Computer Graphics (CS 4731)
Clipping and Culling

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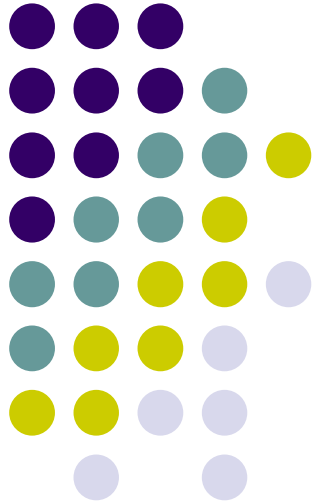
Worcester Polytechnic Institute (WPI)

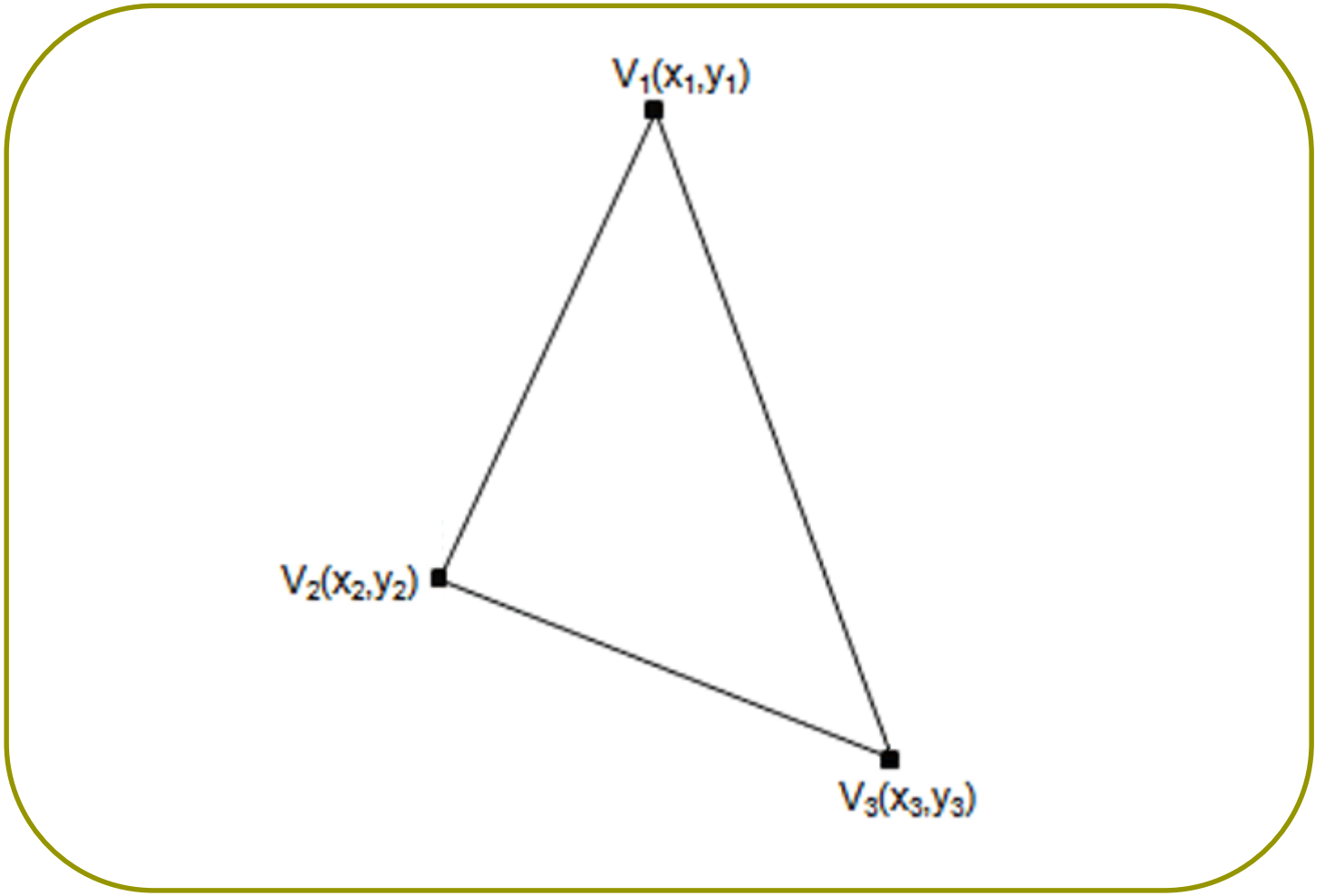


Slides Courtesy of Emmanuel Agu (WPI) and Matt Stoker (Utah)

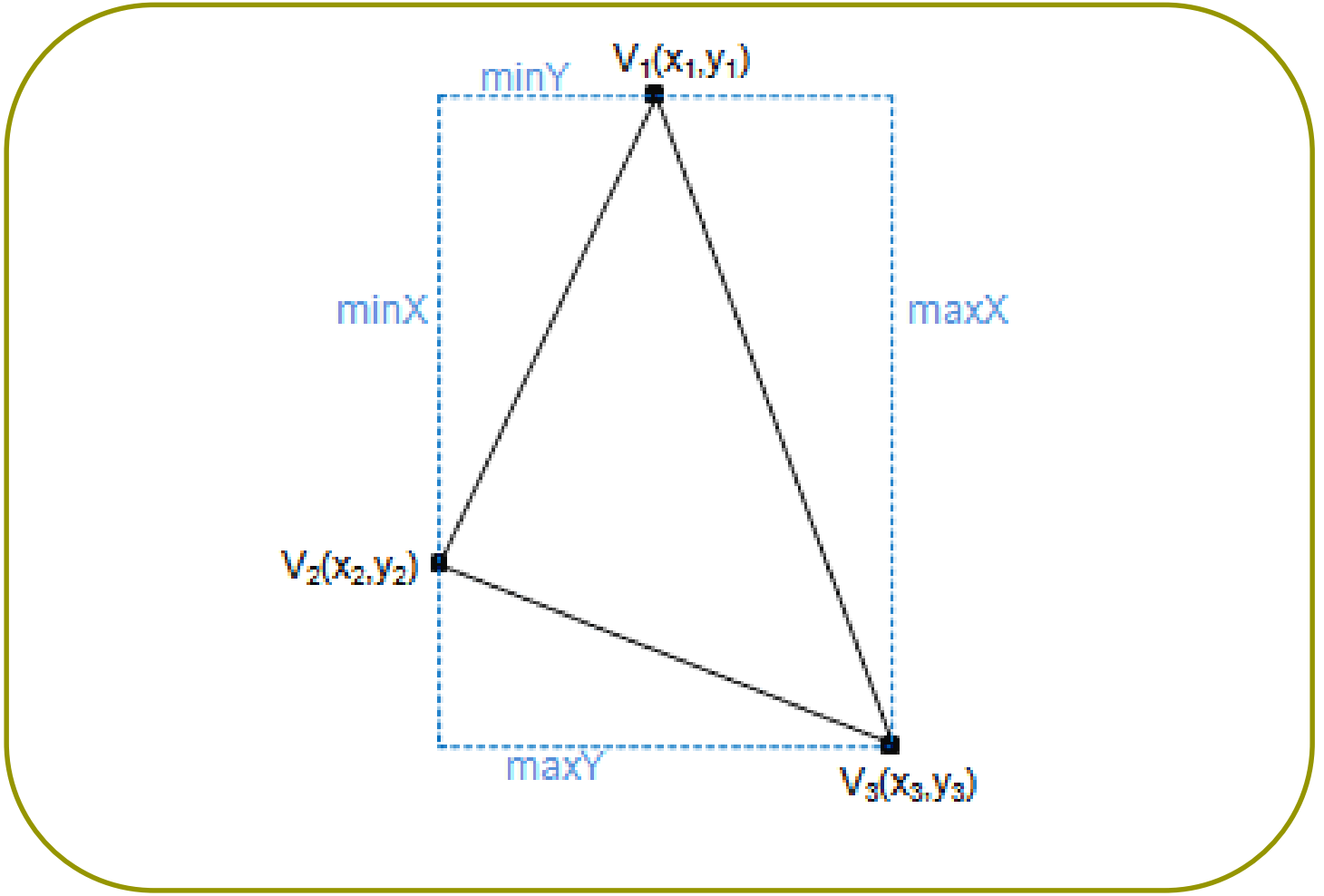
Think-Pair-Share

What's the problem and how can we improve it?

Screen



Bounding Boxes!



Cull (verb)

to reduce or control the size of by removal

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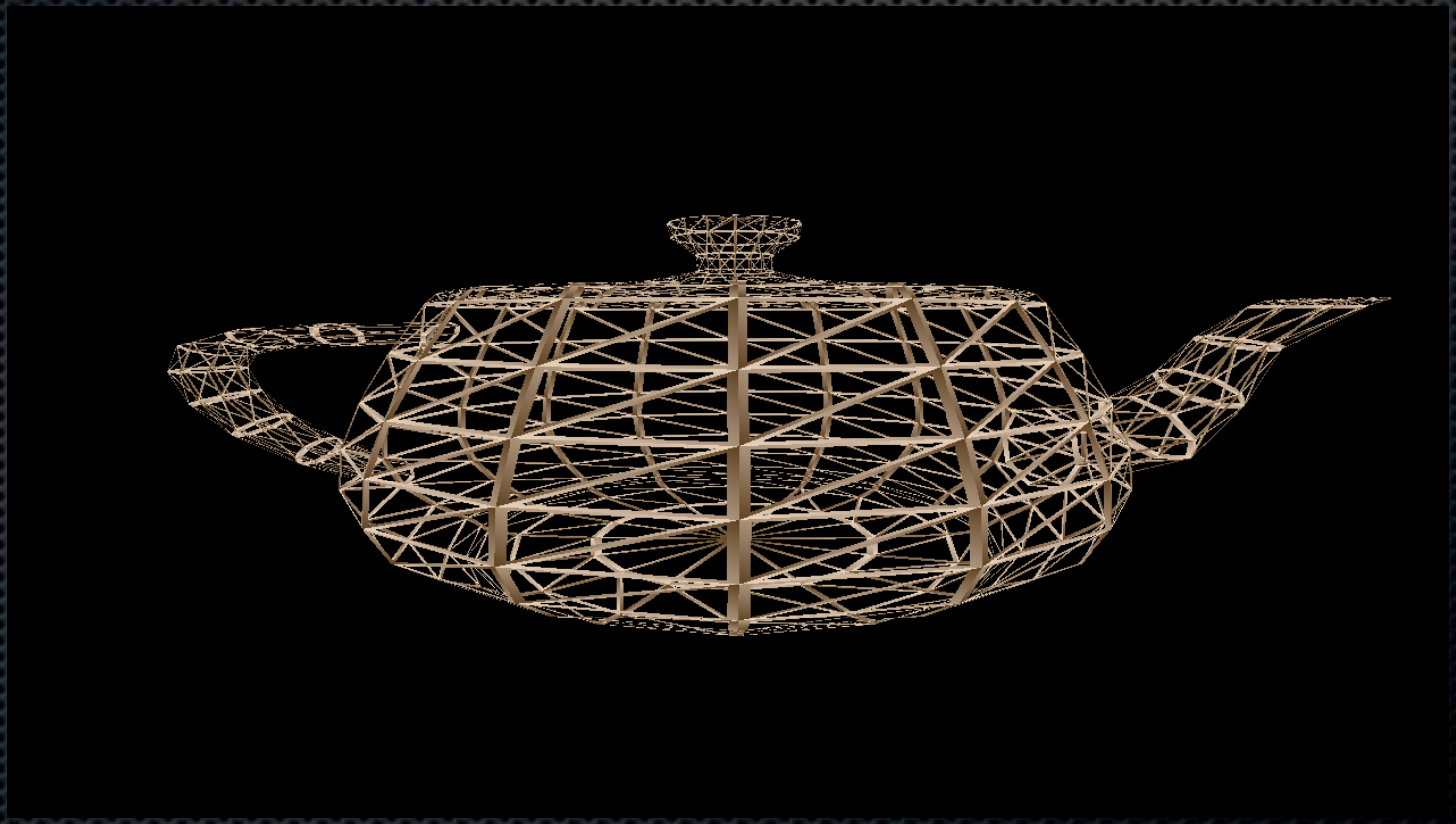

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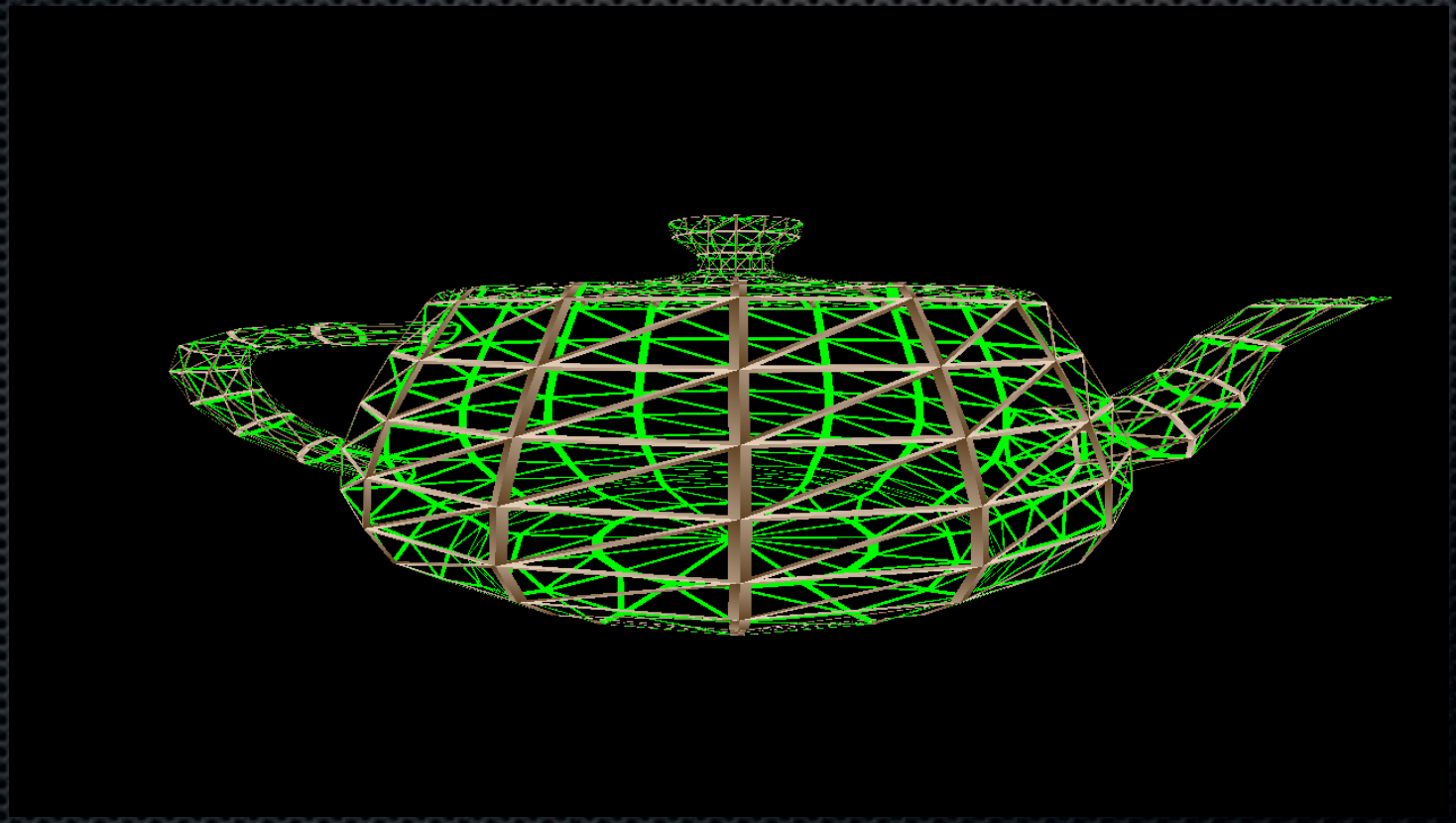
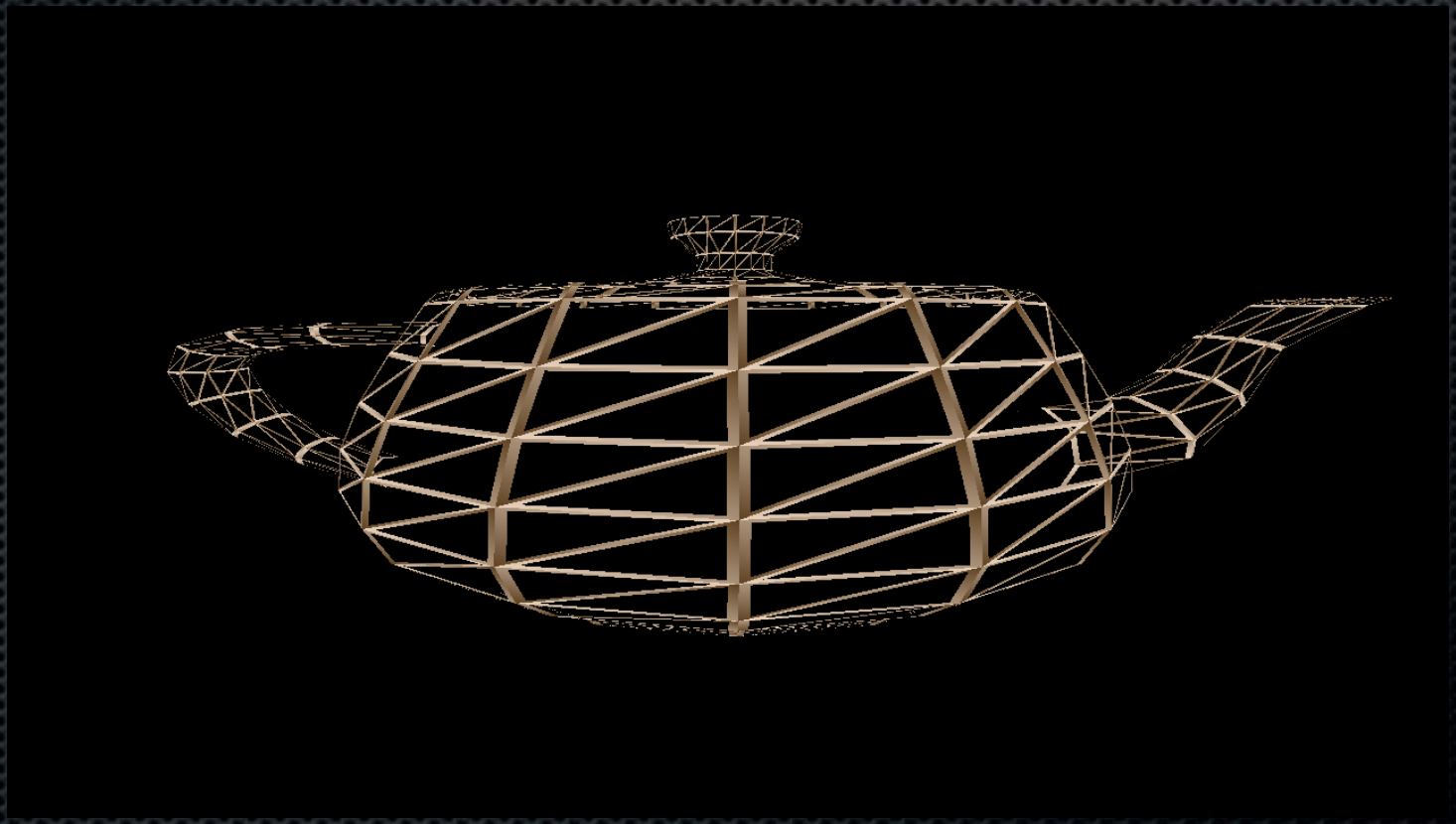


