# CPSC 314
# 14 – CLIPPING & RASTERIZATION

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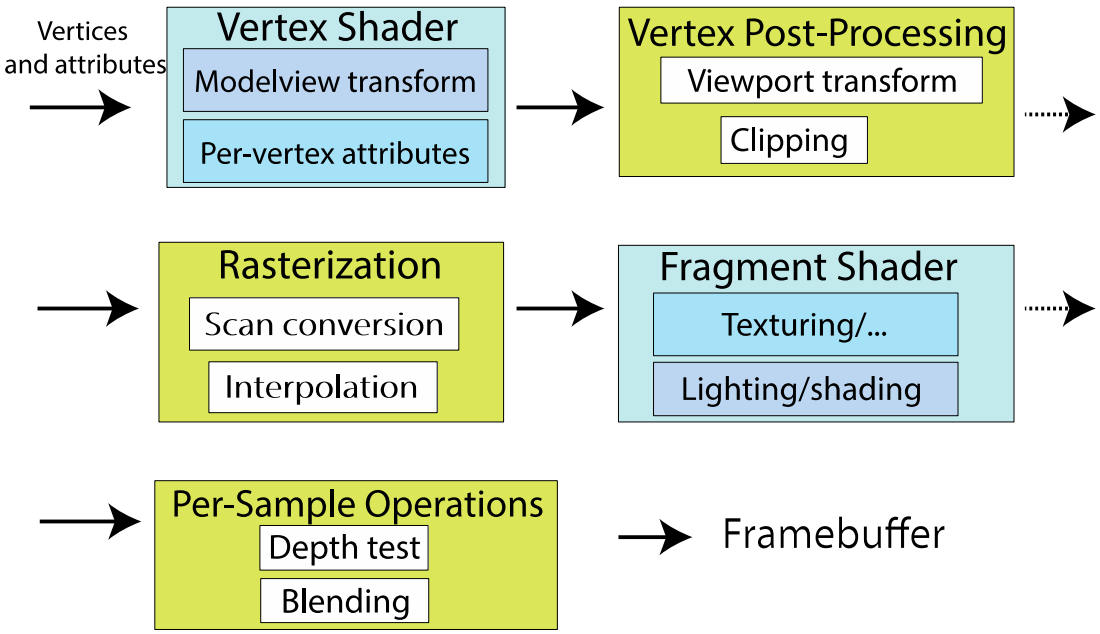
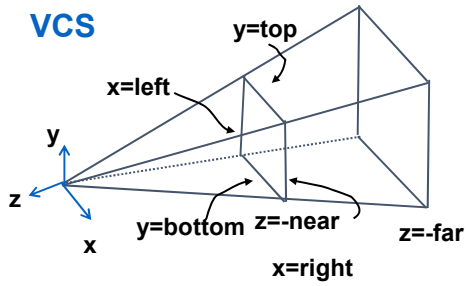
## THE RENDERING PIPELINE



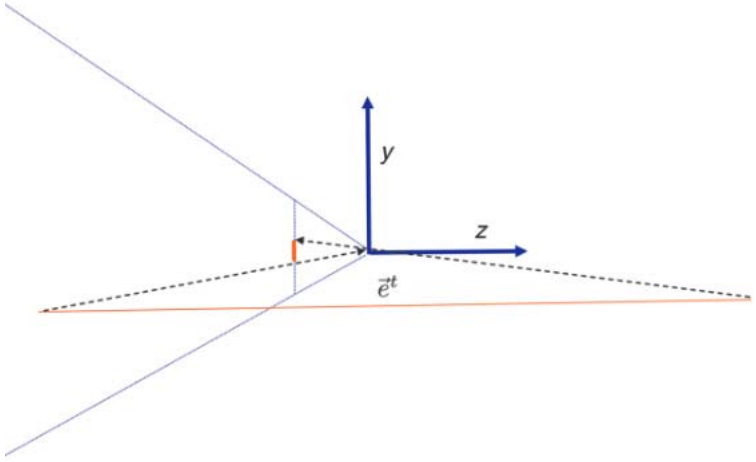
# CLIPPING

- Clip stuff outside our view volume
- Outside includes left/right, top/bottom, far, **near/front**




