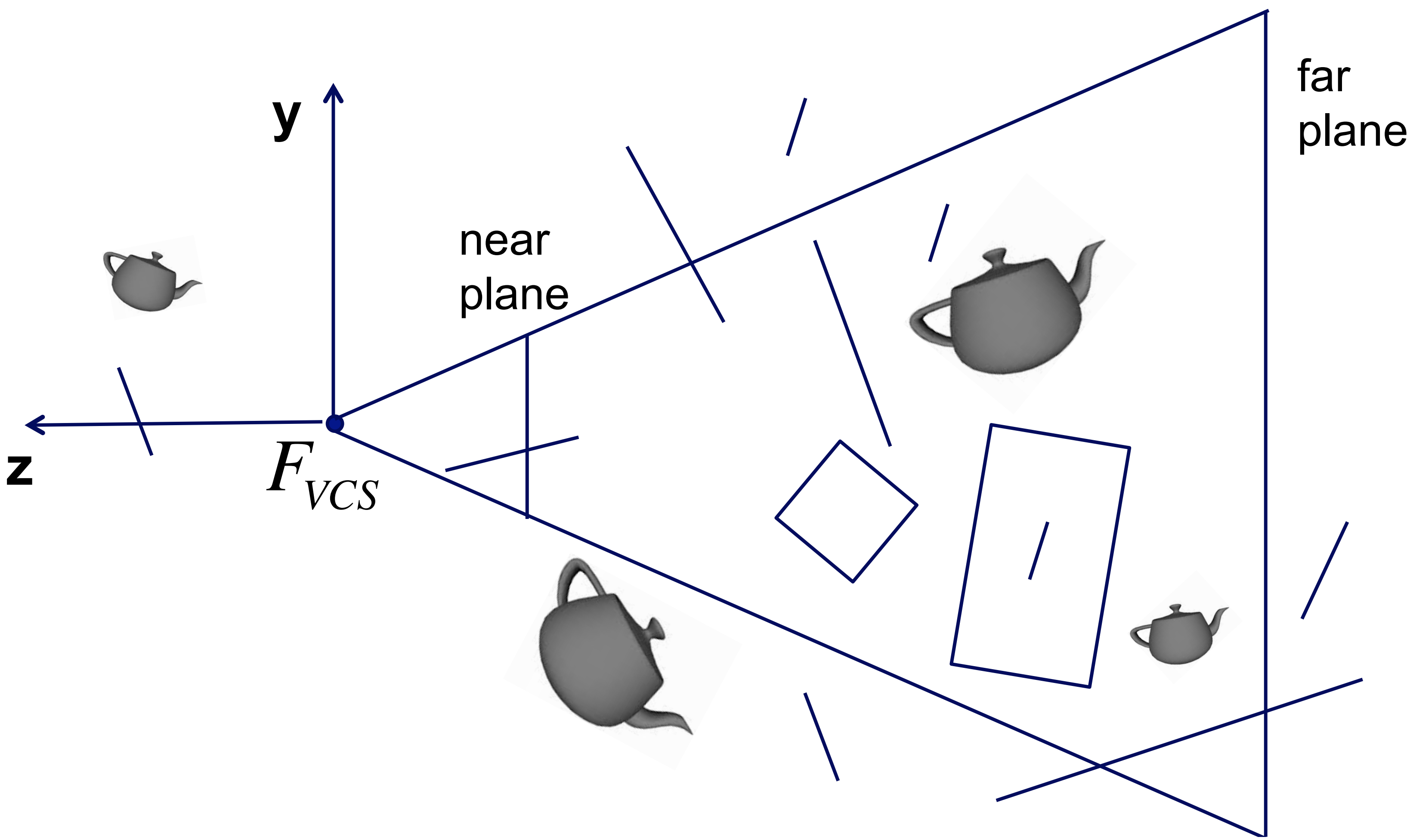
Visibility

Determining which objects / triangles / pixels can be seen

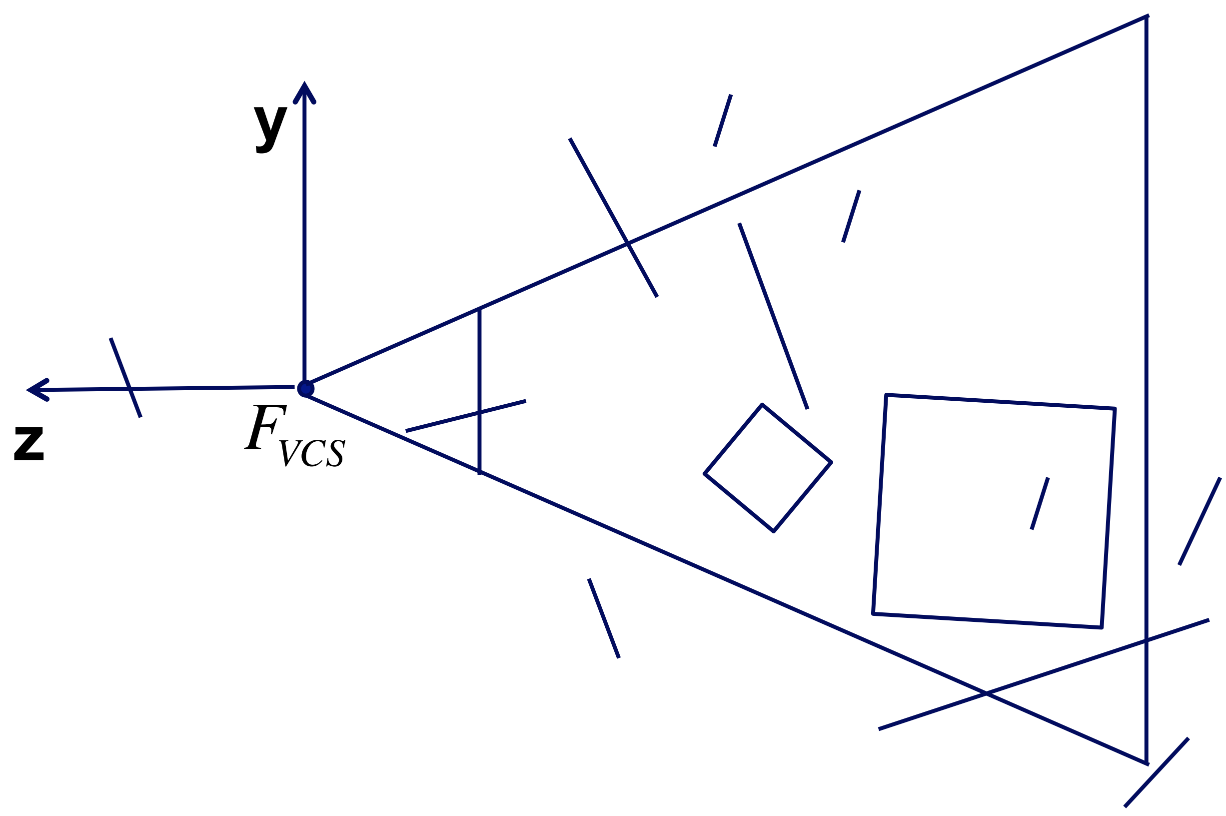


Visibility