Back-Face Culling

Drew 37% (382 of 1024) of triangles in scene

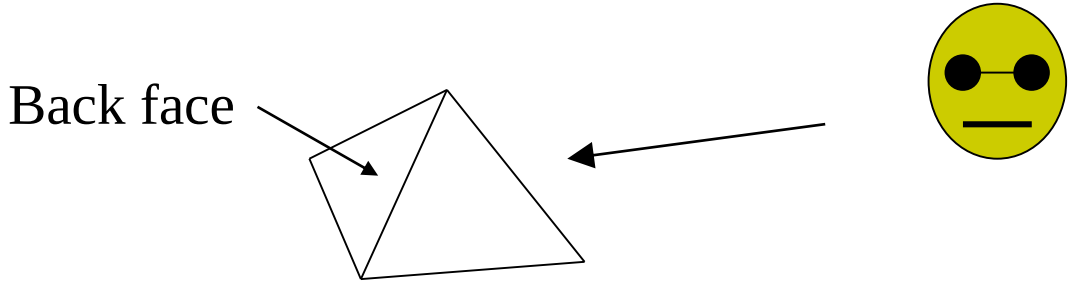


Back-Face Culling

Drew 37% (382 of 1024) of triangles in scene

Back Face Culling

- **Back faces:** faces of opaque object that are “pointing away” from viewer
- **Back face culling:** do not draw back faces (saves resources)

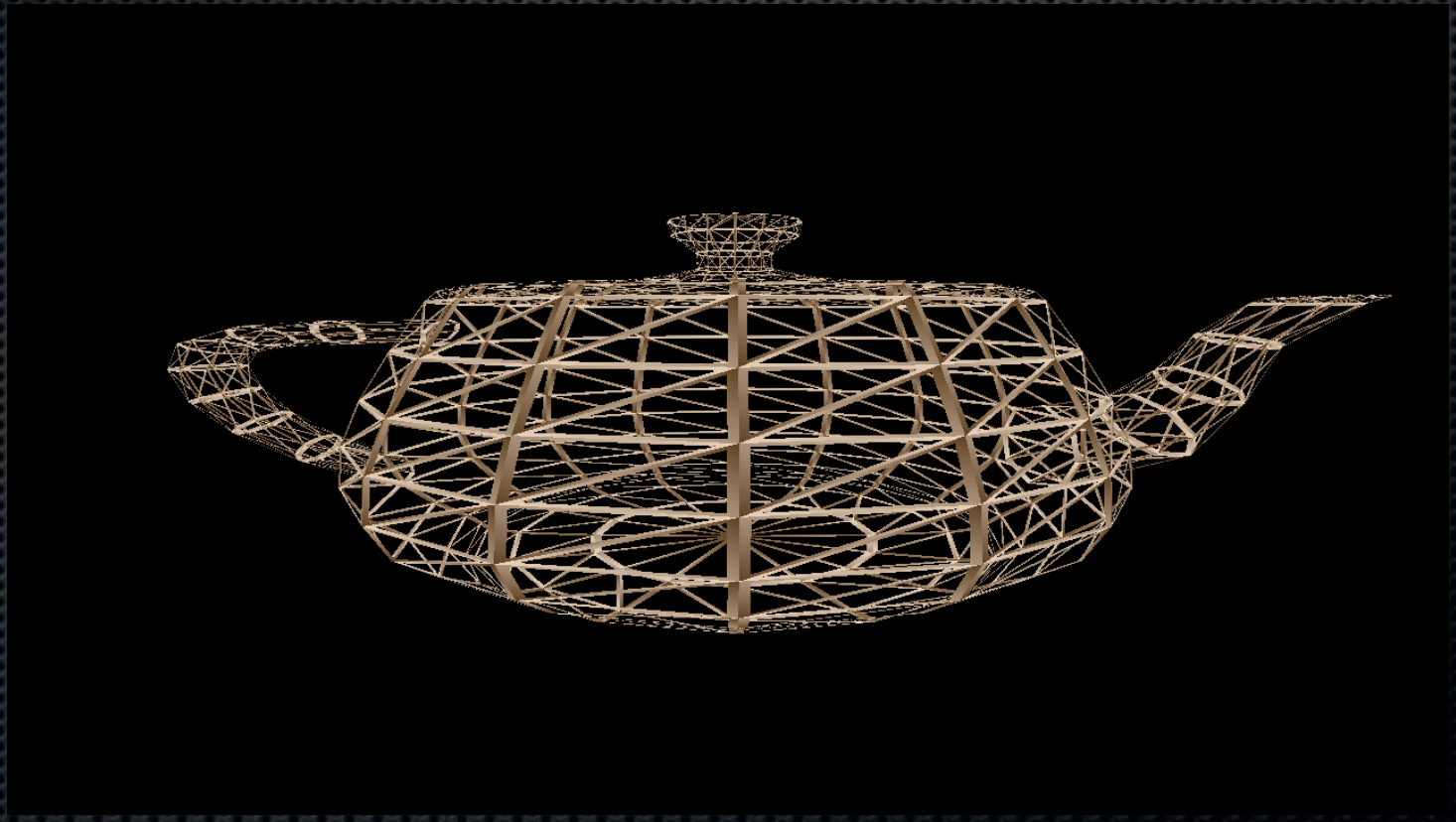


Back-Face Culling

Which triangles are back-facing?

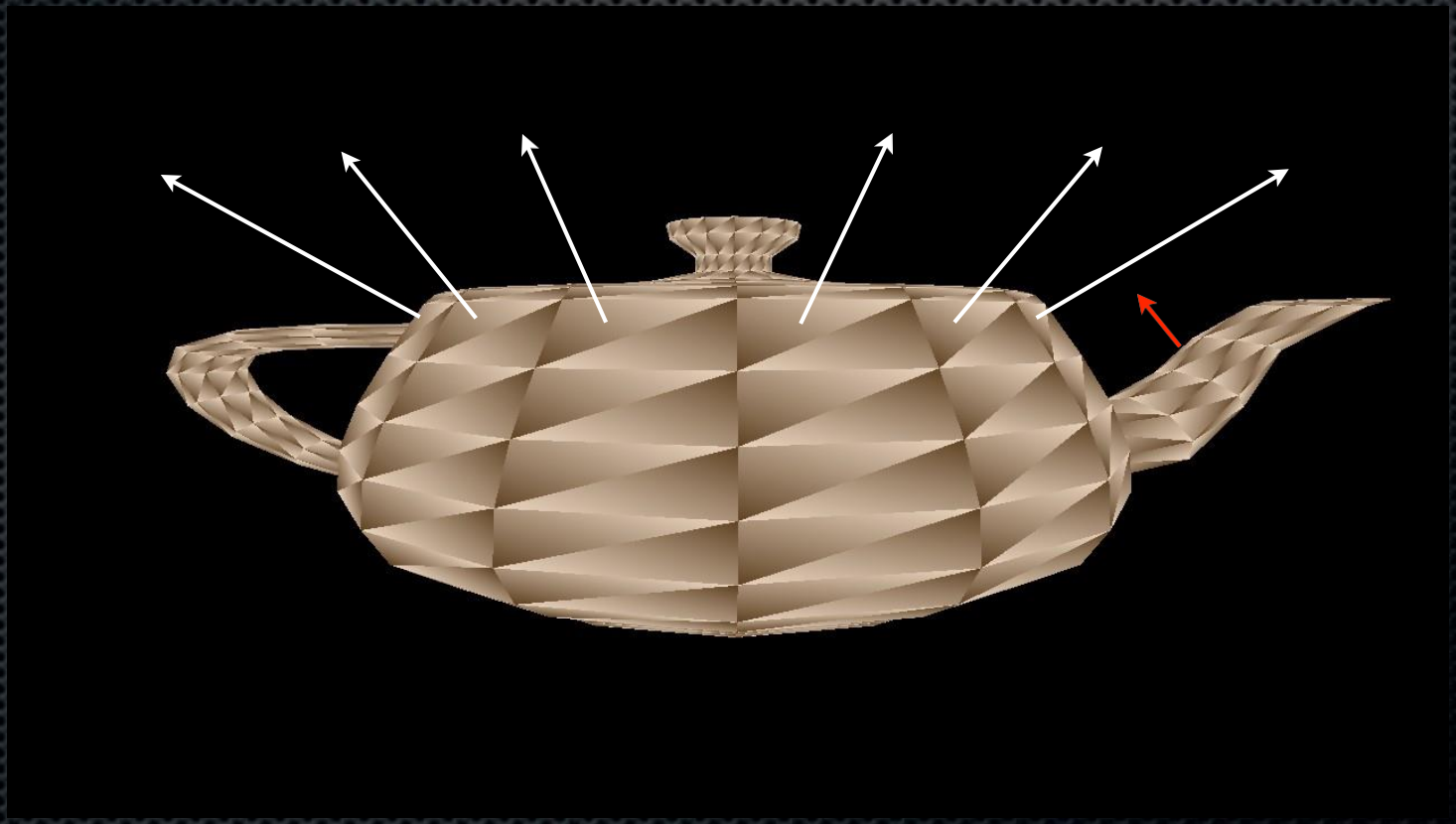
Think-Pair-Share

How can we determine which triangles are back-facing?



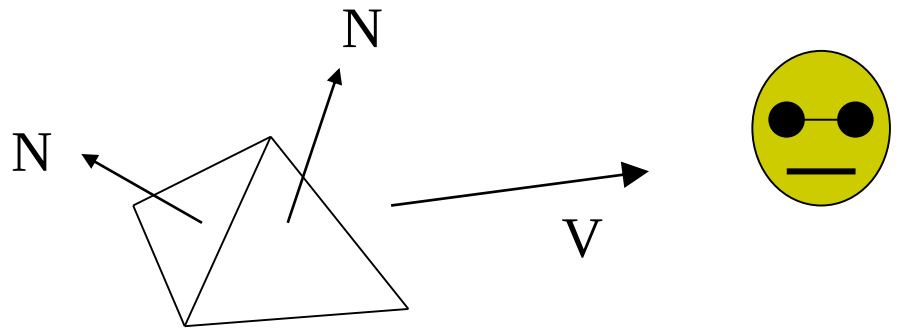
Back-Face Culling

Triangle normal of back-facing triangles points “away”



Back Face Culling

- Goal: Test if a face F is is backface
- How? Form vectors
  - View vector, V
  - Normal N to face F



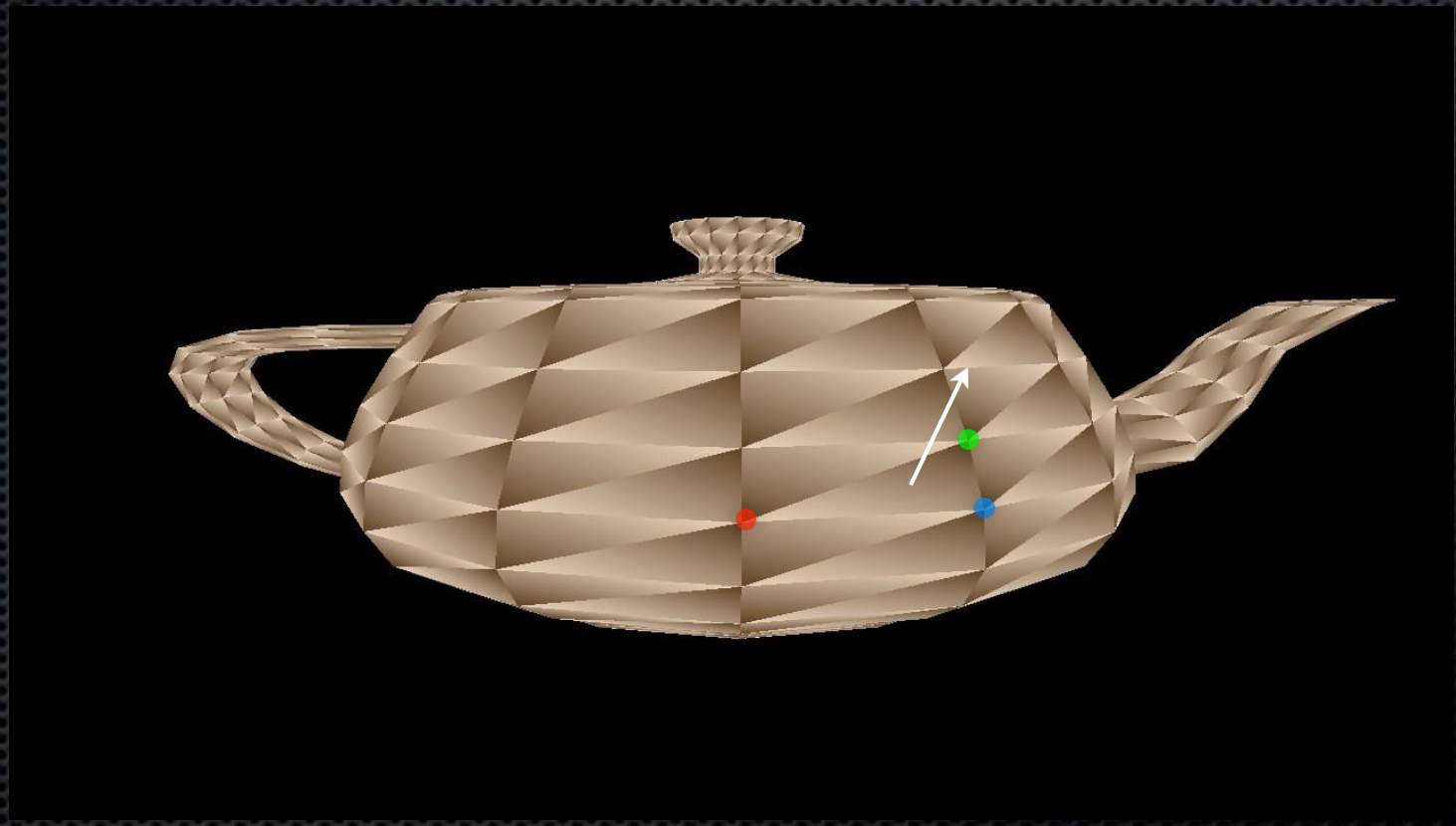
Backface test: F is backface if N.V < 0 why??

Back-Face Culling

What is the triangle's normal?