# CLIPPING

- More importantly, **front/near:**



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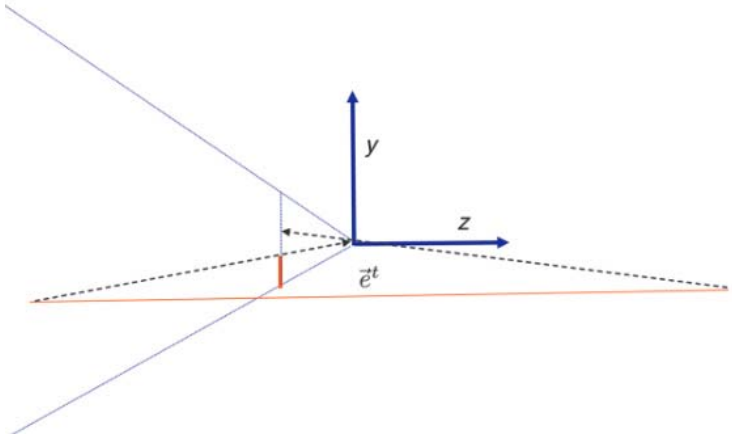


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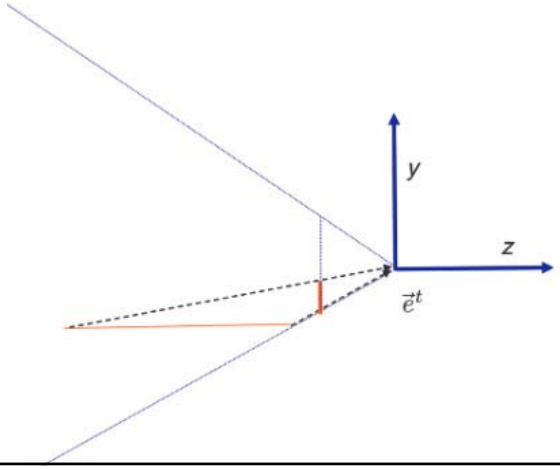

# CLIPPING

- Where to do it in pipeline?

# CLIPPING

- Option 1: Before projection
- Option 2: After NDCS
- Option 3: In between?

# CLIPPING

- ~~Option 1: Before projection~~
  - Then it would have to know all the camera info
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  - Flip already occurred
  - Too many calculations
- Option 3: In between?

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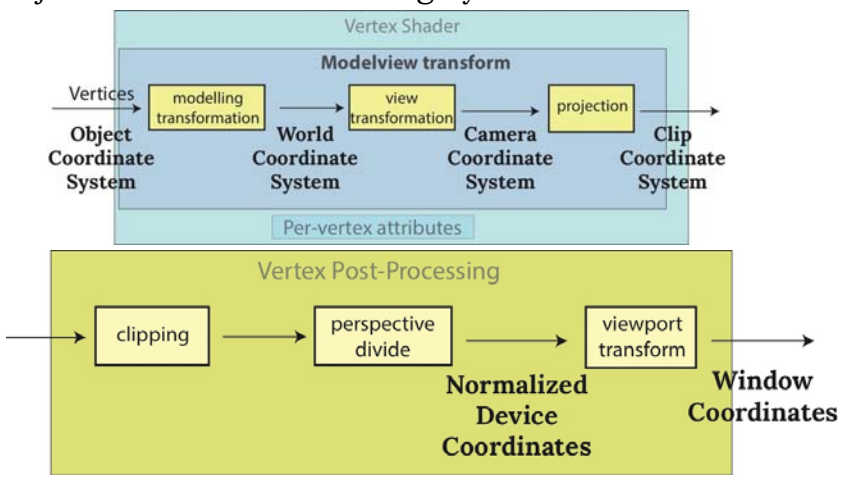
# CLIPPING

- Perform clipping in clip-coordinates!
  - After projection and before dividing by w



# CLIPPING

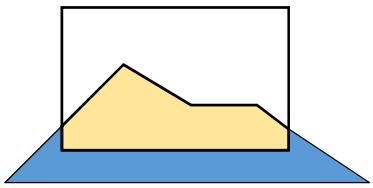
- Perform clipping in clip-coordinates!
  - After projection and before dividing by w

$$-w_c < x_c < w_c$$
$$-w_c < y_c < w_c$$
$$-w_c < z_c < w_c$$

We have not performed any divisions =>
no flip; efficiency

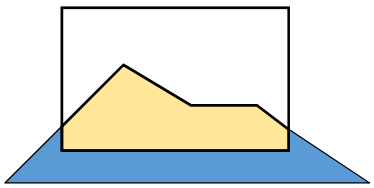
# CLIPPING: UNDER THE HOOD

- Creates new vertices
- How?



