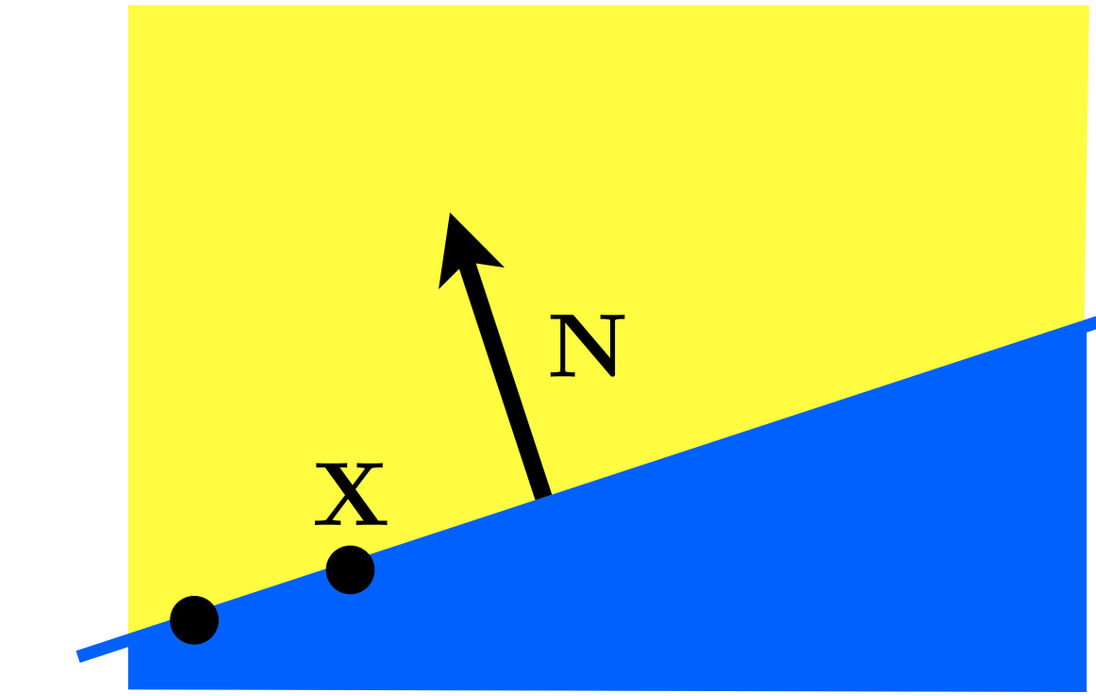




Clipping against a plane

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





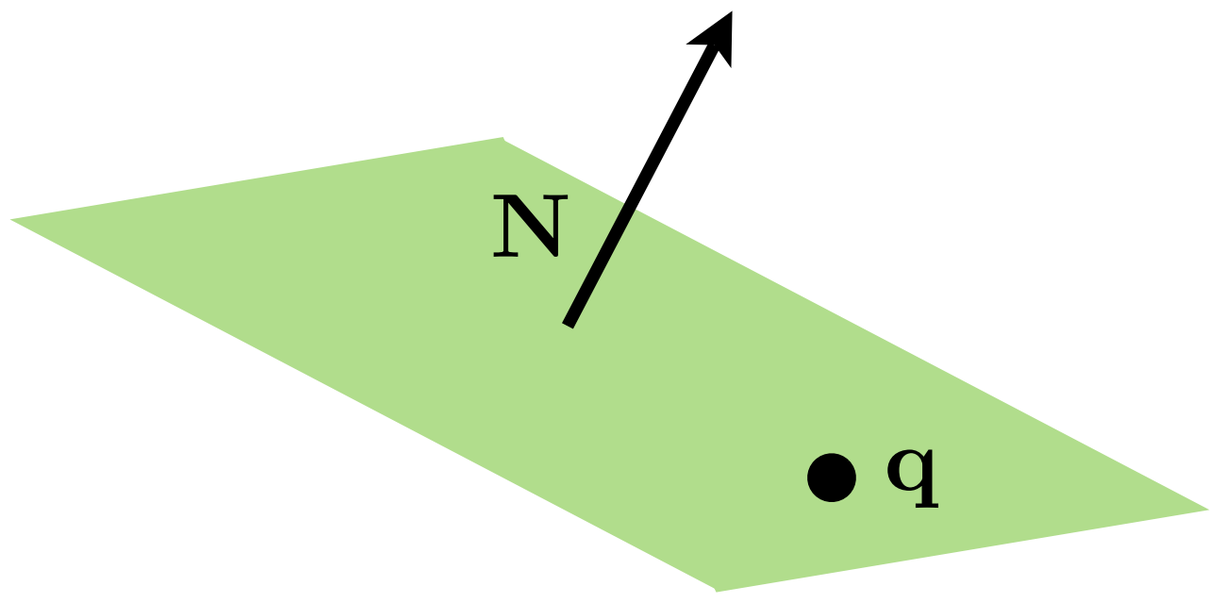
$\mathbf{X}_0 = (x_0, y_0)$

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**?