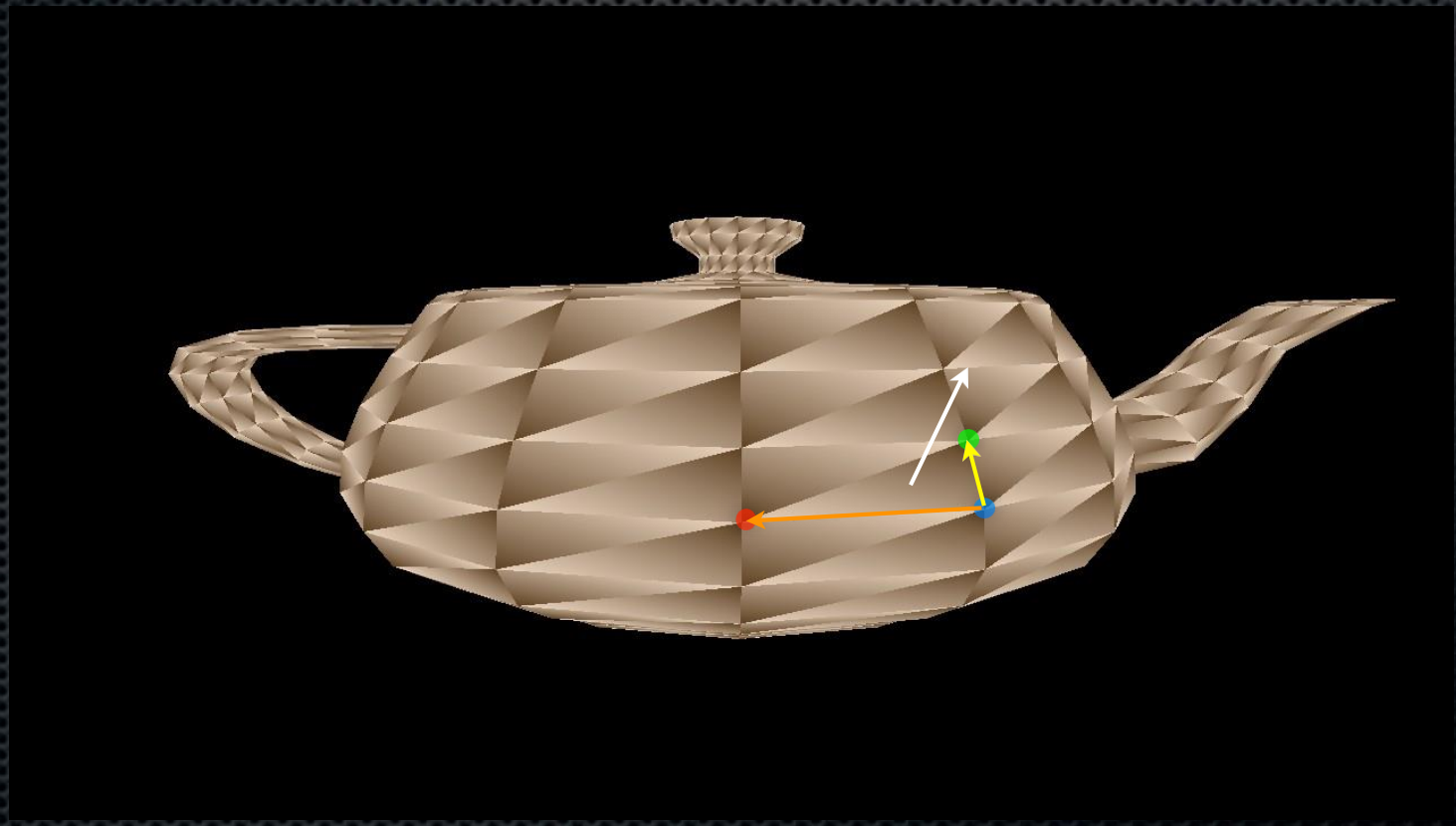
Back-Face Culling

A B C



Back-Face Culling

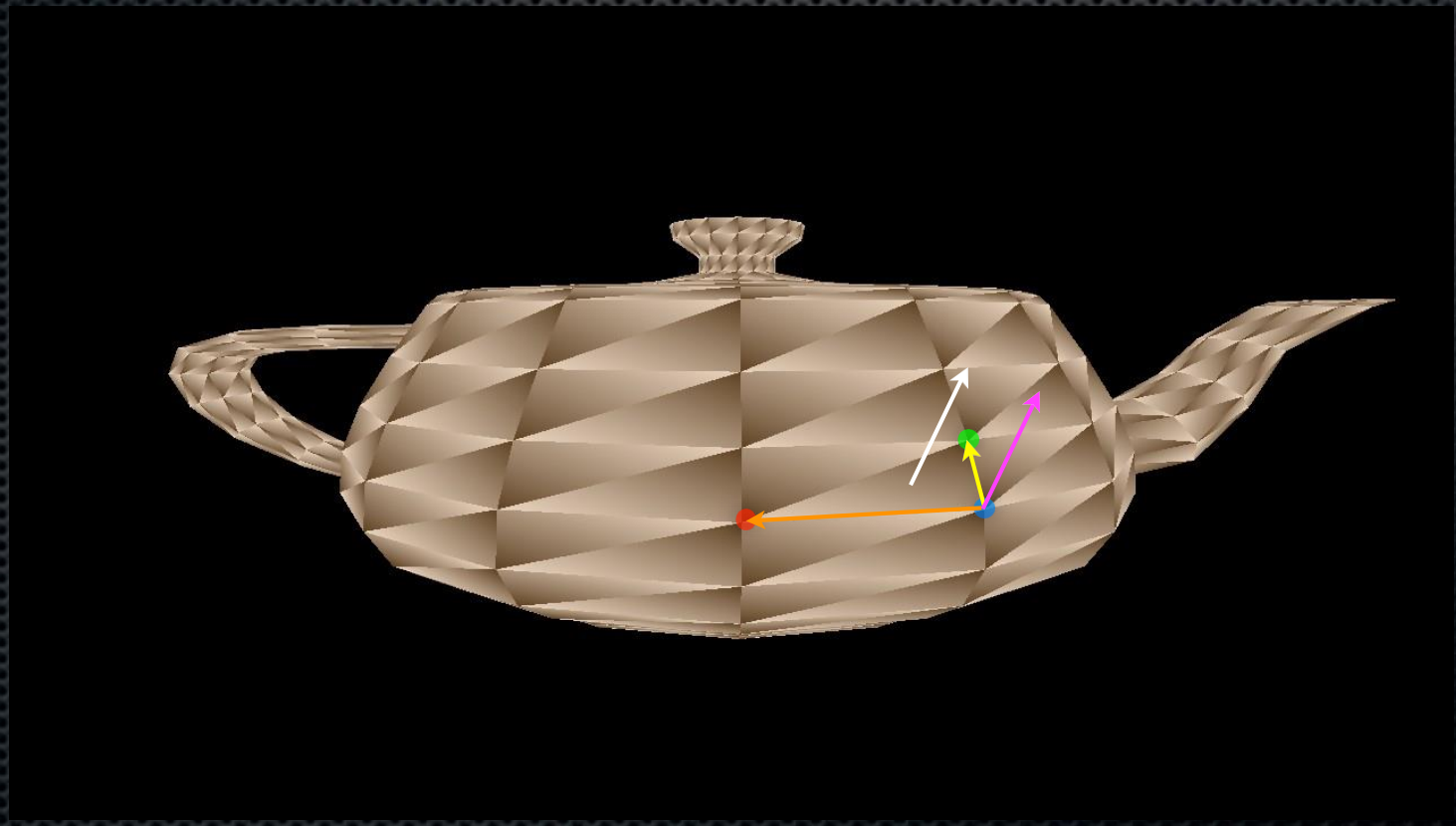
$v_0 = B - A \quad v_1 = C - A$



Back-Face Culling

$v_0 = B - A \quad v_1 = C - A$

$n = v_0 \times v_1$

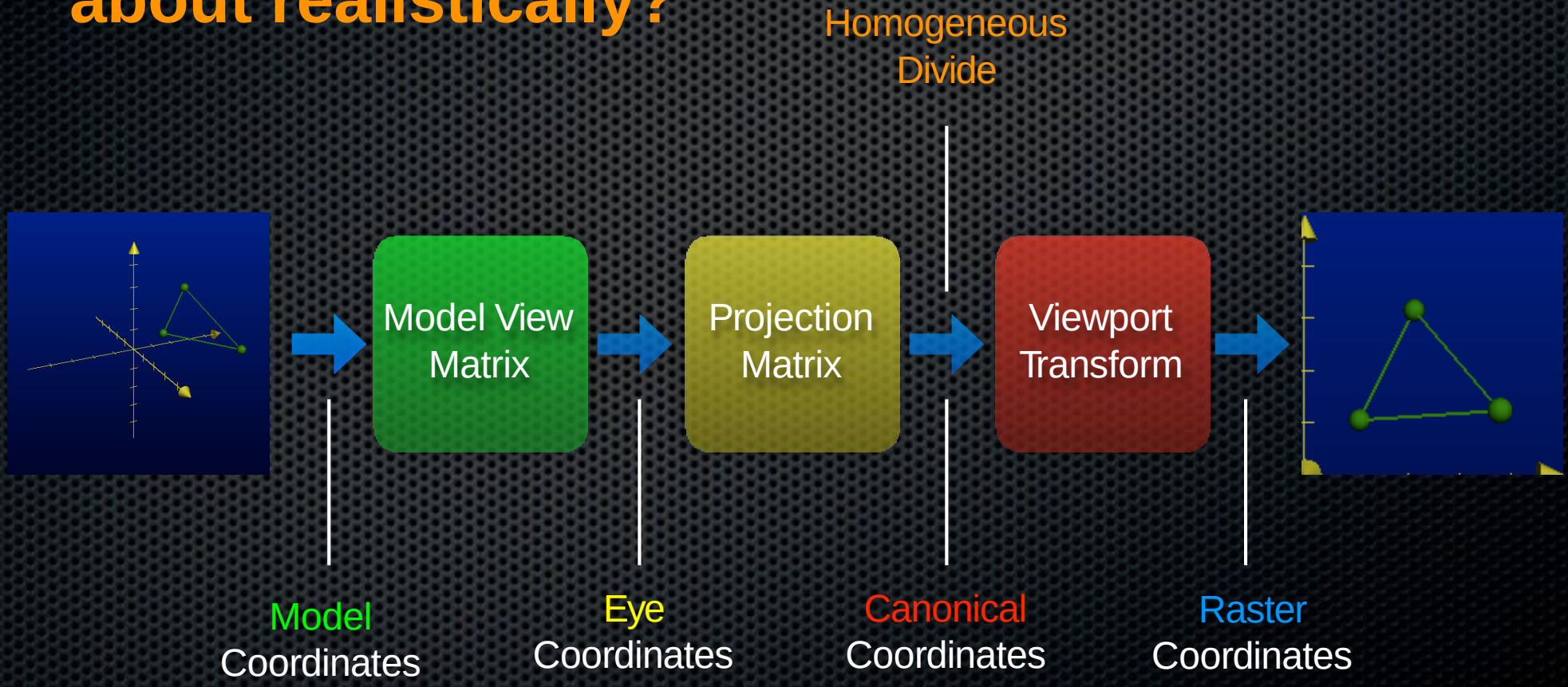


Back-Face Culling

- When to back-face cull?

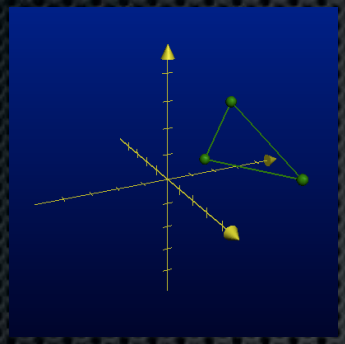
Think-Pair-Share

Ideally, where is the best place to cull? What about realistically?



Back-Face Culling

if (n.z < 0)
cull

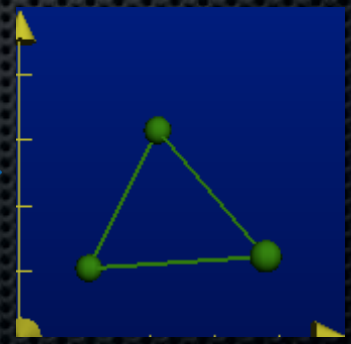


Model View Matrix

Projection Matrix

Homogeneous Divide

Viewport Transform



Model Coordinates

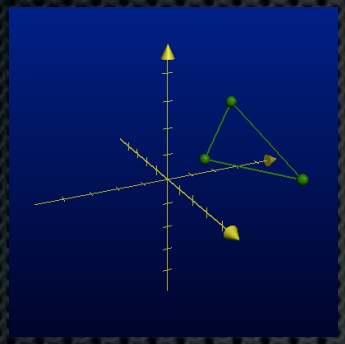
Eye Coordinates

Canonical Coordinates

Raster Coordinates

Back-Face Culling

if (n.z < 0)
cull



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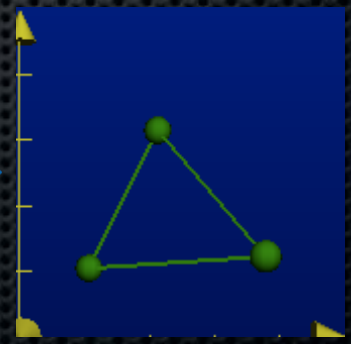

Model Coordinates

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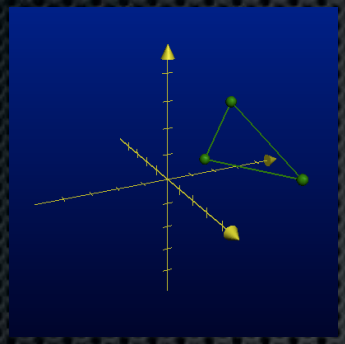
Back-Face Culling

if ($n \bullet (t_{center} - origin) > 0$)
cull



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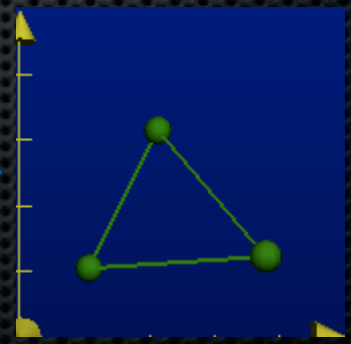

Model Coordinates

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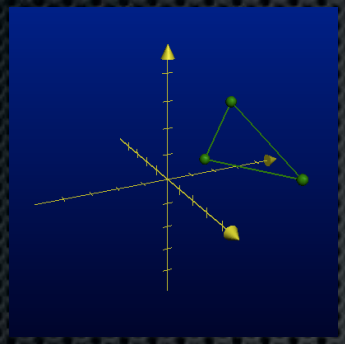
Raster Coordinates

Back-Face Culling

transform eye to model coordinates

if $(n \bullet (t_{center} - eye) > 0)$
  cull



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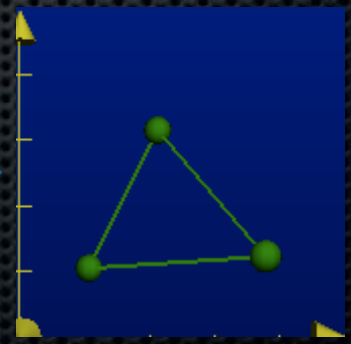

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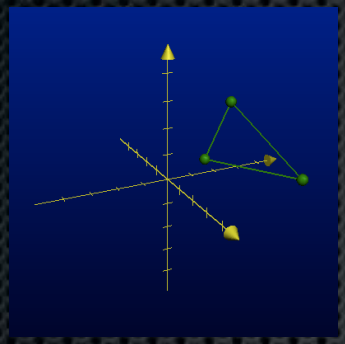

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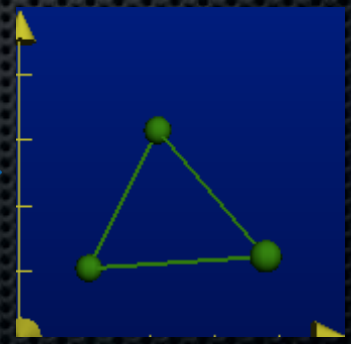

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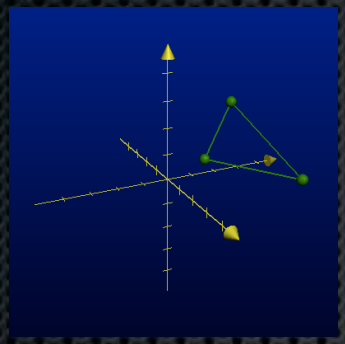

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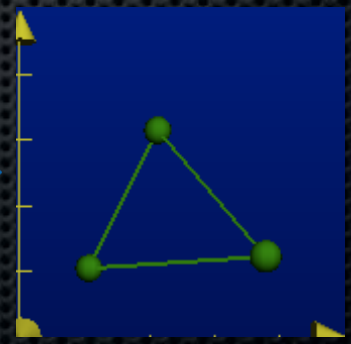

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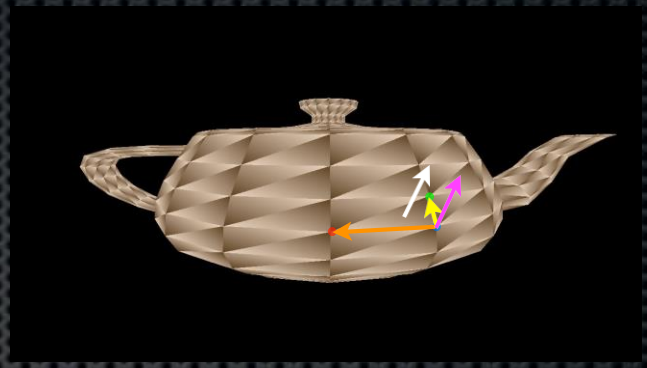
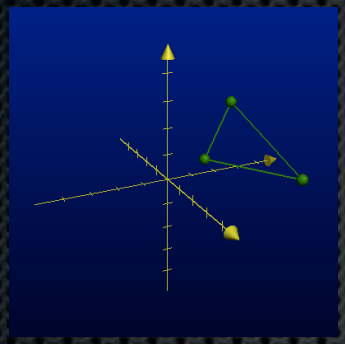


if ($n \bullet t_a > 0$)
cull

Homogeneous Divide



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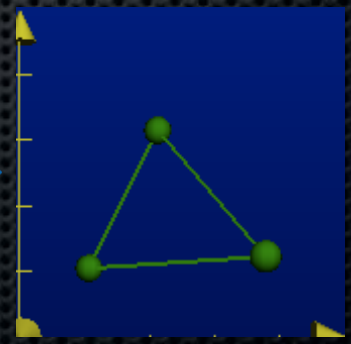


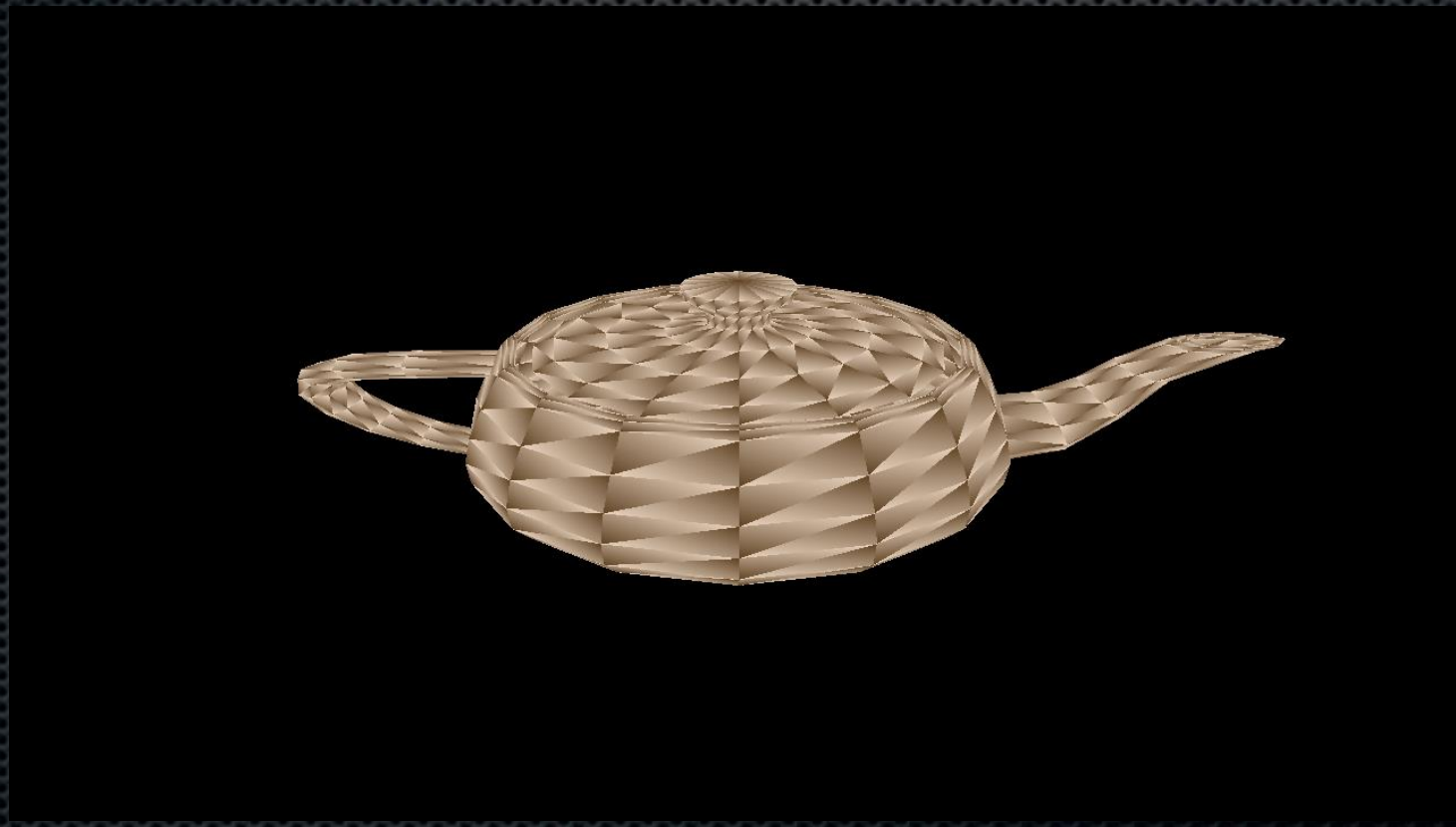
Model Coordinates

Eye Coordinates

Canonical Coordinates

Raster Coordinates

Back-Face Culling Issues



Back-Face Culling Issues

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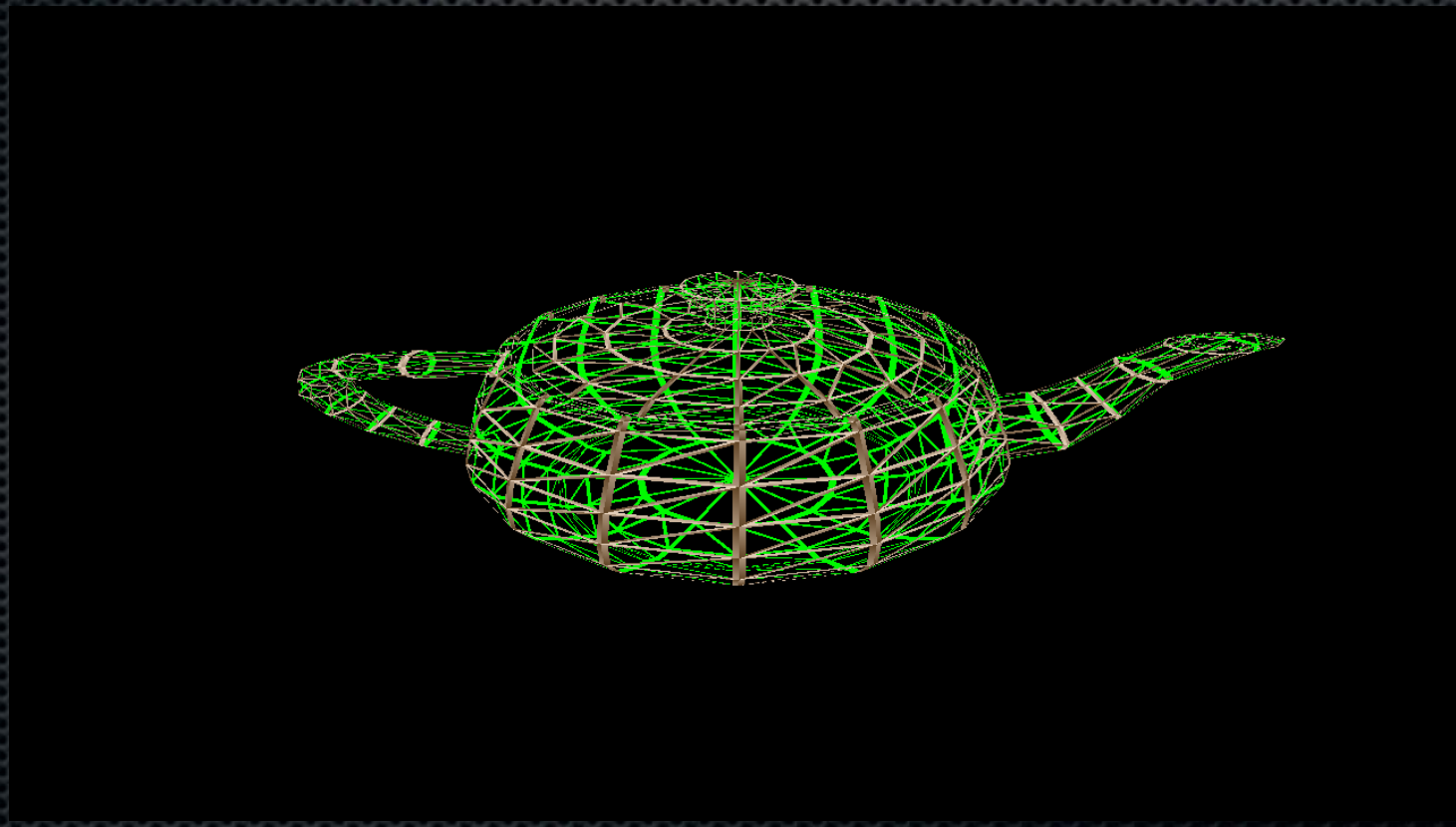
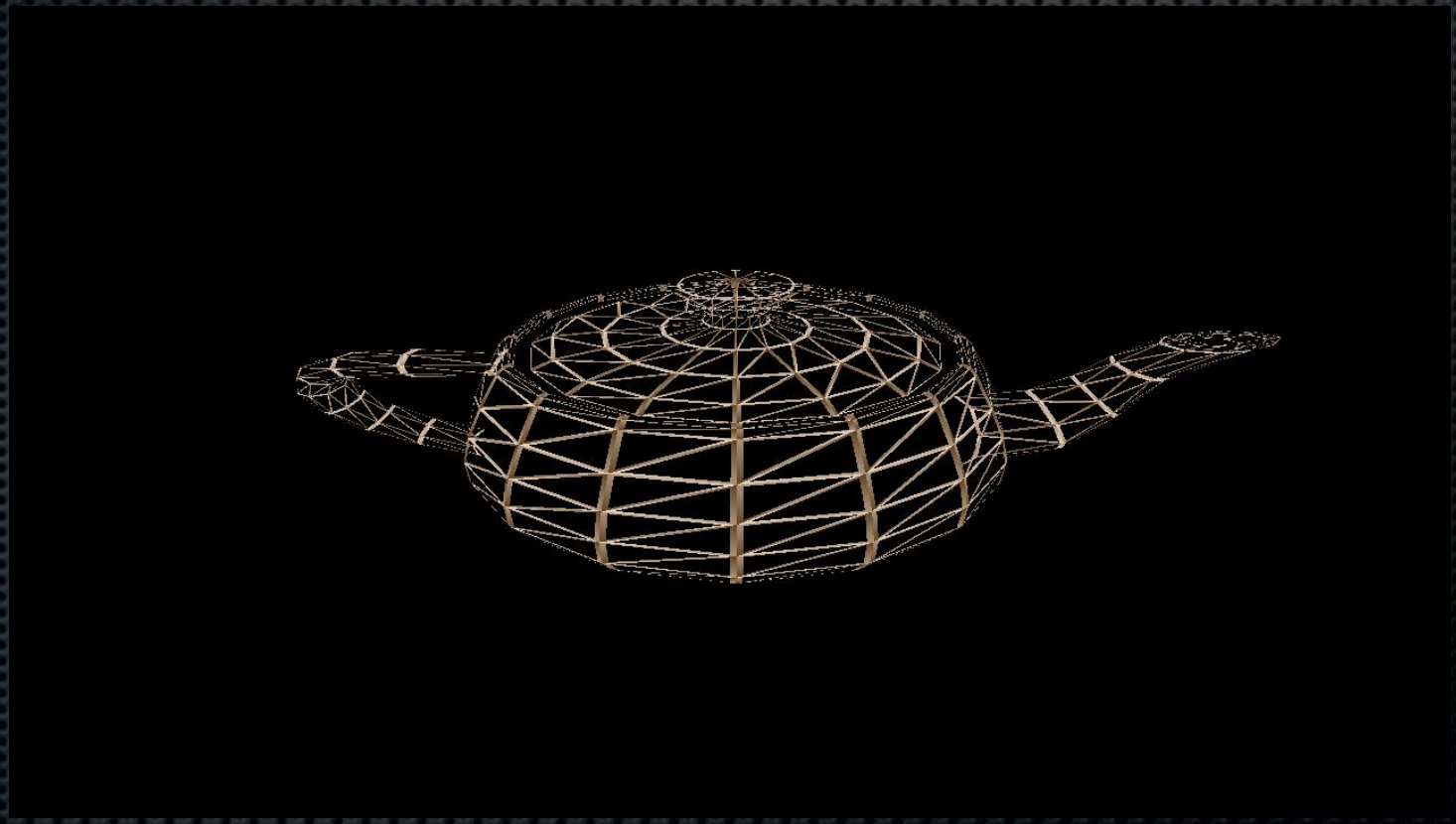