# CLIPPING: UNDER THE HOOD

- Creates new vertices
- How?
- Clip:
  - Points -> discard (easy)
  - Triangles -> clip (harder)

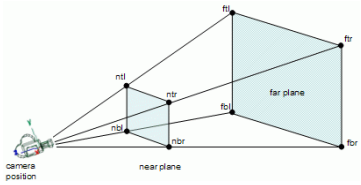


Bonus question: What is the maximal side number for triangle clipped by box? Bring an example

# CLIPPING COORDINATES

- Eye coordinates (projected) → clip coordinates → normalized device coordinates (NDCs)
- Dividing clip coordinates $(x_c, y_c, z_c, w_c)$ by the $w_c (w_c = w_n)$ component (the fourth component in the homogeneous coordinates) yields normalized device coordinates (NDCs).

$$\begin{bmatrix} x_n w_n \\ y_n w_n \\ z_n w_n \\ w_n \end{bmatrix} = \begin{bmatrix} x_c \\ y_c \\ z_c \\ w_c \end{bmatrix} = \begin{bmatrix} s_x & 0 & -c_x & 0 \\ 0 & s_y & -c_y & 0 \\ 0 & 0 & \frac{f+n}{f-n} & -\frac{2fn}{f-n} \\ 0 & 0 & -1 & 0 \end{bmatrix} \begin{bmatrix} x_e \\ y_e \\ z_e \\ 1 \end{bmatrix}$$

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# VIEWPORT MATRIX

- We need a transform that maps the lower left corner to $[-0.5, -0.5]^t$ and upper right corner to $[W - 0.5, H - 0.5]^t$

- The appropriate scale and shift can be done using the viewport matrix:

$$\begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix} = \begin{bmatrix} W/2 & 0 & 0 & (W-1)/2 \\ 0 & H/2 & 0 & (H-1)/2 \\ 0 & 0 & 1/2 & 1/2 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_n \\ y_n \\ z_n \\ 1 \end{bmatrix}$$

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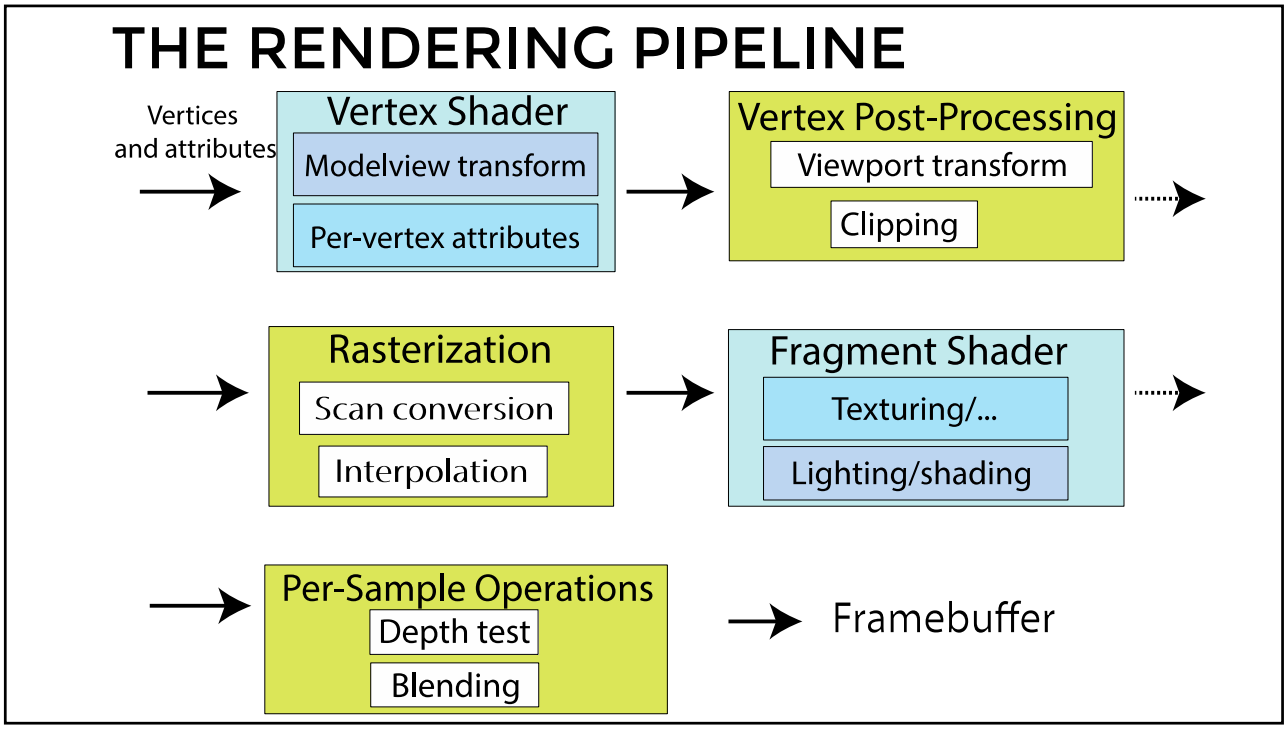
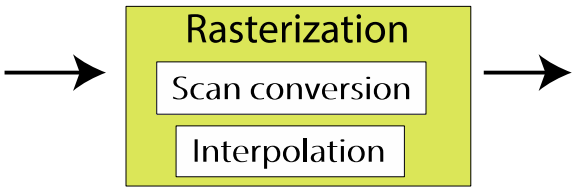