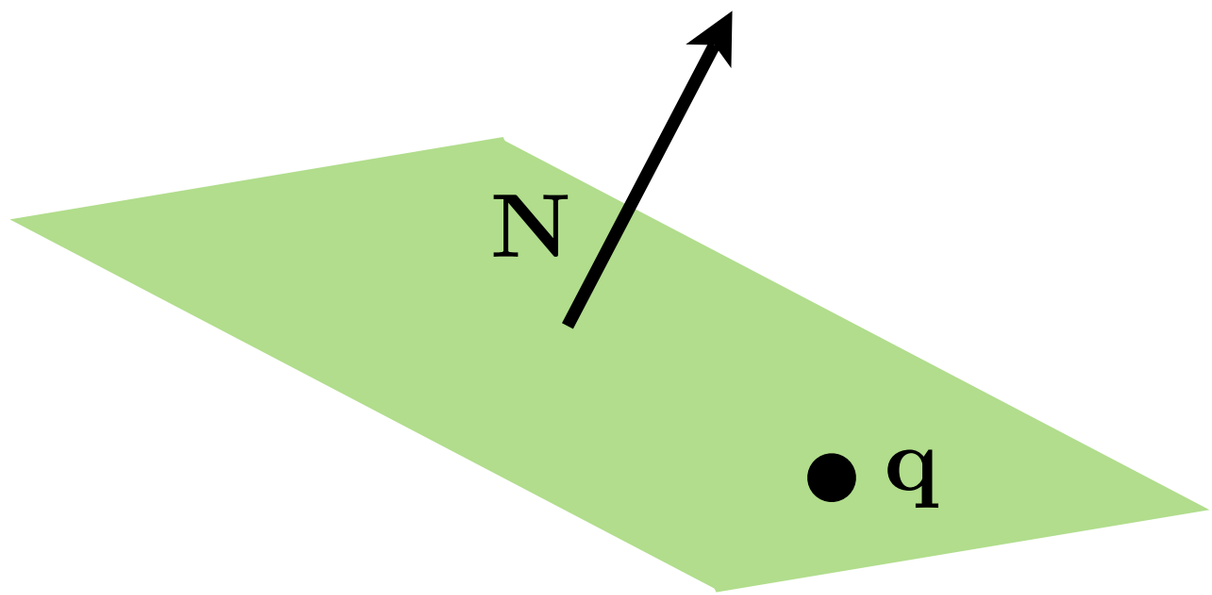


$$f(\mathbf{p}) =? = 0$$

<whiteboard>

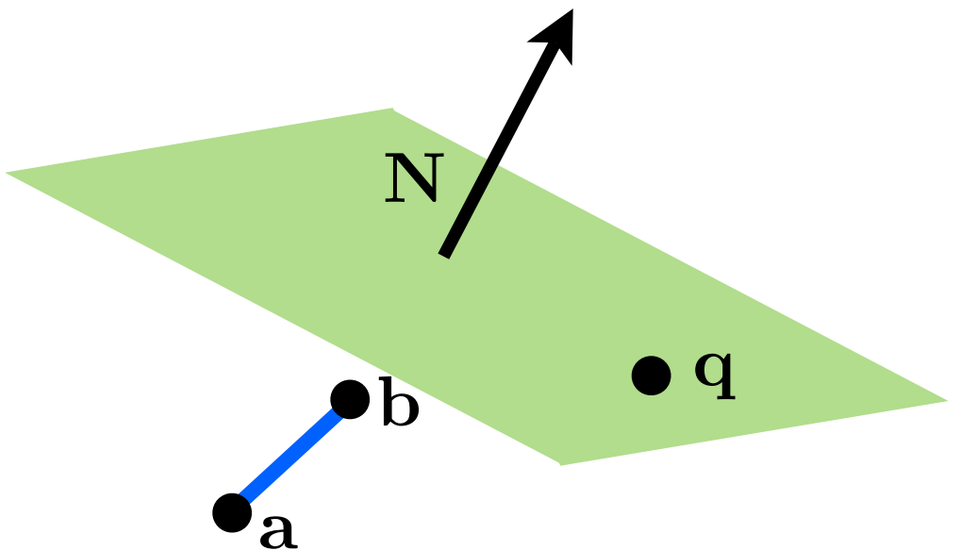
Clipping against a plane

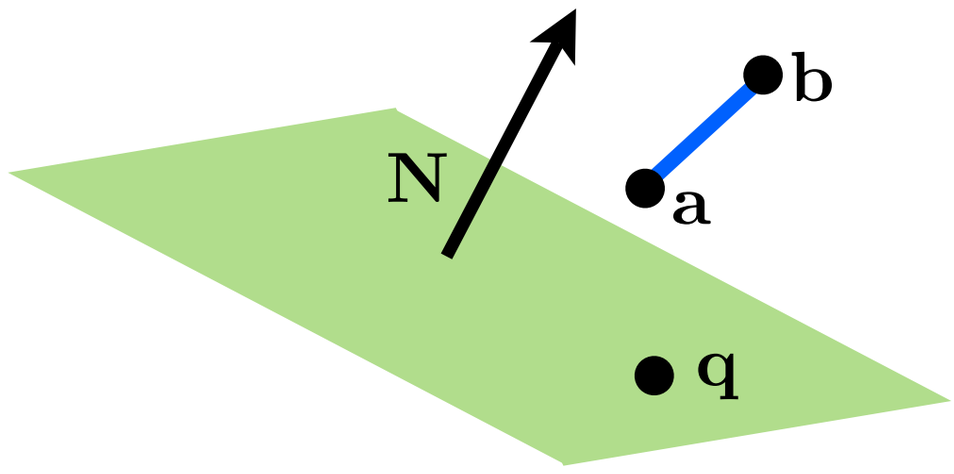