Back-Face Culling Issues

Think-Pair-Share

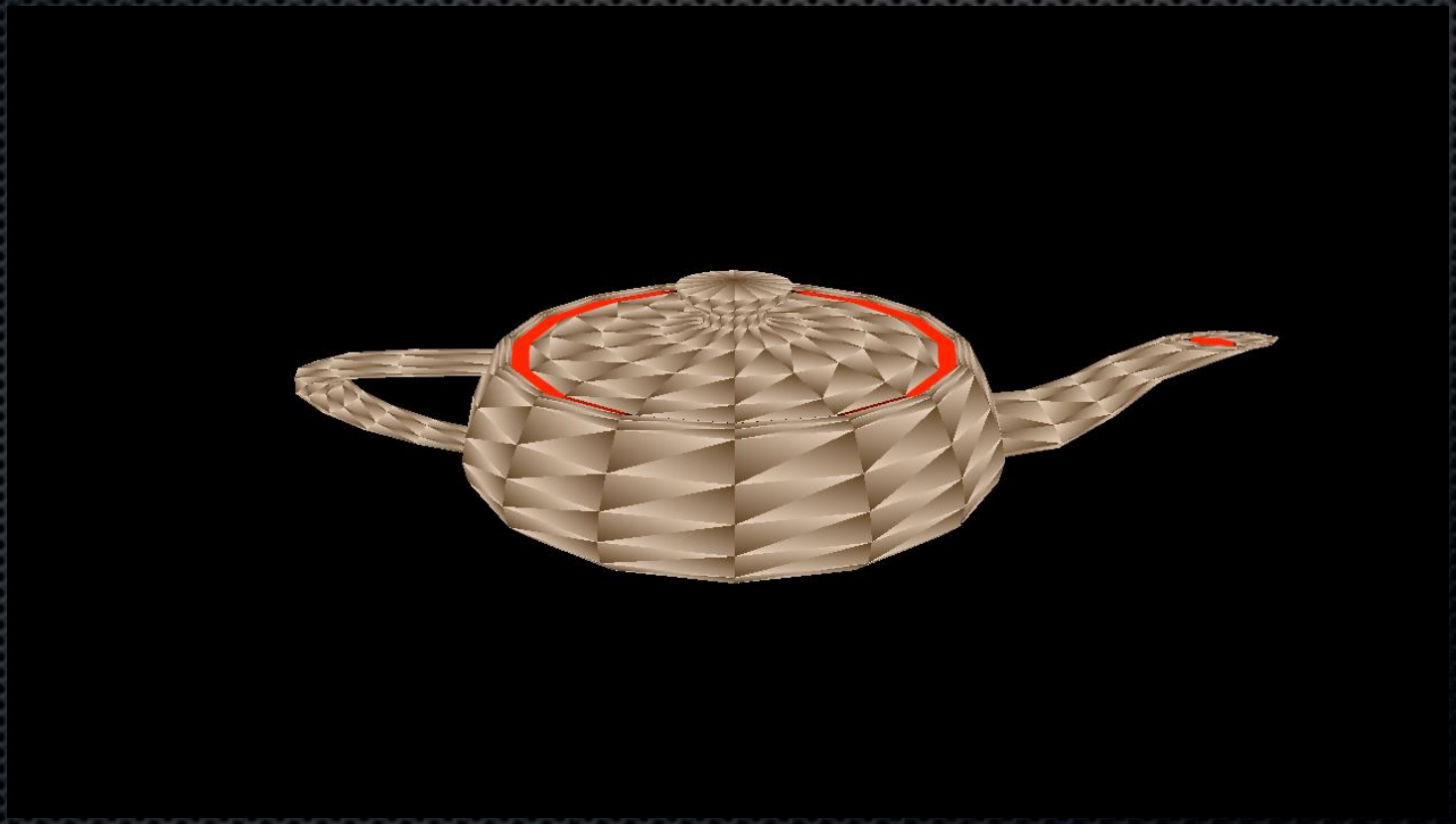
What's the problem here?



Back-Face Culling Issues

Back-Face Culling Issues

Objects drawn with back-face culling need to be solid



Other Culling Opportunities

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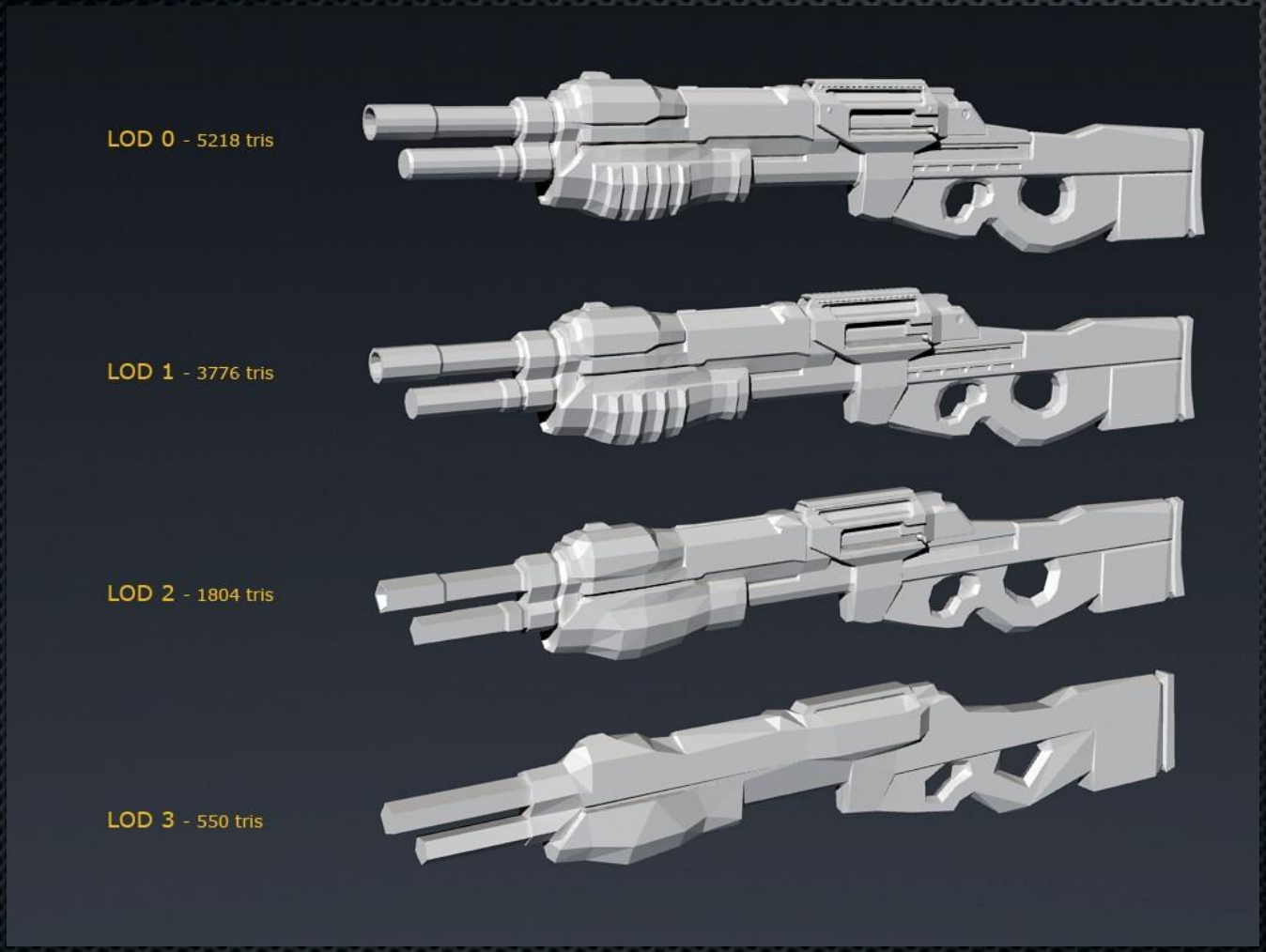
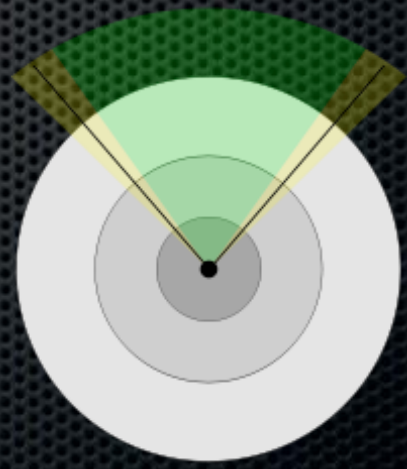
Other Culling Opportunities

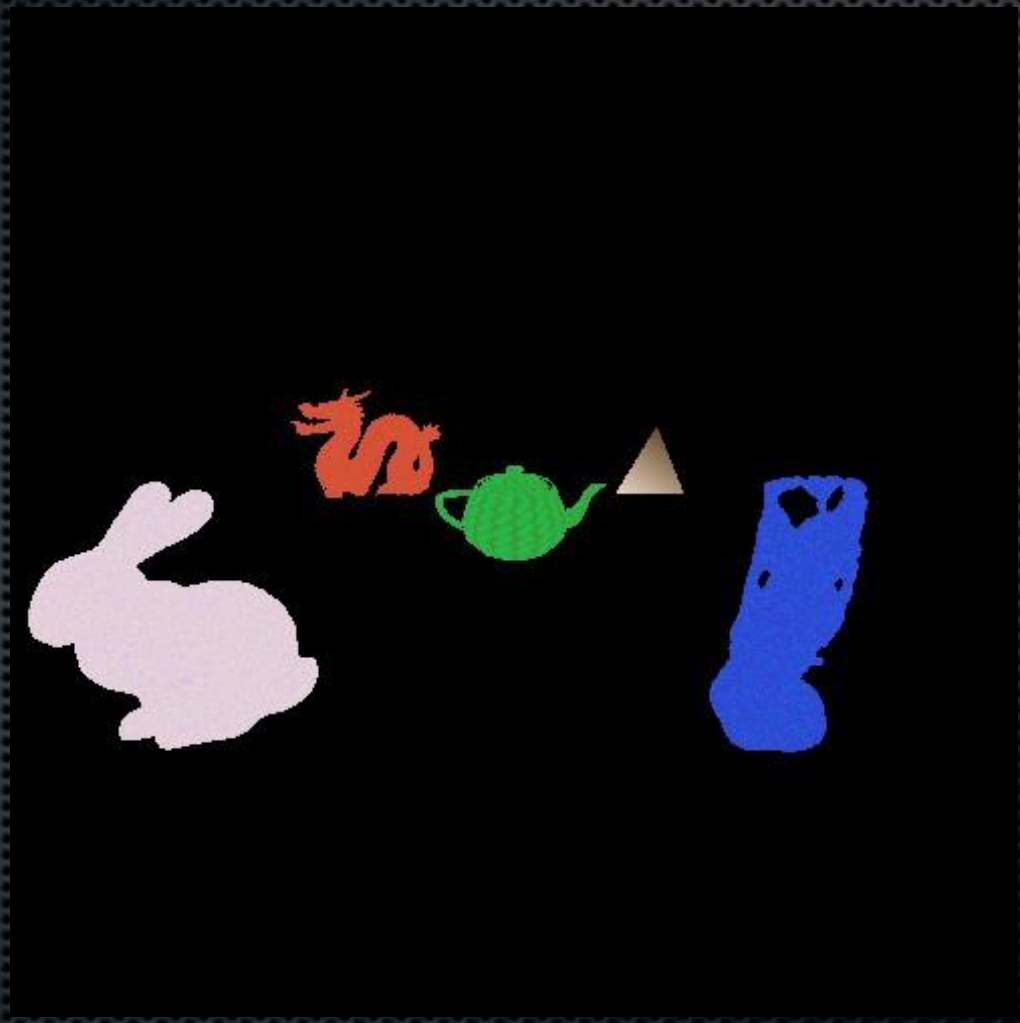
Other Culling Opportunities

Level of Detail (LOD)



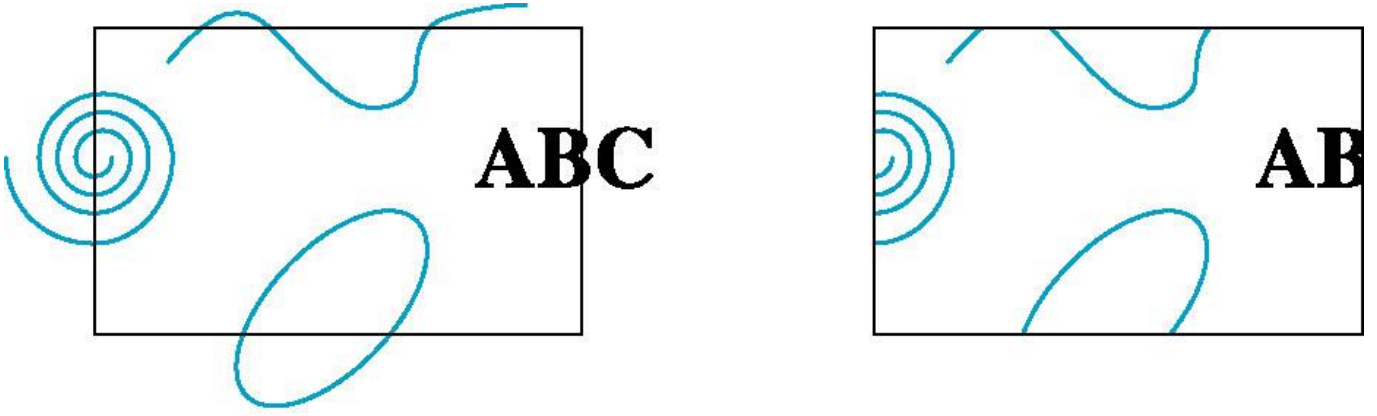


Clipping



Clipping

- **Clipping:** Remove primitives (lines, polygons, text, curves) outside view frustum (canonical view volume)



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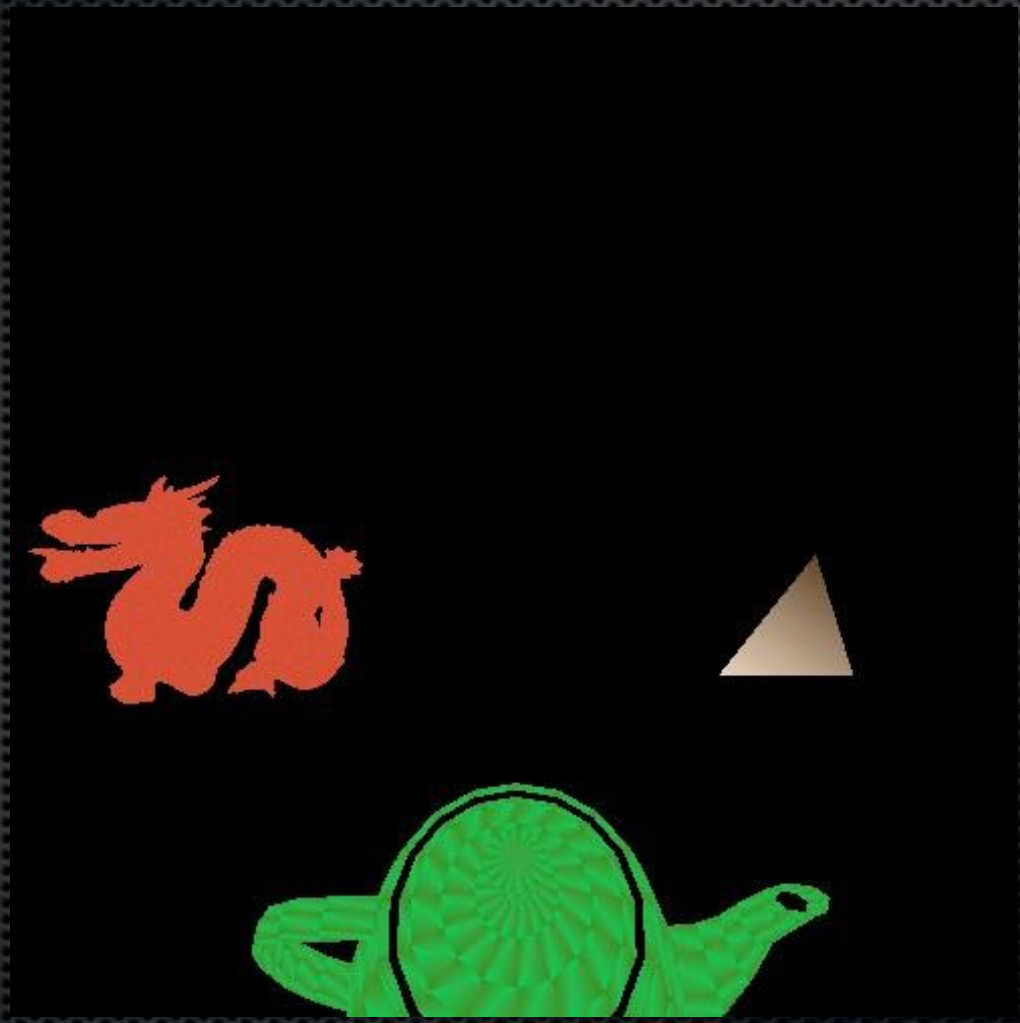
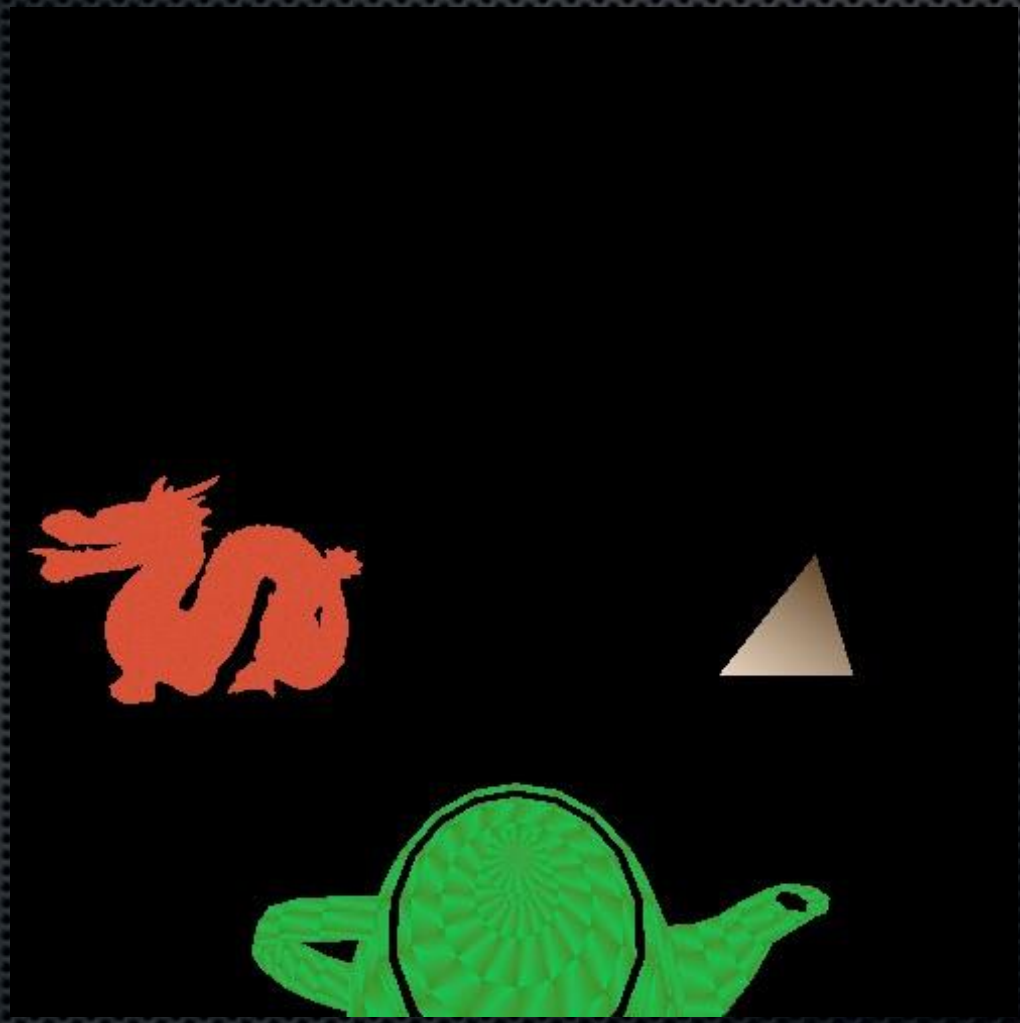