# RASTERIZATION

- This is part of the fixed function pipeline

- Input: all polygons are clipped
- Output: fragments (with **varying variables** interpolated)

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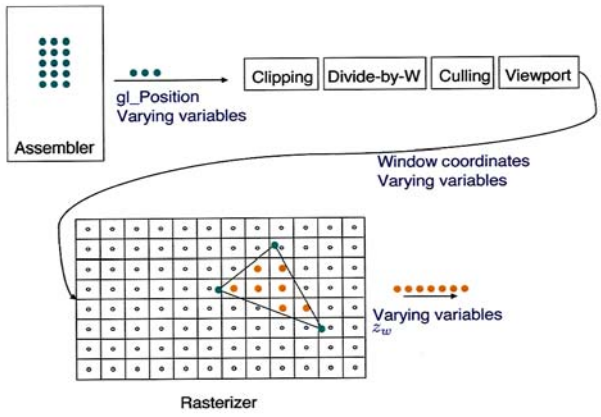
# PATH FROM VERTEX TO PIXEL

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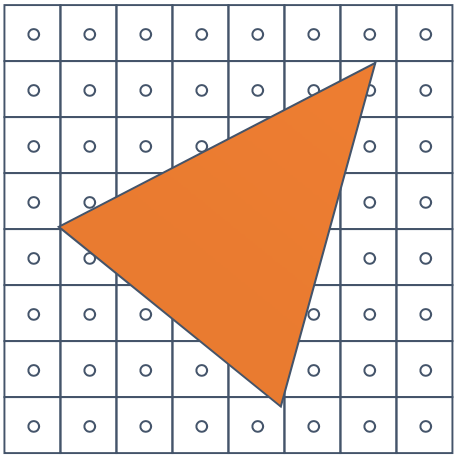
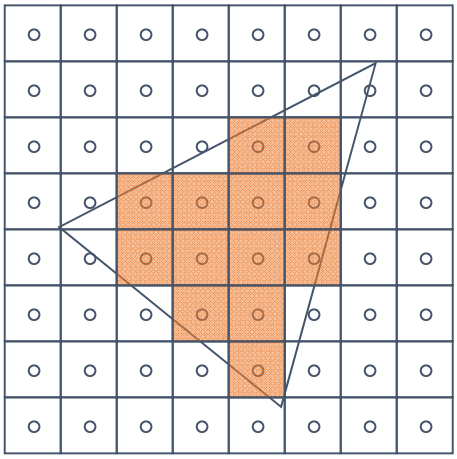
# WHAT IS SCAN CONVERSION? (A.K.A. RASTERIZATION)