What's the equation for the plane through **q** with normal **N**?



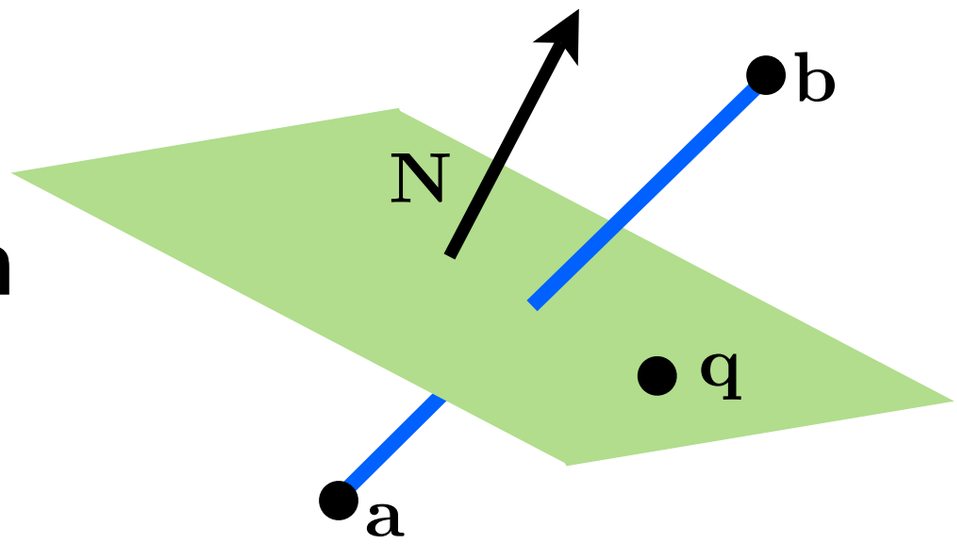
$$f(\mathbf{p}) = \mathbf{N} \cdot (\mathbf{p} - \mathbf{q}) = 0$$