Clipping

Need to draw bunny?

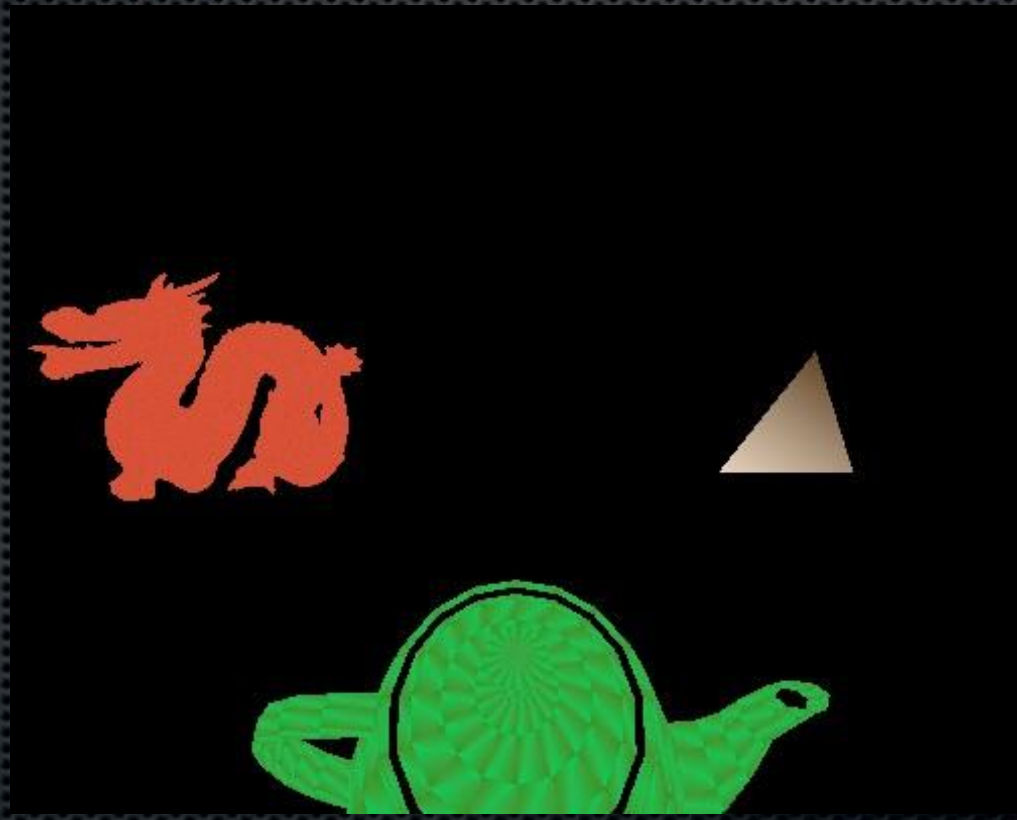


Need to draw budda?

Think-Pair-Share

How do we determine if an object is off-screen?

Need to draw bunny?



Need to draw budda?

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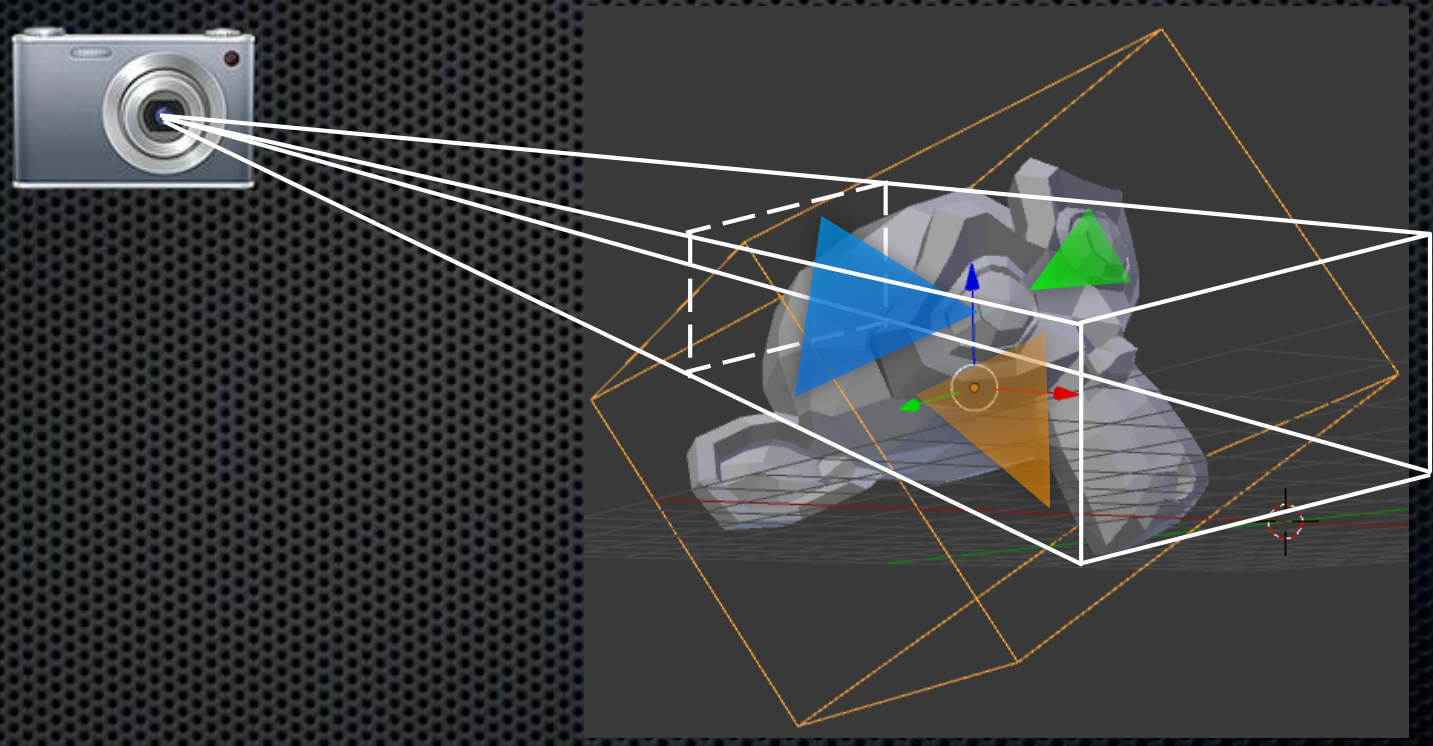
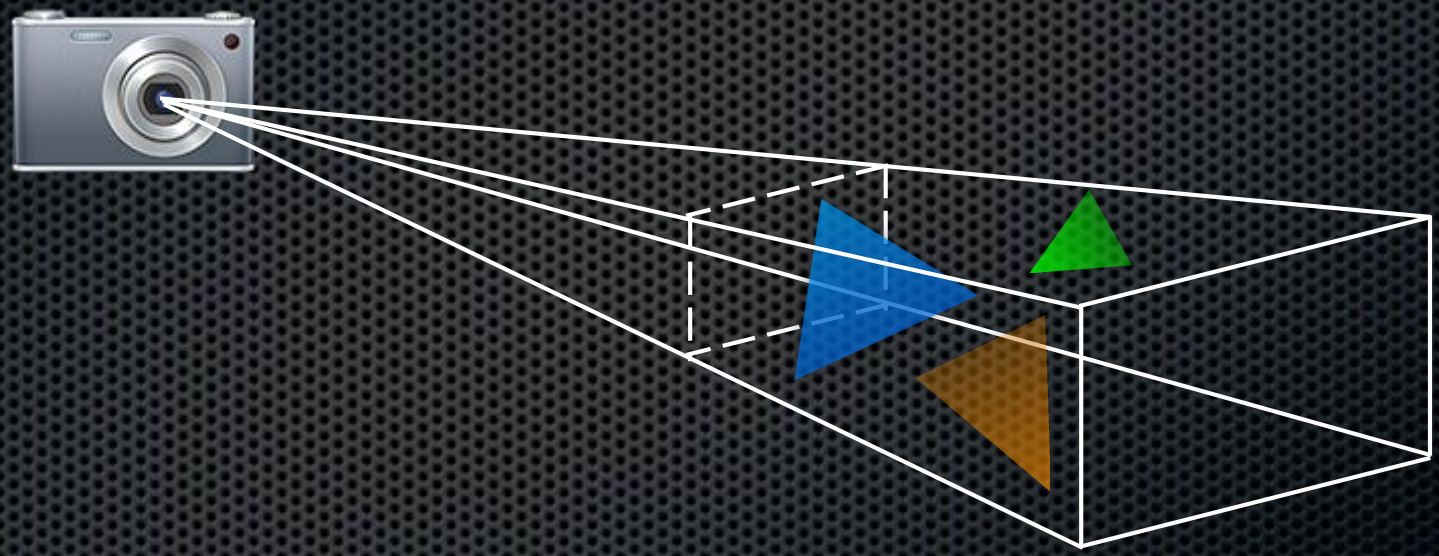


Clipping



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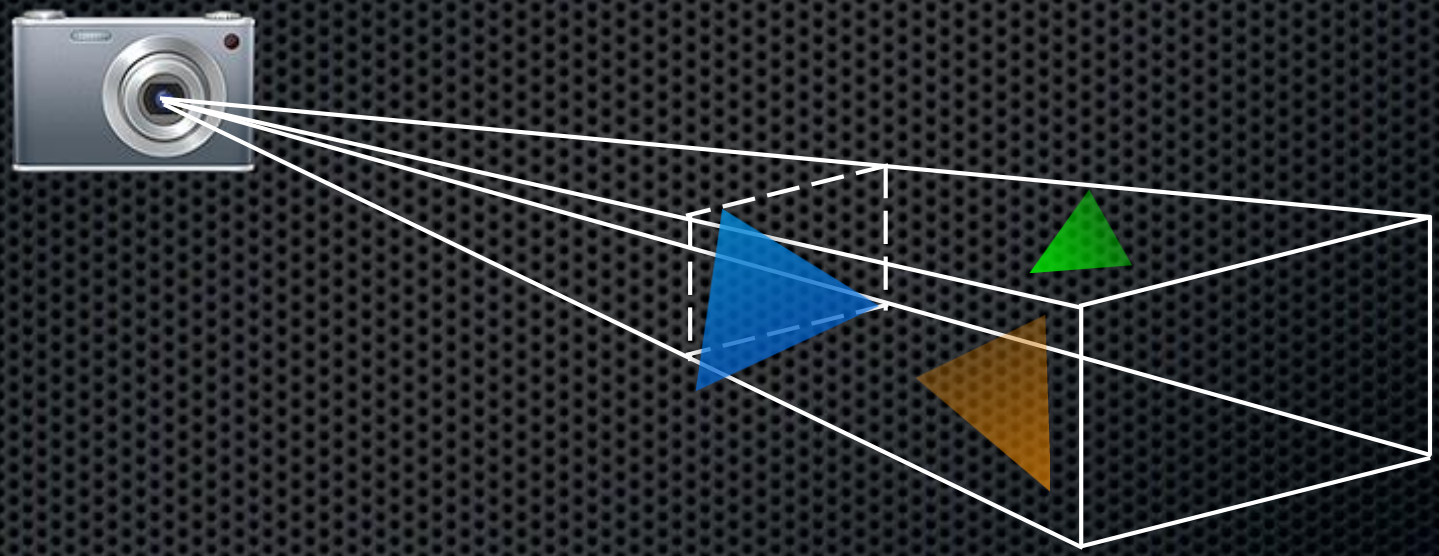

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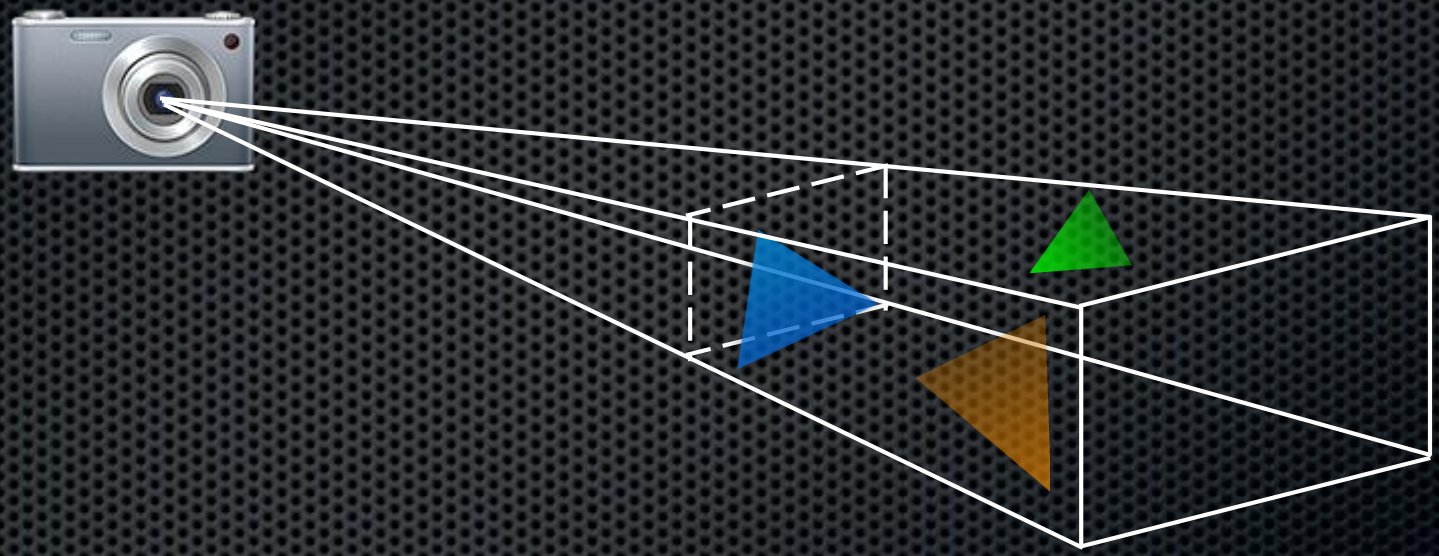

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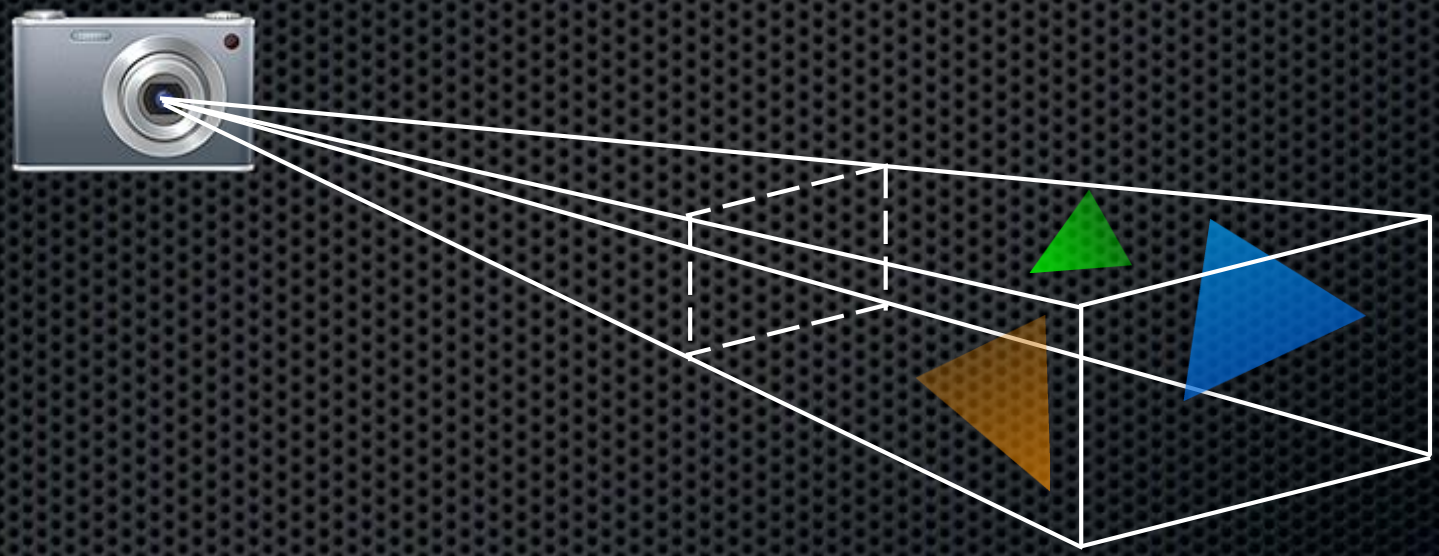
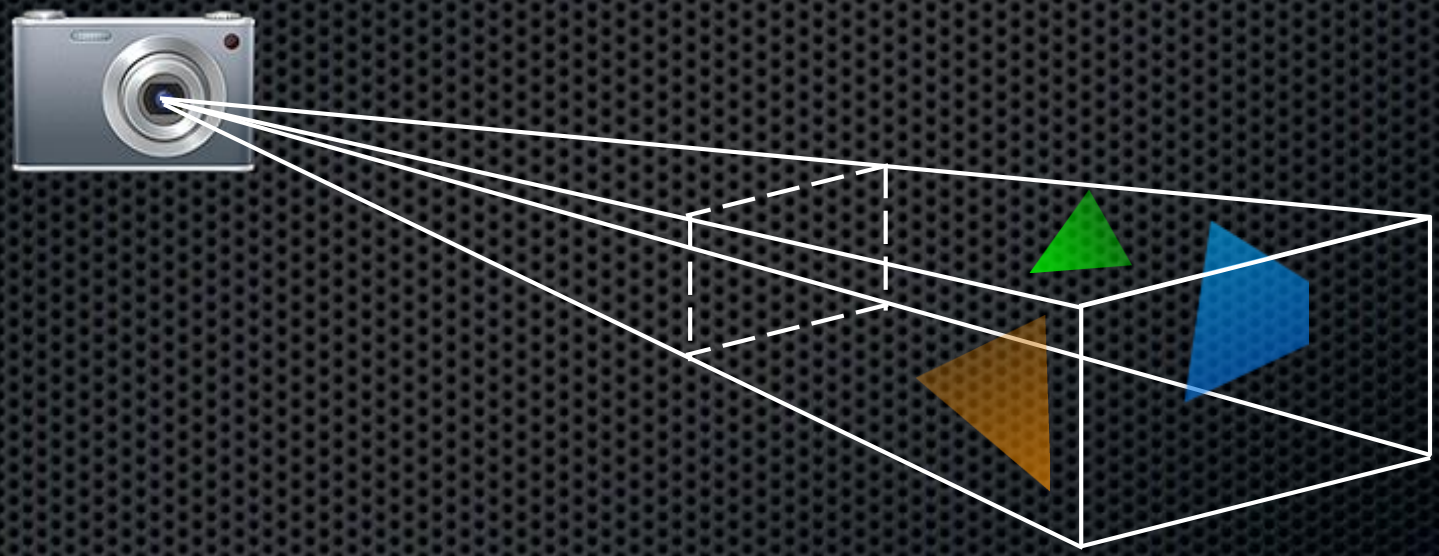
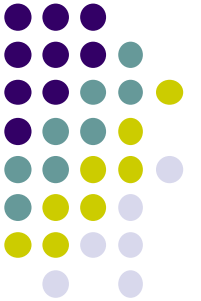