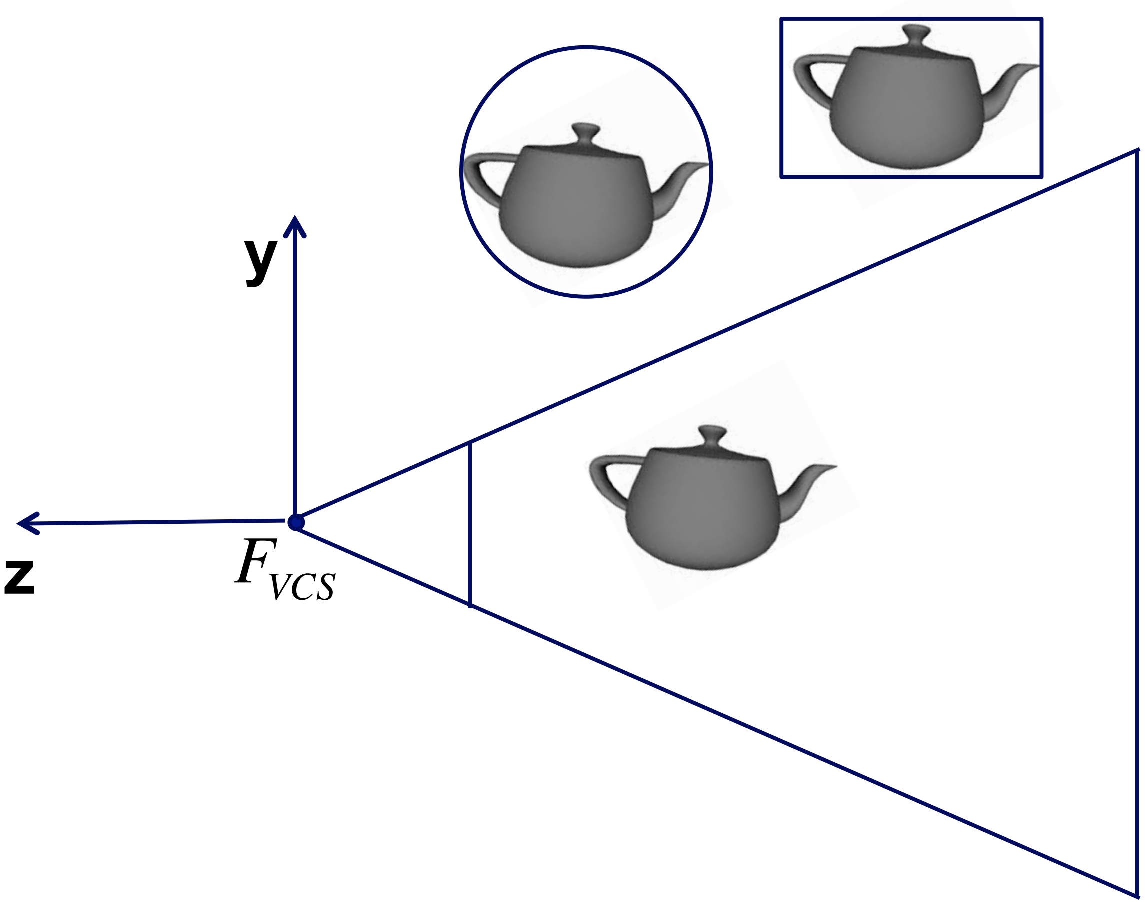
Methods

- view volume culling
- view volume clipping
- backface culling
- occlusion: z-buffer test
- occlusion: object culling
- raycasting (and raytracing)

View Volume Culling (for triangles)



View Volume Culling (for objects)

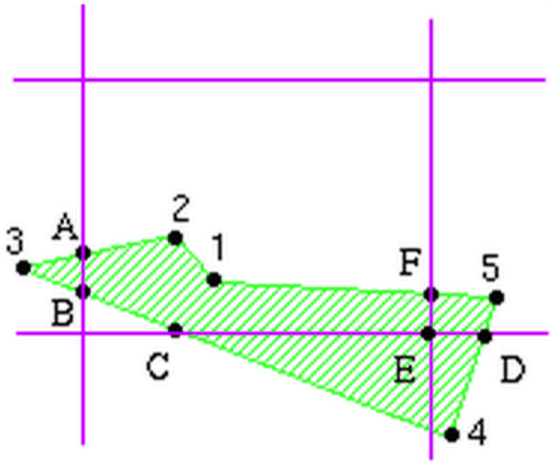


bounding sphere:

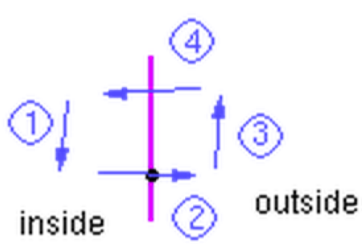
bounding box:

2D Clipping

Sutherland Hodgeman algorithm



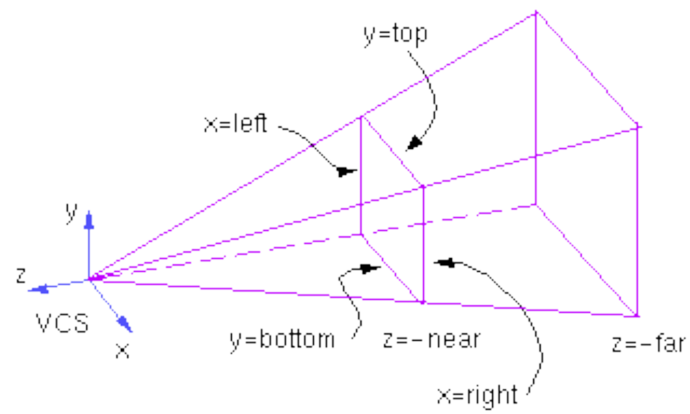

```
for each side of clipping window
   for each edge of polygon
      output points based upon the following table
```



case #	first point	second point	output point(s)
1	inside	inside	second point
2	inside	outside	intersection point
3	outside	outside	none
4	outside	inside	intersection point and second point

View Volume Clipping

general polygon clipping:



tor triangles with bounding-box scan conversion:

Clipping in VCS

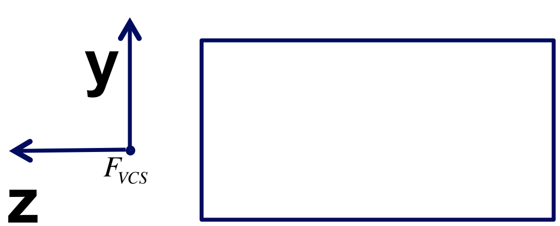
Plane equations

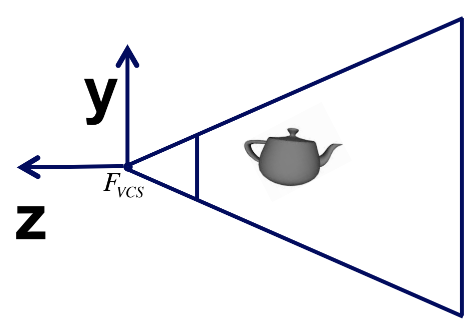
Othographic View Volume

```
left:     x - left = 0
right:   -x + right = 0
bottom:   y - bottom = 0
top:     -y + top = 0
front:   -z - near = 0
back:     z + far = 0
```

Perspective View Volume

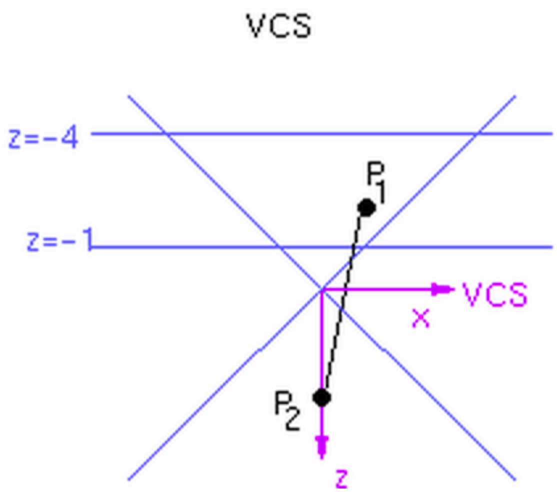
```
left:     x + left*z/near = 0
right:   -x - right*z/near = 0
top:     -y - top*z/near = 0
bottom:   y + bottom*z/near = 0
front:   -z - near = 0
back:     z + far = 0
```