Intersection of line and plane



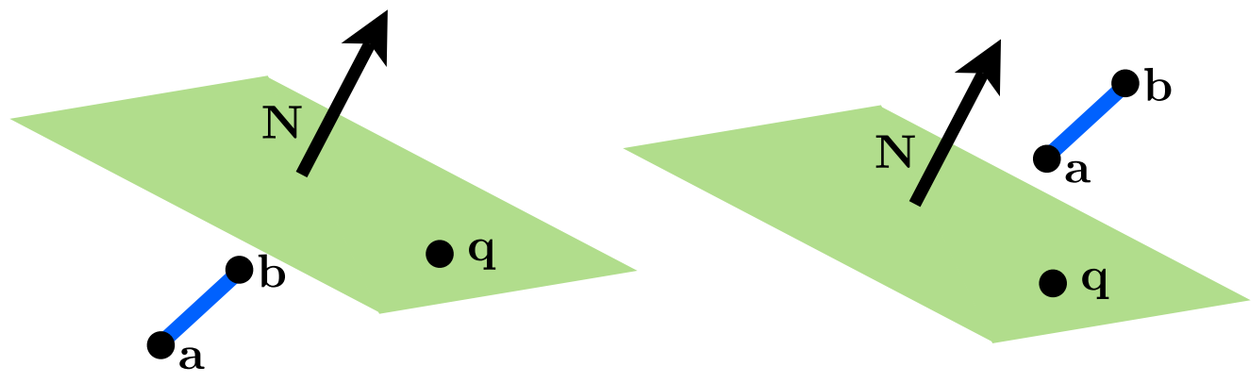


How can we distinguish between these cases?

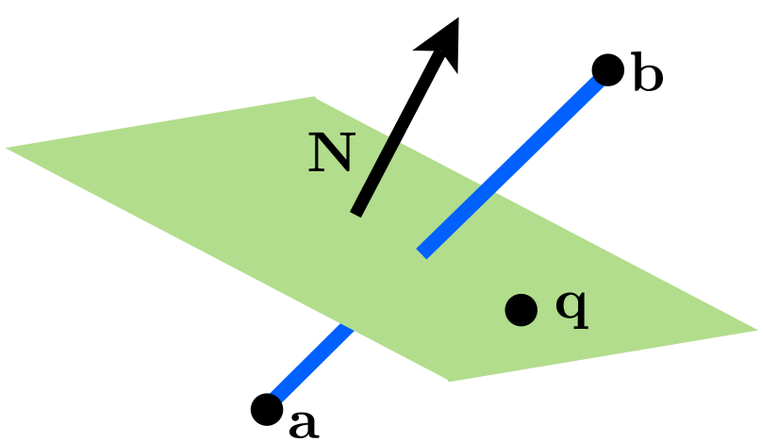


Intersection of line and plane

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

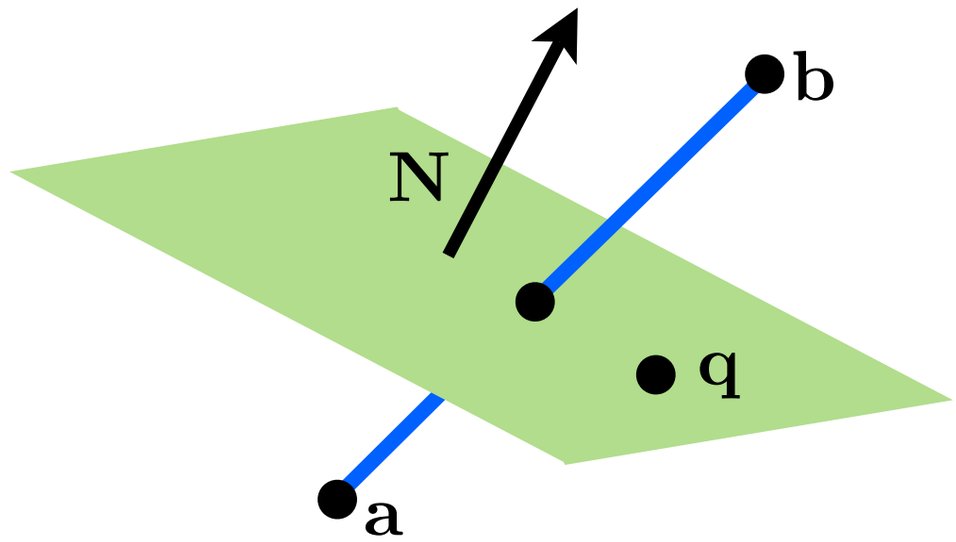


$$f(\mathbf{a})f(\mathbf{b}) < 0$$



Intersection of line and plane

How can we find the intersection point?



<whiteboard>

Clip against view volume

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

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

need to generate new triangles