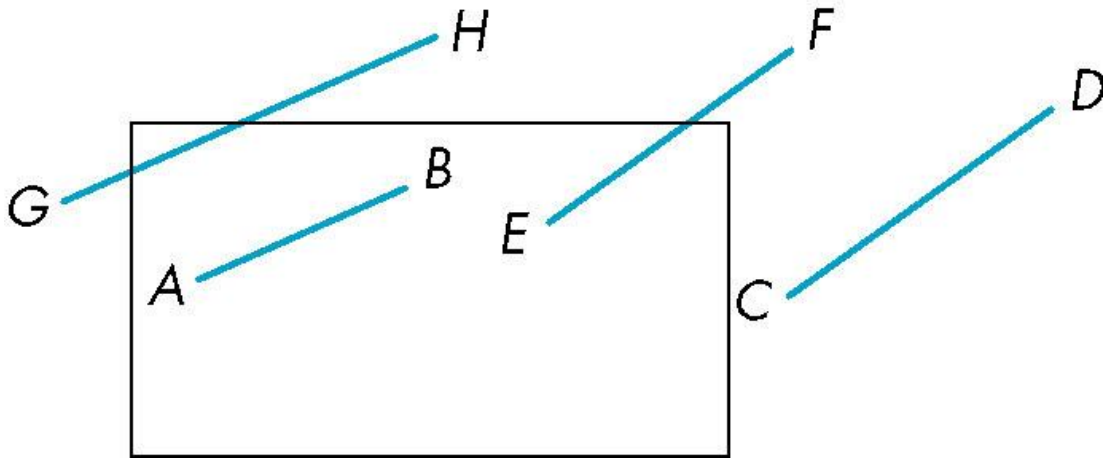
Clipping



Clipping 2D Line Segments

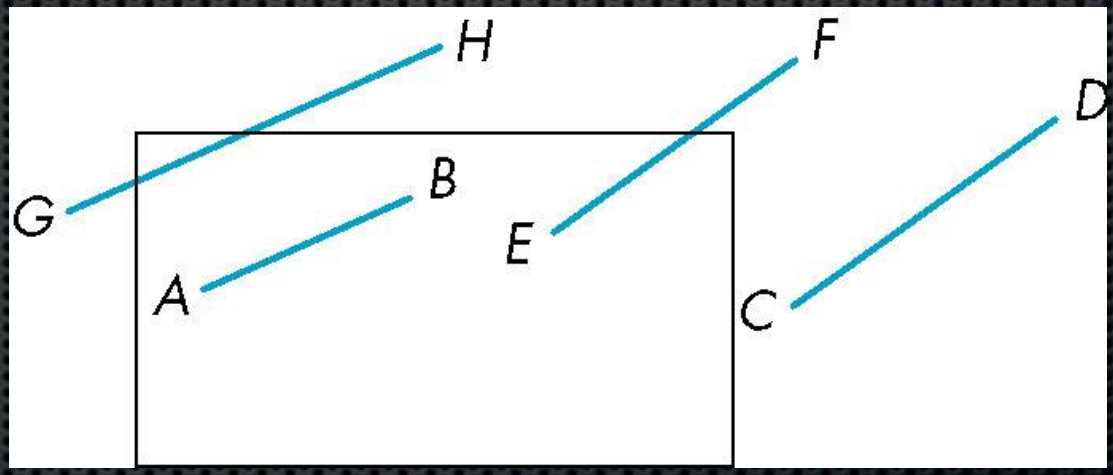


- **Brute force approach:** compute intersections with all sides of clipping window
  - Inefficient: one division per intersection



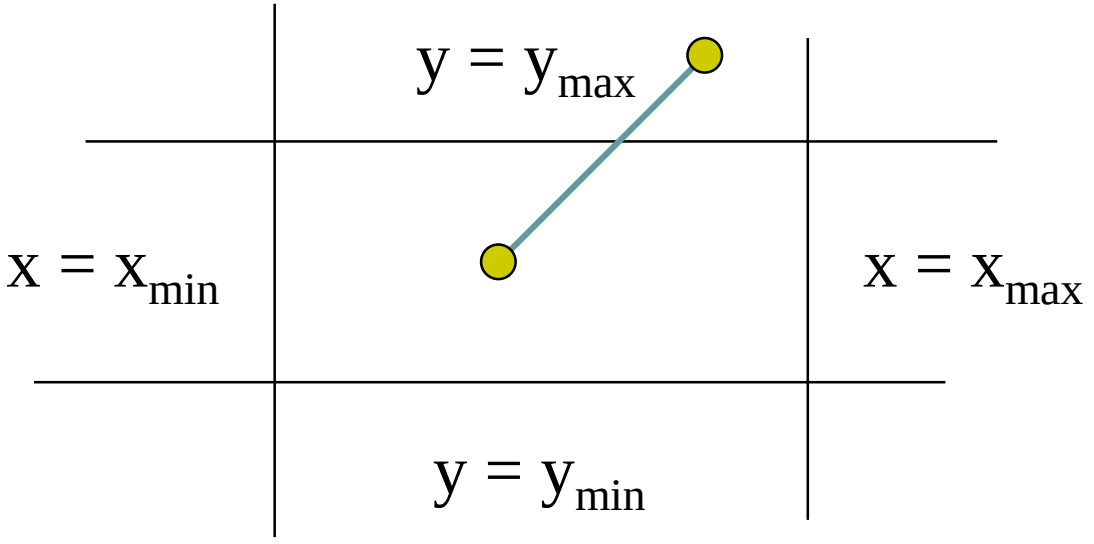
Think-Pair-Share

What's a faster approach?

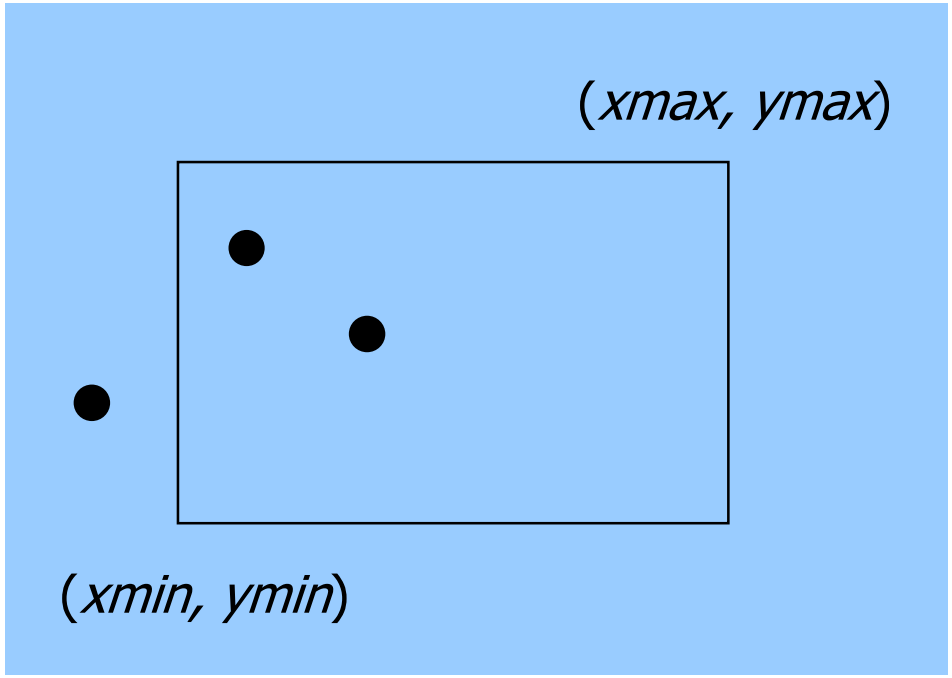


2D Clipping

- **Better Idea:** eliminate as many cases as possible without computing intersections



Clipping Points

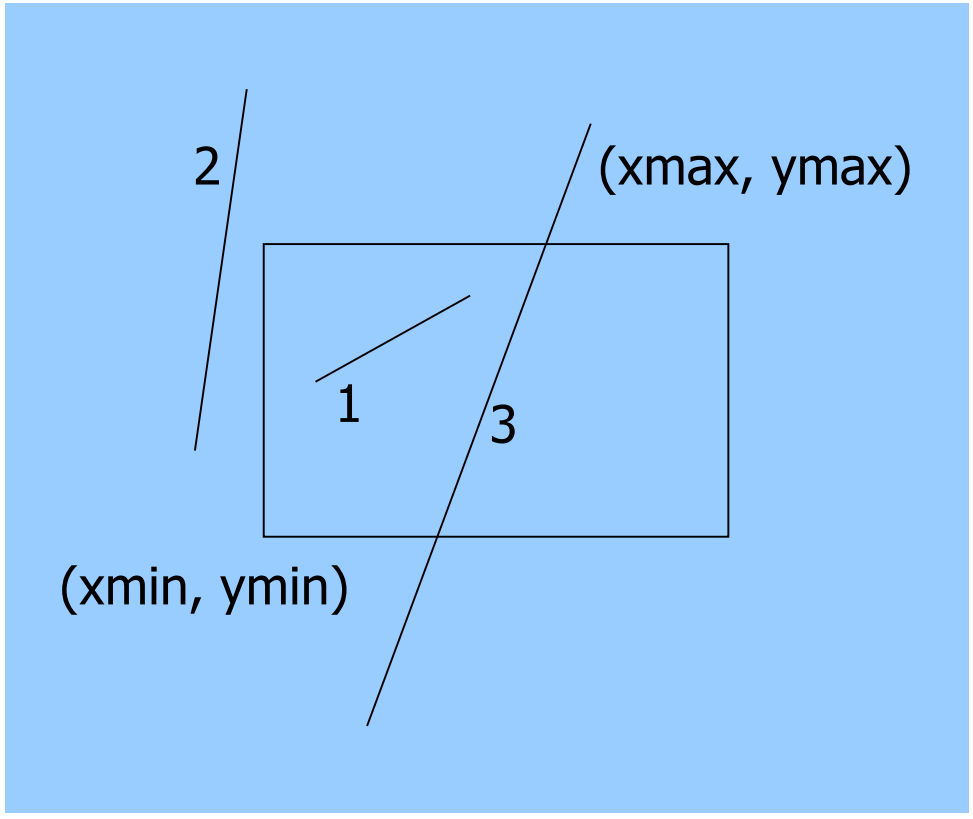


Determine whether a point (x,y) is inside or outside of the world window?

If (xmin <= x <= xmax)
and (ymin <= y <= ymax)

then the point (x,y) is inside
else the point is outside

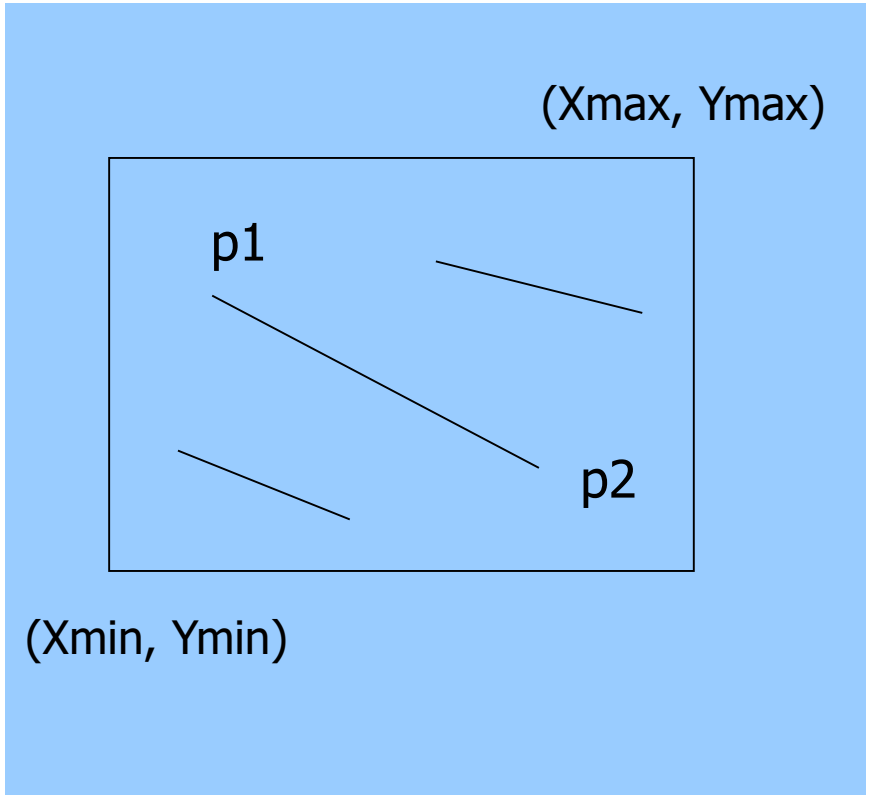
Clipping Lines



3 cases:

- **Case 1:** All of line in
- **Case 2:** All of line out
- **Case 3:** Part in, part out

Clipping Lines: Trivial Accept



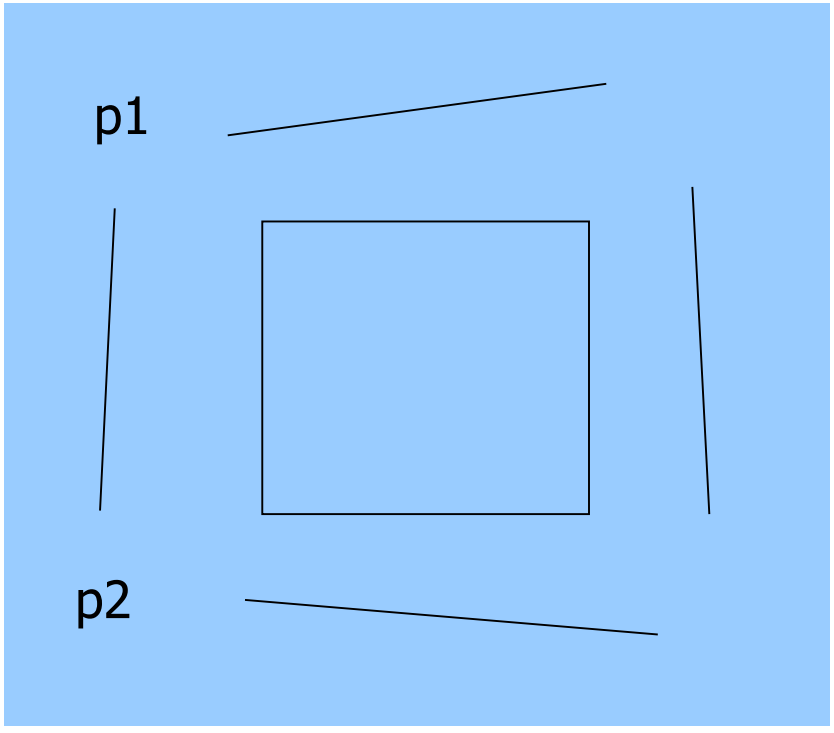
Case 1: All of line in
Test line endpoints:

Xmin <= P1.x, P2.x <= Xmax and
Ymin <= P1.y, P2.y <= Ymax

Note: simply comparing x,y values of endpoints to x,y values of rectangle

Result: trivially accept.
Draw line in completely

Clipping Lines: Trivial Reject



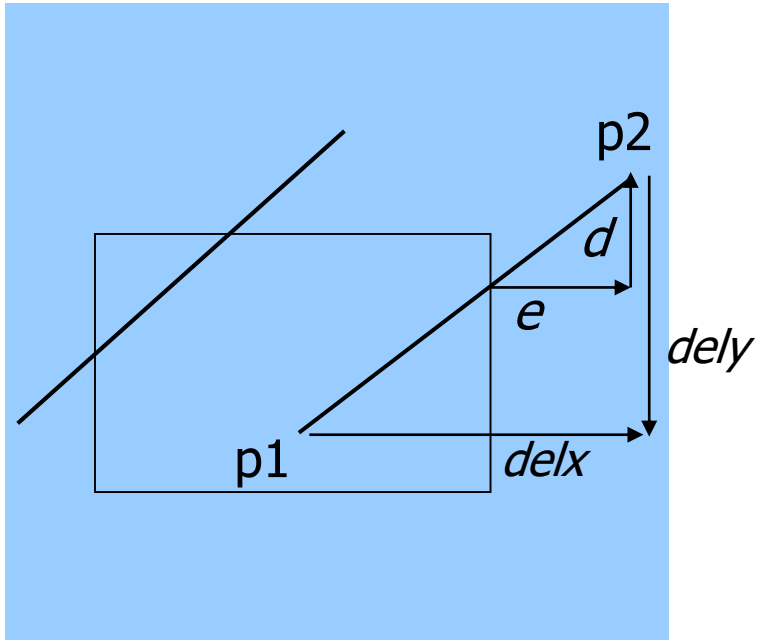
Case 2: All of line out
Test line endpoints:

- ***p1.x, p2.x <= Xmin*** **OR**
- ***p1.x, p2.x >= Xmax*** **OR**
- ***p1.y, p2.y <= ymin*** **OR**
- ***p1.y, p2.y >= ymax***

Note: simply comparing x,y values of endpoints to x,y values of rectangle

Result: trivially reject.
Don't draw line in

Clipping Lines: Non-Trivial Cases



Case 3: Part in, part out

Two variations:

- One point in, other out
- Both points out, but part of line cuts through viewport