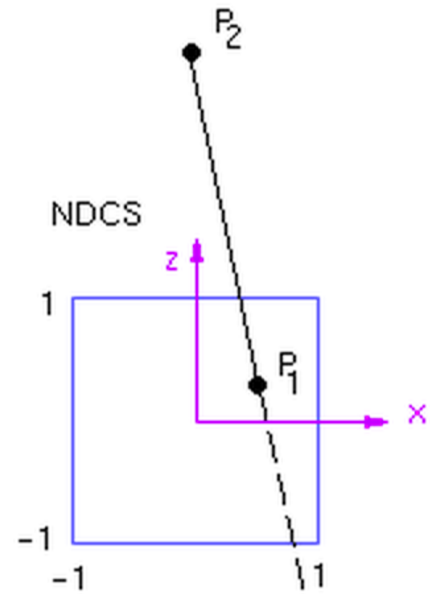




Clipping in NDCS (?)

NDCS

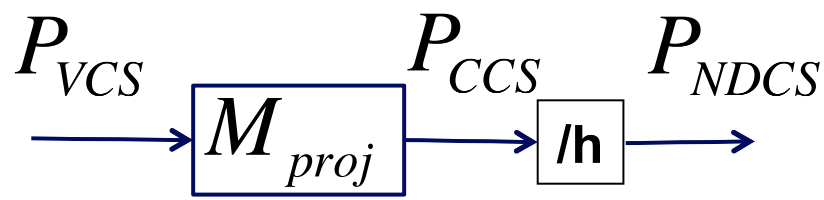




$$\begin{bmatrix} 1 & & & \\ & 1 & & \\ & & -5/3 & -8/3 \\ & & -1 & \end{bmatrix}$$

	P_1	P_2
VCS	(1, 0, -2)	(0,0,2)
CCS	(1, 0, 2/3, 2)	(0,0,-6,-2)
NDCS	(1/2, 0, 1/3)	(0, 0, 3)

Clipping in CCS

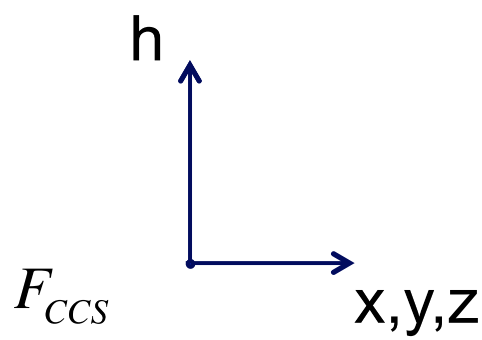


NDCS:

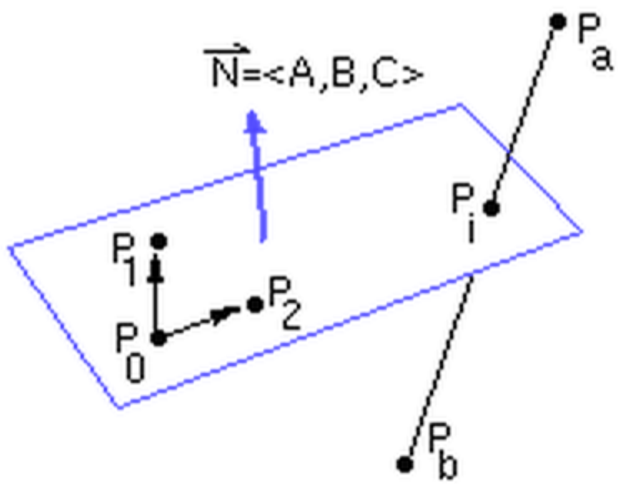
CCS:

canonical plane equations:

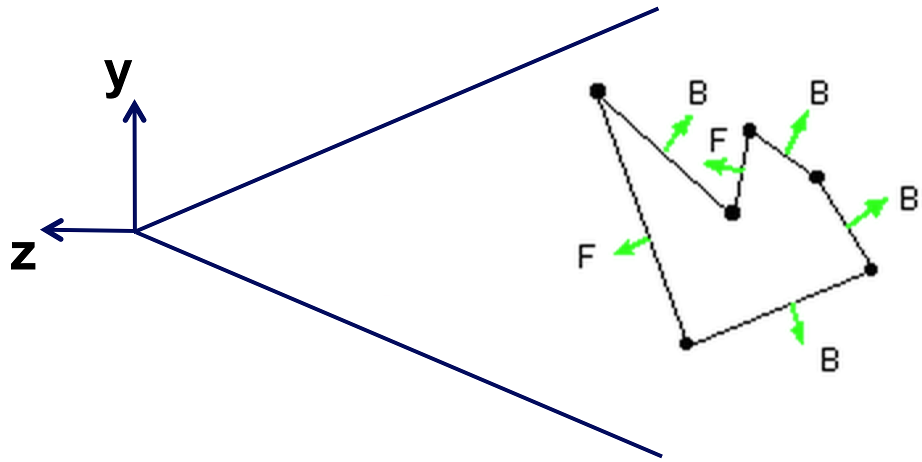
```
left:    x + h = 0
right: -x + h = 0
bot:     y + h = 0
top:    -y + h = 0
near:    z + h = 0
far:    -z + h = 0
```