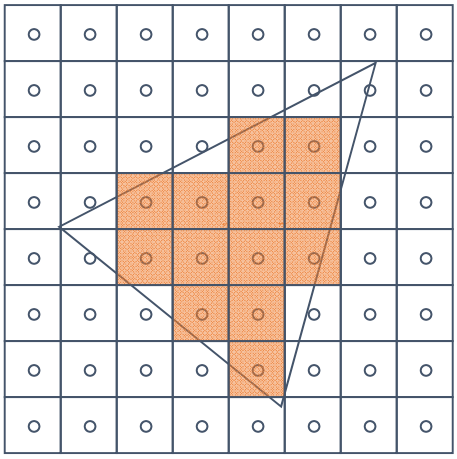
•screen is discrete



•one possible scan conversion

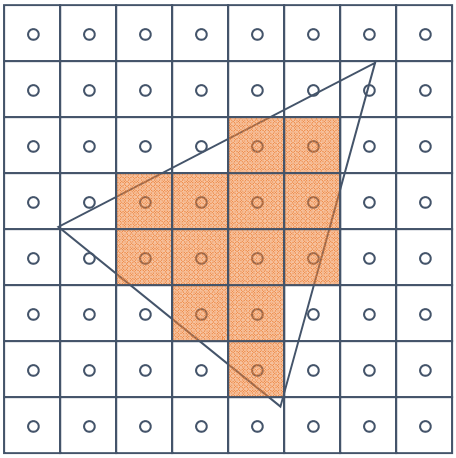


## HOW TO CHECK IF A PIXEL IS INSIDE?



# HOW TO CHECK IF A PIXEL IS INSIDE?

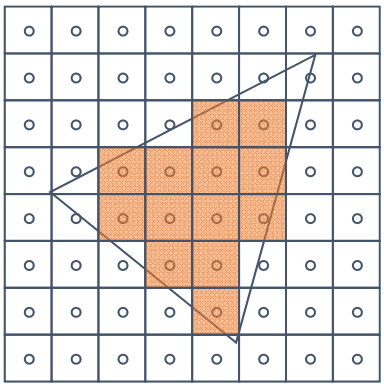
- Use implicit line equation:
  - $Ax + By + C = 0$
- How to find A,B,C?
- Orientation?



# HOW TO CHECK IF A PIXEL IS INSIDE?

A point is inside ⇔

$$A_i x + B_i y + C > 0, i = 1, \ldots, 3$$



# HOW TO TREAT BOUNDARY?

# HOW TO TREAT BOUNDARY?

- If two triangles share an edge, scan conversion should be consistent
  - No pixel drawn twice
  - No gaps
- Strategy ideas?

# BONUS 2

- With the algorithm above, what's the minimum number of pixels that will be drawn for the following triangle:

$$P_1 = (0.5,0.5)$$
$$P_2 = (99.5,100.5)$$
$$P_3 = (-98.5,100.5)$$

- Proof!
- 5 first solutions accepted; +5% to final grade

# NAÏVE SCAN CONVERSION

- Testing every pixel is suboptimal
- Better ideas?

# SCANLINE IDEA

- Basic structure of code:
  - Setup: compute edge equations, bounding box
  - (Outer loop) For each scanline in bounding box...
  - (Inner loop) ...check each pixel on scanline, evaluating edge equations and drawing the pixel if all three are positive

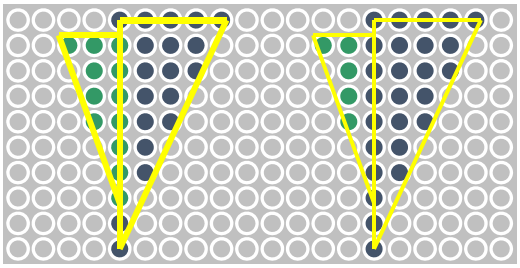
# SCANLINE: CODE

```
findBoundingBox(xmin, xmax, ymin, ymax);
setupEdges (a0,b0,c0,a1,b1,c1,a2,b2,c2);

for (int y = yMin; y <= yMax; y++) {
  for (int x = xMin; x <= xMax; x++) {
    float e0 = a0*x + b0*y + c0;
    float e1 = a1*x + b1*y + c1;
    float e2 = a2*x + b2*y + c2;
    if (e0 > 0 && e1 > 0 && e2 > 0)
        Image[x][y] = TriangleColor;
  }
}
```

# TRIANGLE RASTERIZATION ISSUES

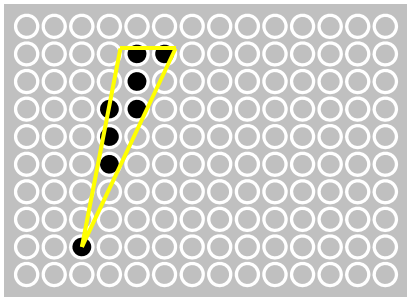
- Exactly which pixels should be lit?
- A: Those pixels inside the triangle edges
- What about pixels exactly on the edge?

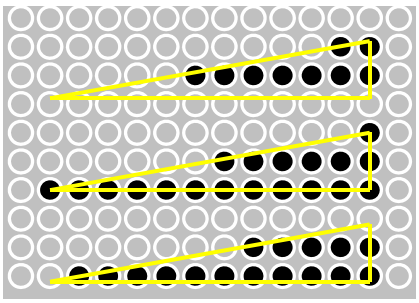


# TRIANGLE RASTERIZATION ISSUES

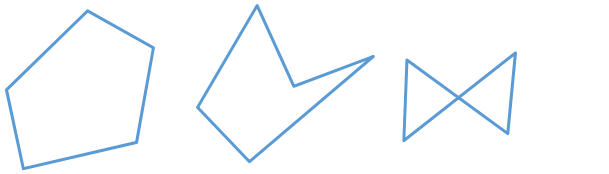
***Sliver***

- Moving Slivers





# GENERALIZATION TO POLYGONS: HOW TO TEST IF A POINT IS IN A POLYGON?



**simple convex**

**simple concave**

**non-simple (self-intersection)**