Need to find inside segments

Use similar triangles to figure out length of inside segments

$$\frac{d}{dely} = \frac{e}{delx}$$

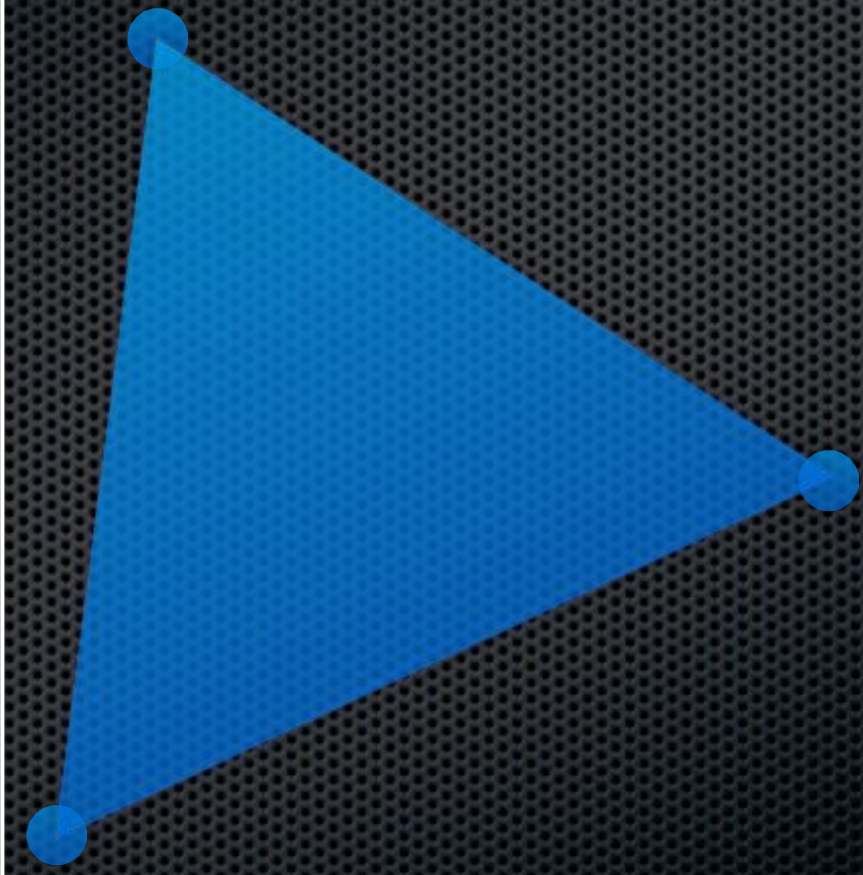
Clipping

Clipping

All 3 Points Inside

Outside

Inside

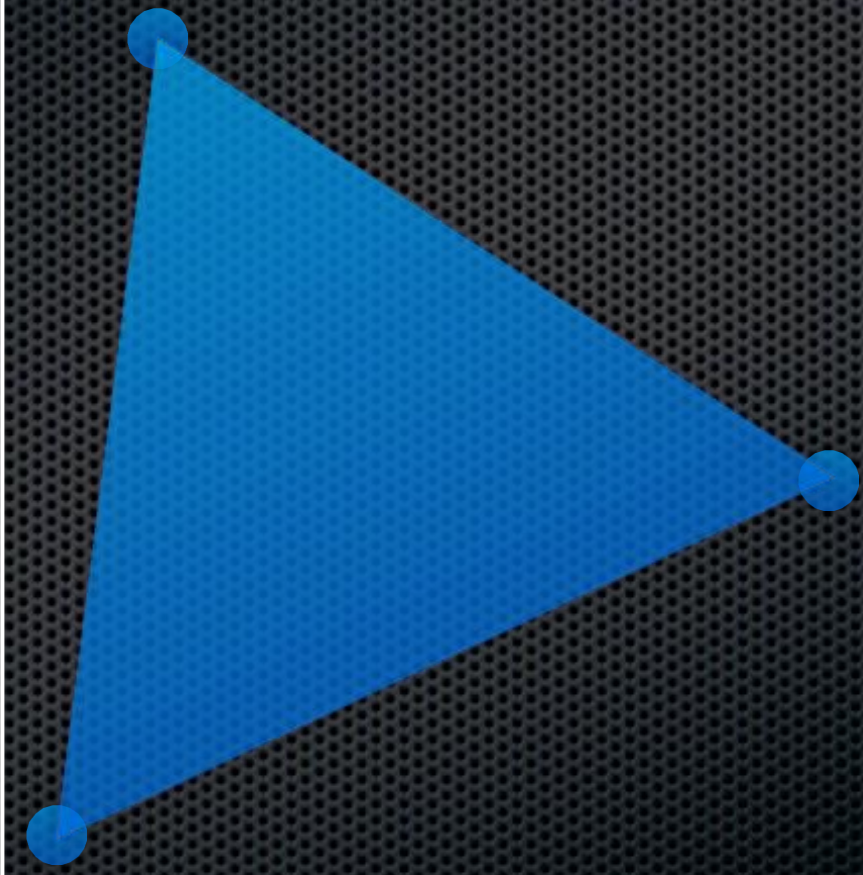


Clipping

All 3 Points Outside

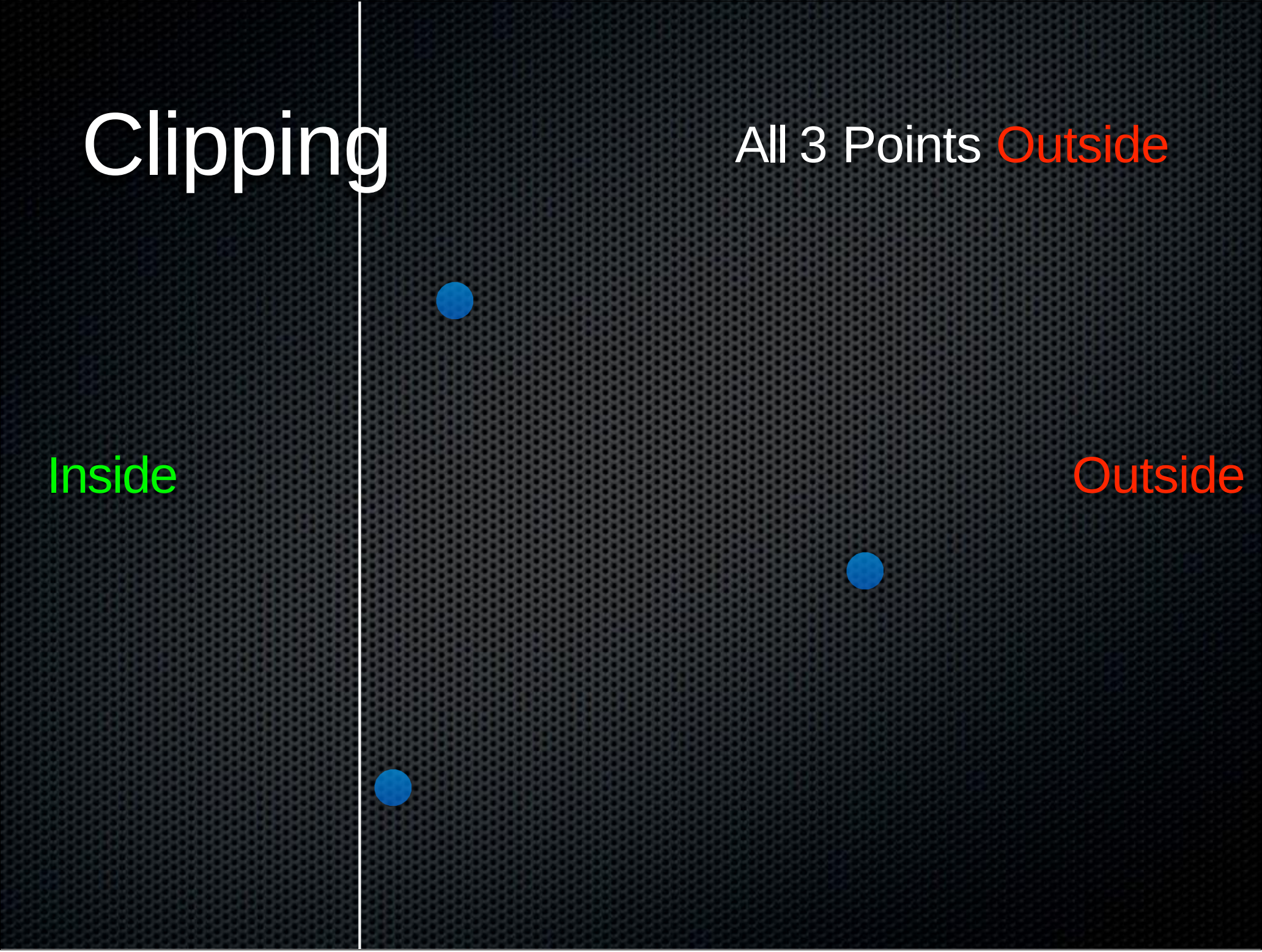
Inside

Outside



Clipping

All 3 Points Outside

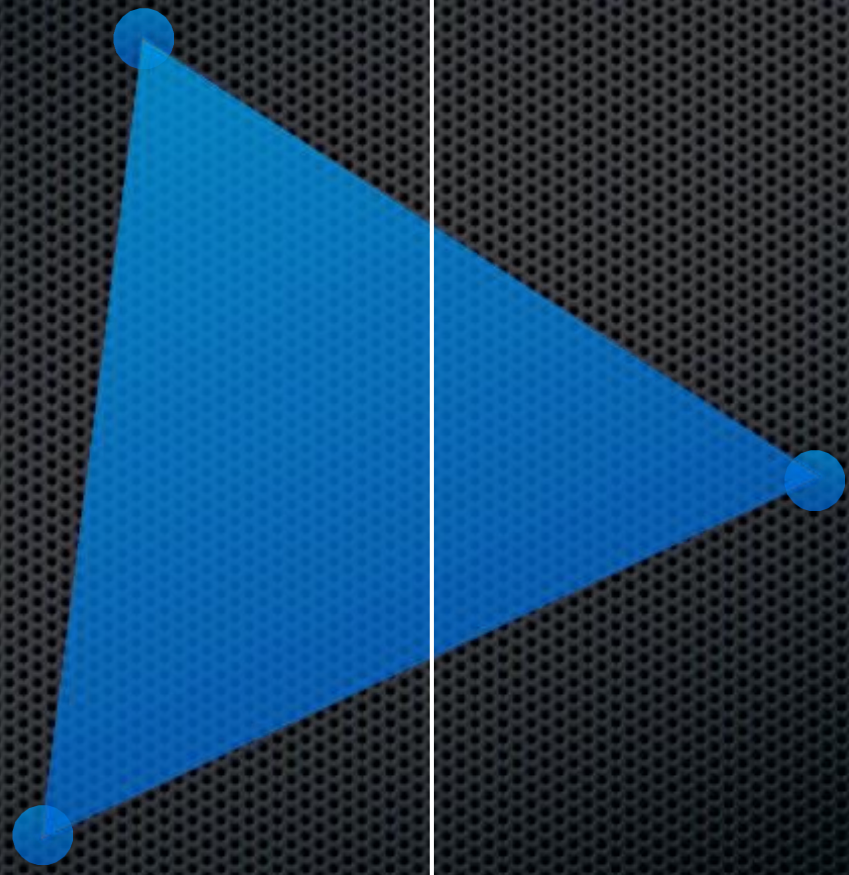


Clipping

1 Point Inside

Outside

Inside



Clipping

1 Point Inside

Outside

Inside

Clipping

1 Point Inside

Outside

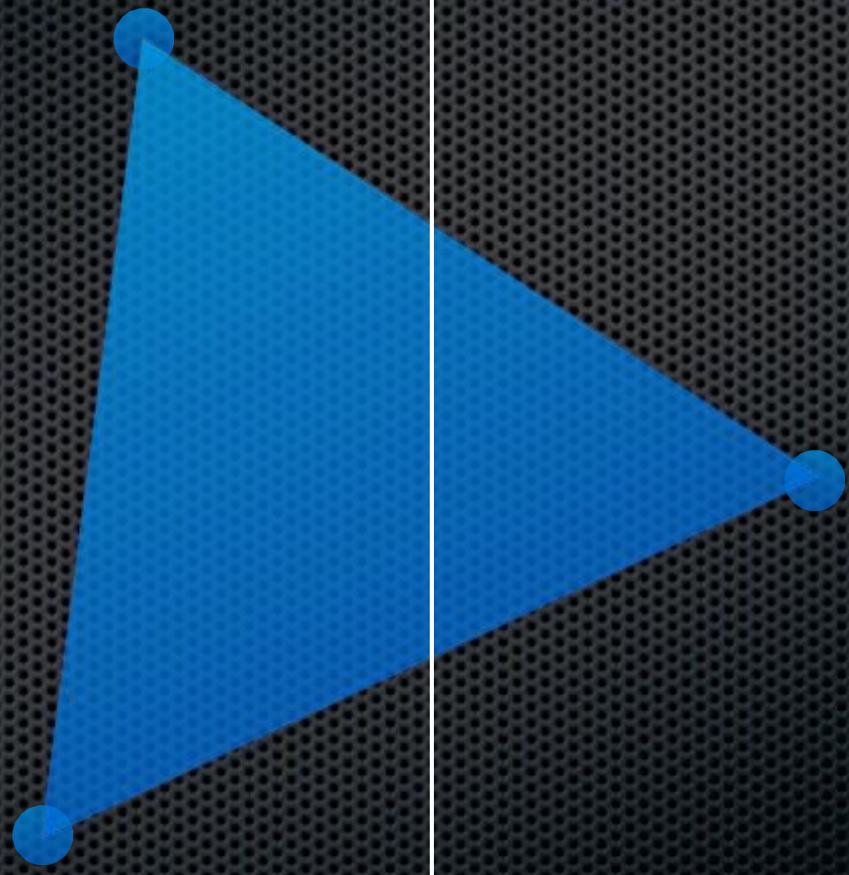
Inside

Clipping

2 Points Inside

Inside

Outside



Clipping

Inside

2 Points Inside

Outside

Clipping

2 Points Inside

Inside

Outside

Clipping

2 Points Inside

Inside

Outside

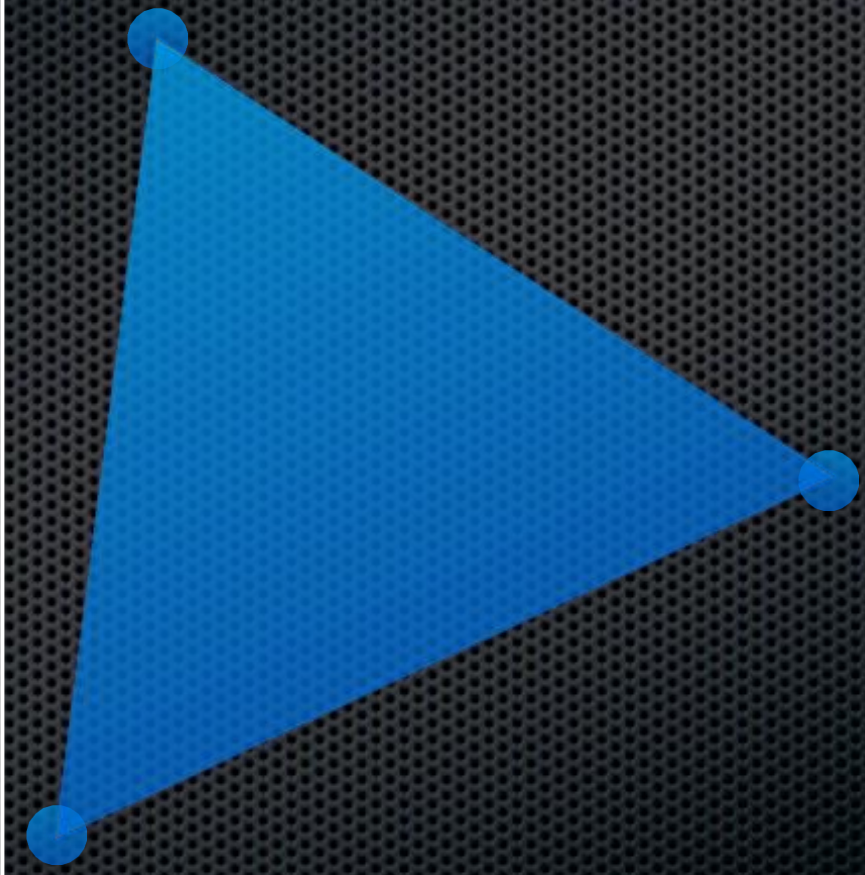
Need 2 Triangles!