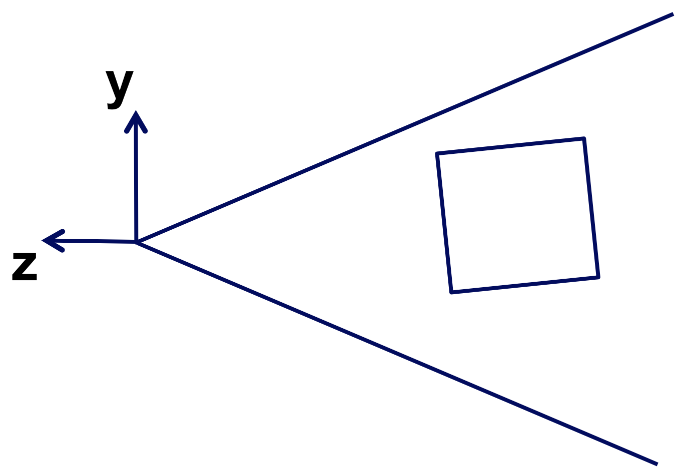


Line-Plane intersection

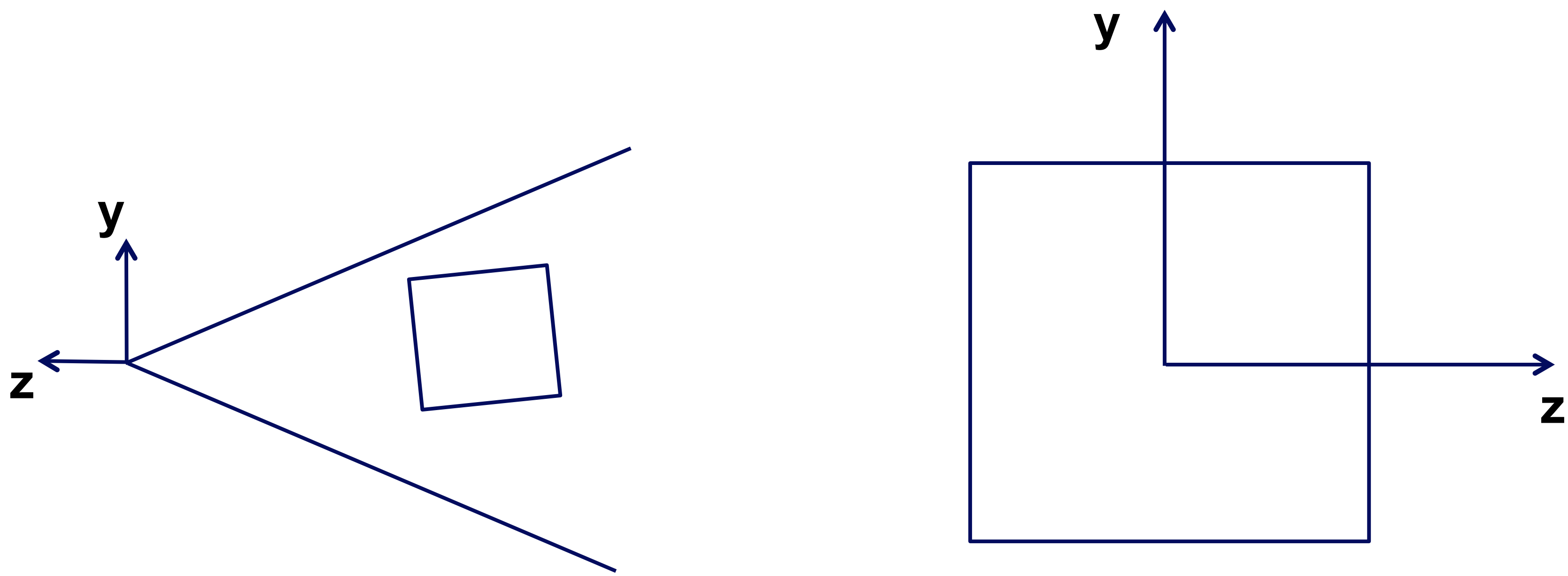


Backface Culling in VCS





Backface Culling in NDCS



Transforming Normals

Using h=0

$$\begin{bmatrix} & & & \\ & & & \\ & & & \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

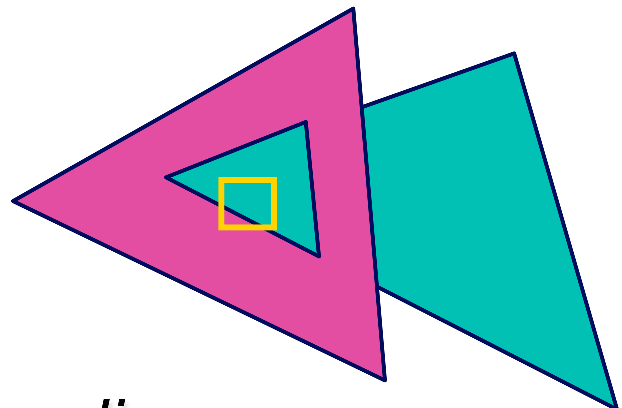
Problem

Transforming Normals

consider a plane, before and after transformation:

Occlusion

view occluded by objects in front of a given pixel or polygon ?



- image space algorithms:
  - *operate on pixels or scan-lines*
  - *visibility resolved to the precision of the display*
  - *e.g.: Z-buffer*
- object space algorithms:
  - *explicitly compute visible portions of polygons*
  - *painter's algorithm: depth-sorting, BSP trees*

Z-buffer

store (r,g,b,z) for each pixel

```
for all i,j {
 Depth[i,j] = MAX_DEPTH
 Image[i,j] = BACKGROUND_COLOUR
}
for all polygons P {
  project vertices into screen-space, i.e., DCS
  for all pixels in P {
    if (Z_pixel < Depth[i,j]) {     // closer?
      Image[i,j] = C_pixel  // overwrite pixel
      Depth[i,j] = Z_pixel  // overwrite z
    }
  }
}
```

Z-buffer

- hardware support
- extra memory
- jaggies, i.e., steps along intersections
- poor performance for high depth complexity scenes;
  - use occlusion culling to mitigate this

Occlusion Culling

- occlusion queries
  - virtual render of bounding box
- precomputed visibility tables
  - *store a list of visible cells*
- horizon maps
  - *for terrain models*

Visibility in Practice: WebGL, OpenGL

Commonly supported by hardware & OpenGL / DirectX

- view volume culling (for triangles)
- view volume clipping
- backface culling
- z-buffer occlusion test

Software, i.e., on your own

- view volume culling (for objects)
- occlusion culling

Raycasting and Raytracing

alternative to projective rendering

- for each pixel p
  - *construct ray r from eye through p*
  - *intersect r with all polygons or objects*
  - *color p according to closest surface*