Poor Man's Clip

All 3 Points Inside

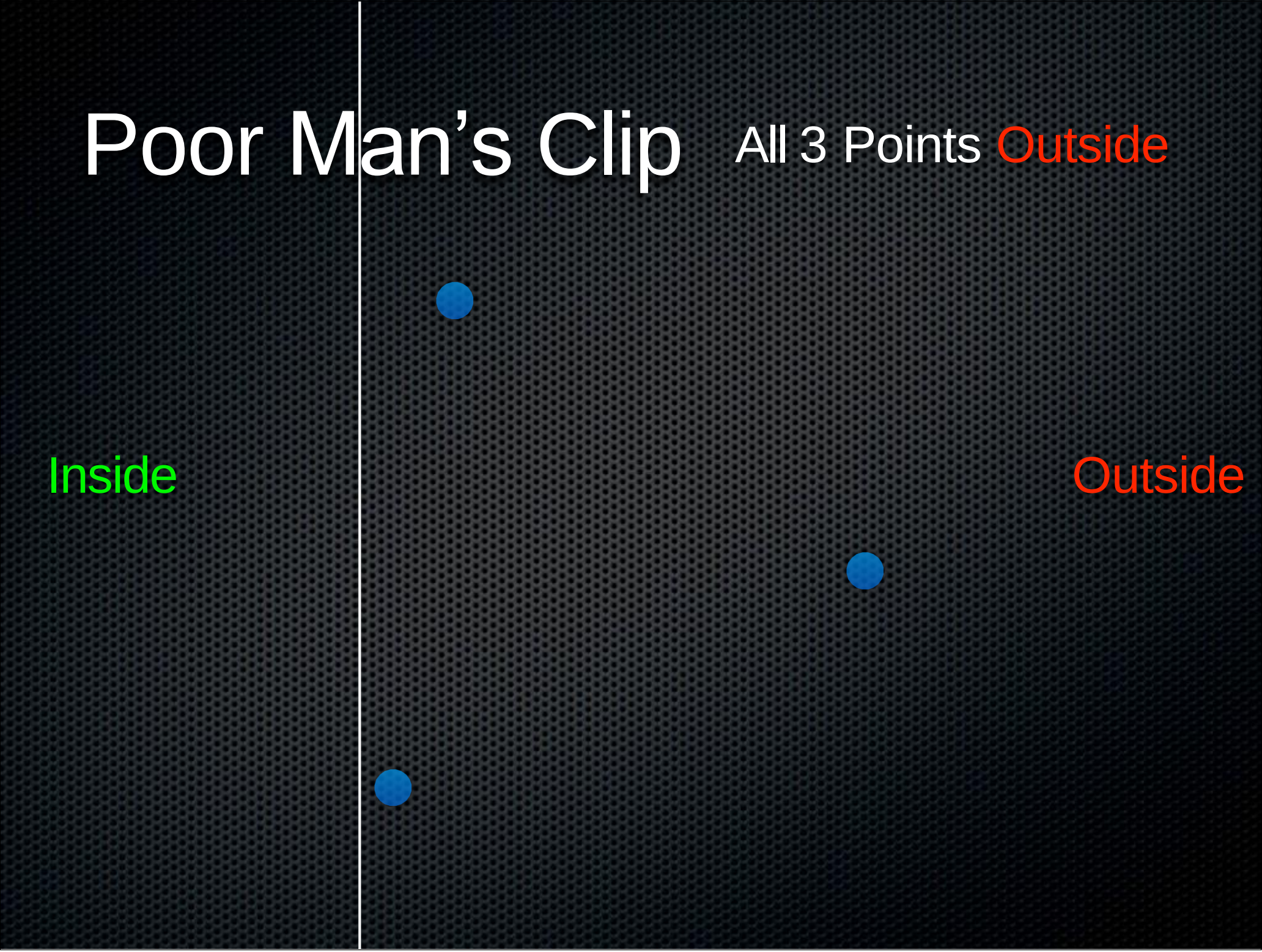
Outside

Inside

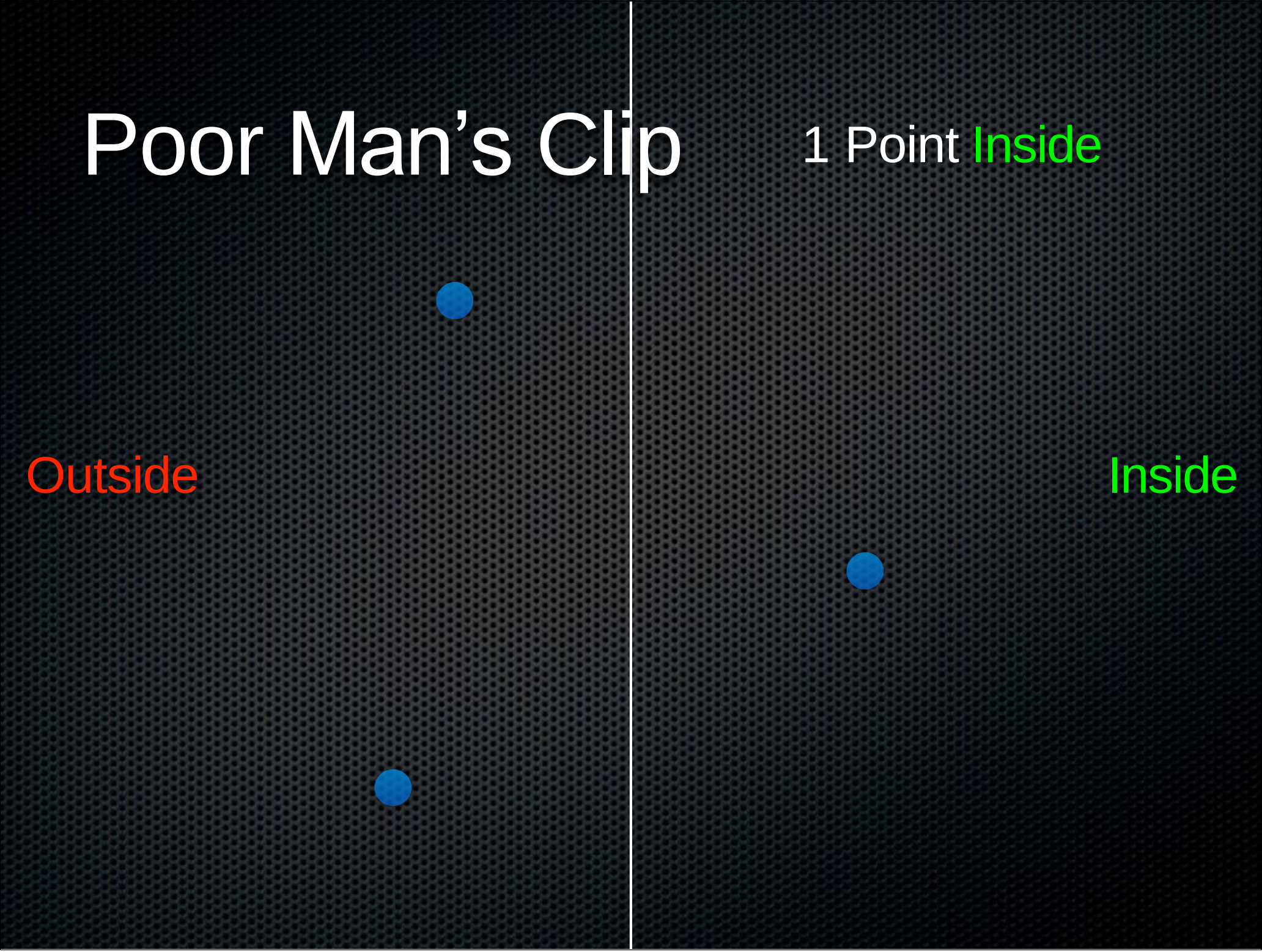


Poor Man's Clip

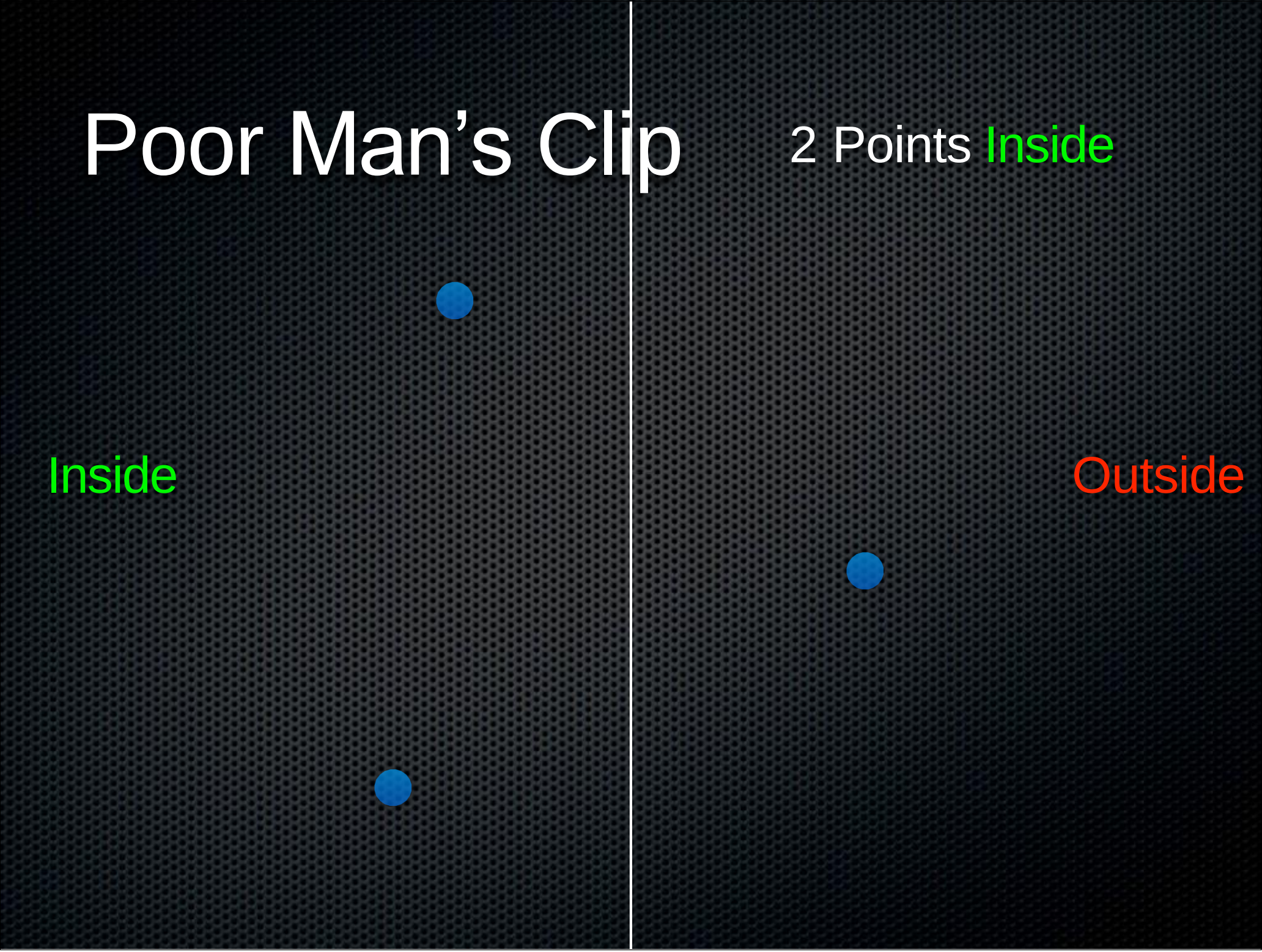
All 3 Points Outside



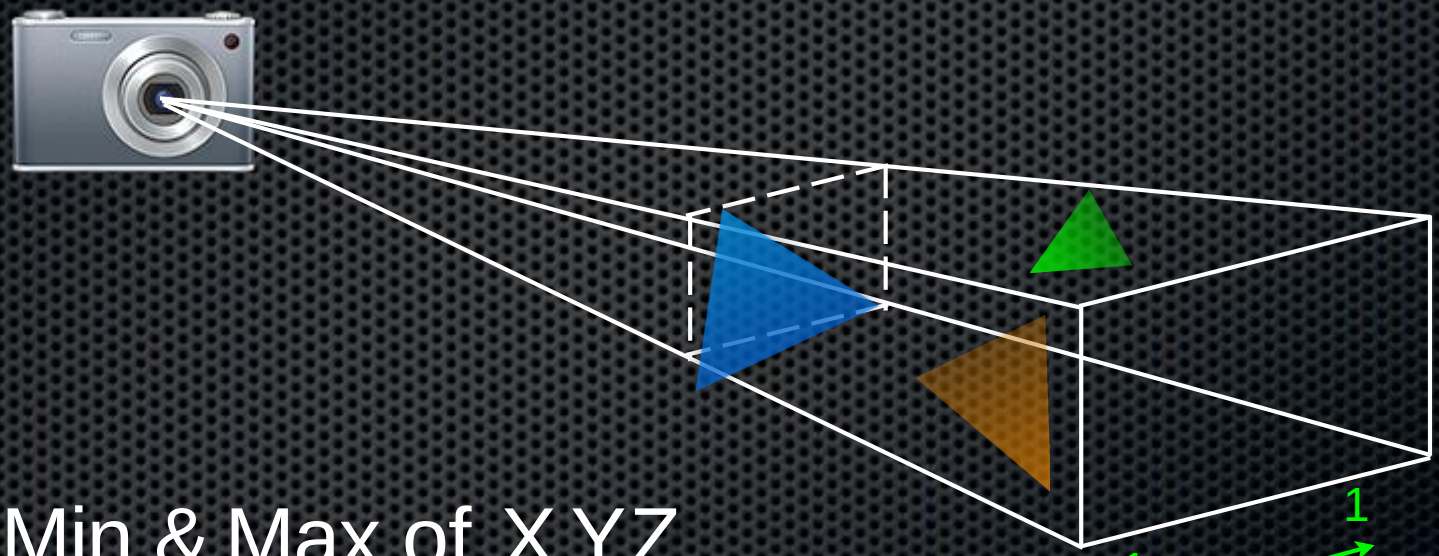
Poor Man's Clip



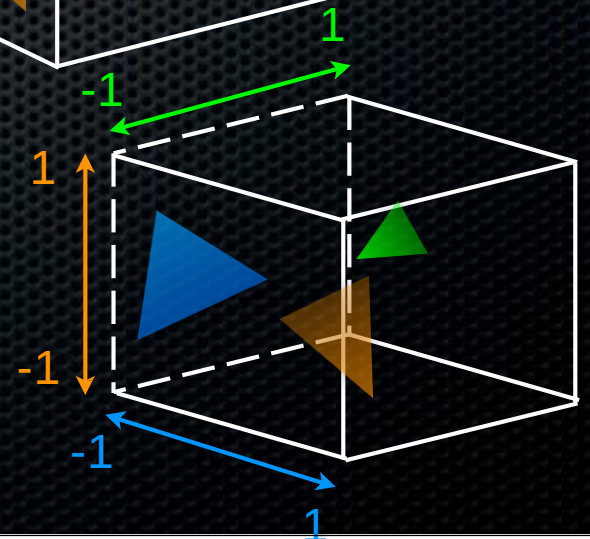
Poor Man's Clip



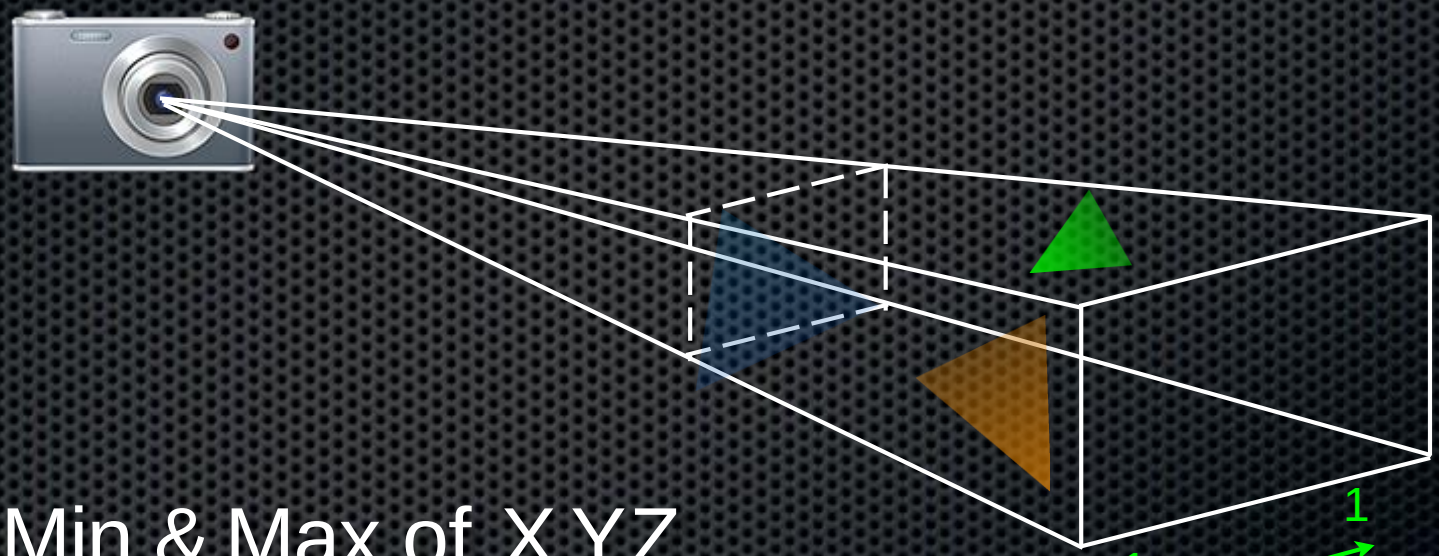
Poor Man's Clip



Check Min & Max of X,Y,Z

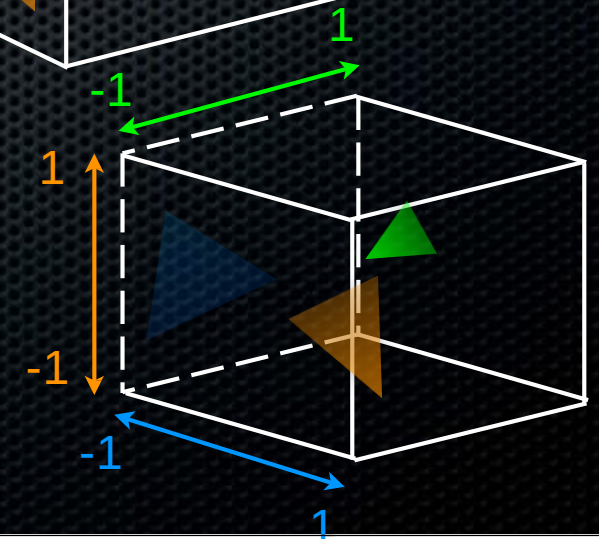


Poor Man's Clip

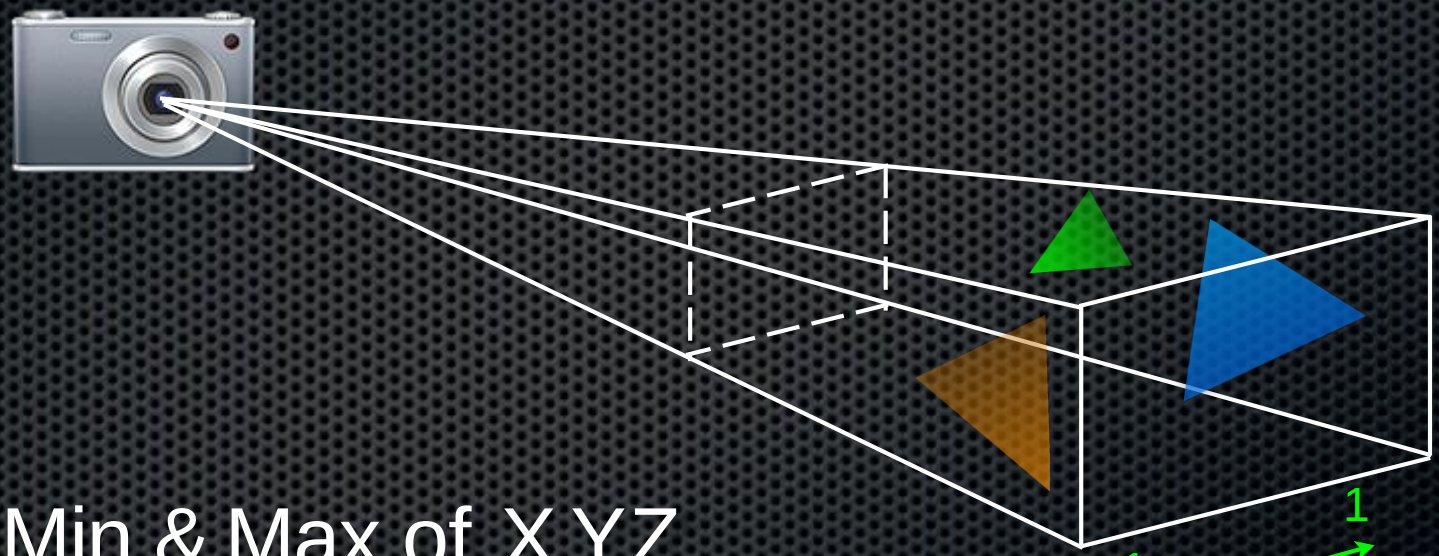


Check Min & Max of X,Y,Z

In Canonical Coordinates:
if Min < -1 or Max > 1
  Ignore Triangle

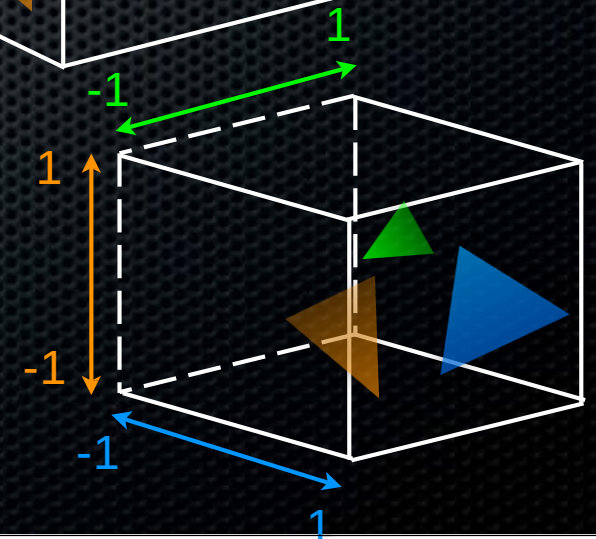


Poor Man's Clip

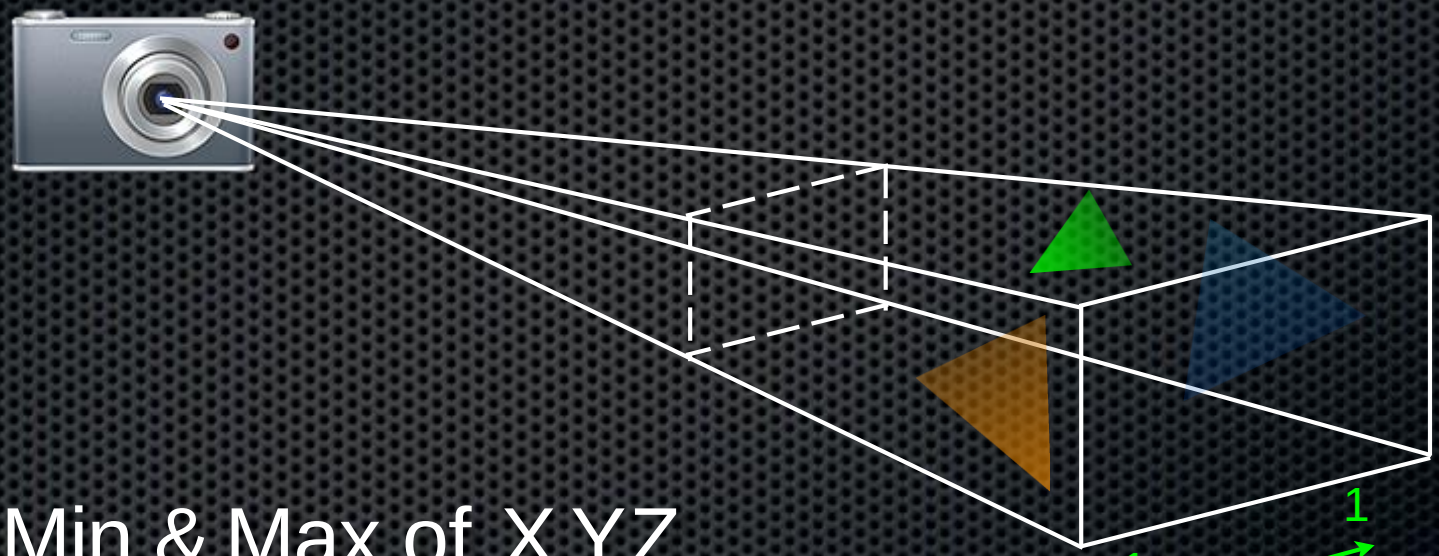


Check Min & Max of X,Y,Z

In Canonical Coordinates:
if Min < -1 or Max > 1
  Ignore Triangle



Poor Man's Clip



Check Min & Max of X,Y,Z

In Canonical Coordinates:
if Min < -1 or Max > 1
  Ignore Triangle