Computer Graphics (CS 4731)
Lecture 20: 2D Clipping

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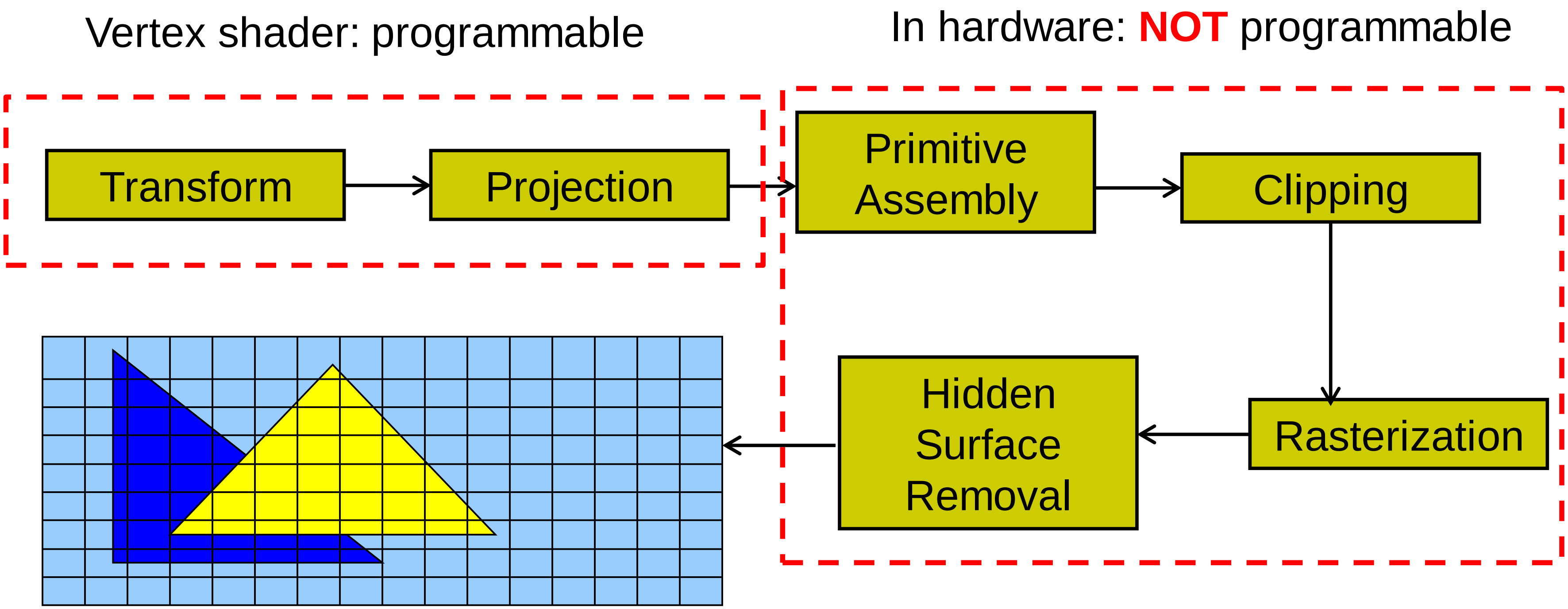
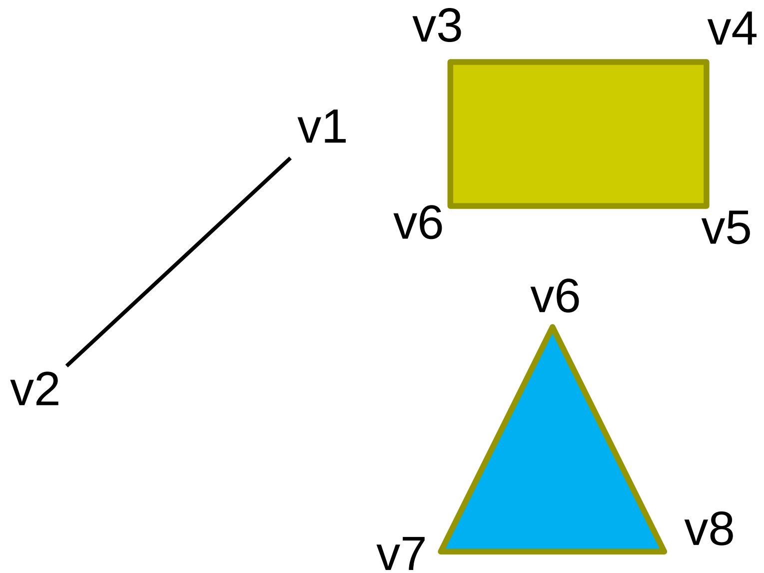
OpenGL Stages

- After projection, several stages before objects drawn to screen
- These stages are **NOT** programmable



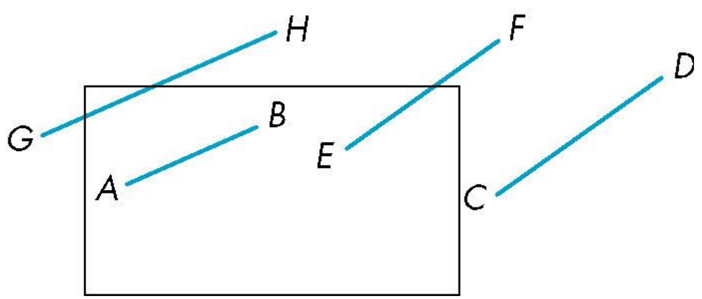
Hardware Stage: Primitive Assembly

- Up till now: Transformations and projections applied to vertices individually
- **Primitive assembly:** After transforms, projections, individual vertices grouped back into primitives
- **E.g. v6, v7 and v8** grouped back into triangle

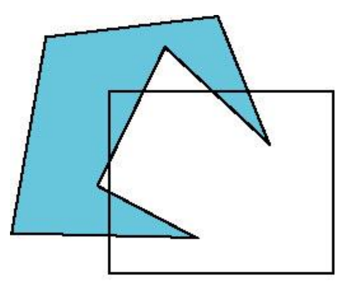


Hardware Stage: Clipping

- After primitive assembly, subsequent operations are per-primitive
- **Clipping:** Remove primitives (lines, polygons, text, curves) outside view frustum (canonical view volume)



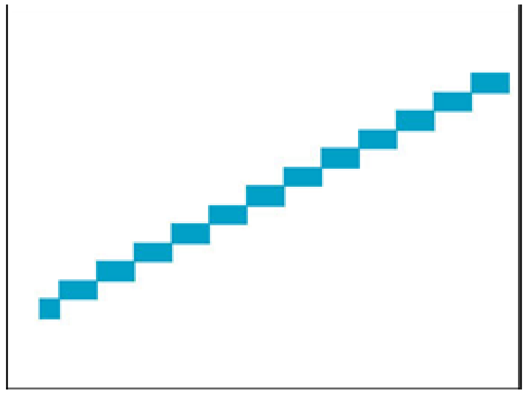
Clipping lines



Clipping polygons

Rasterization

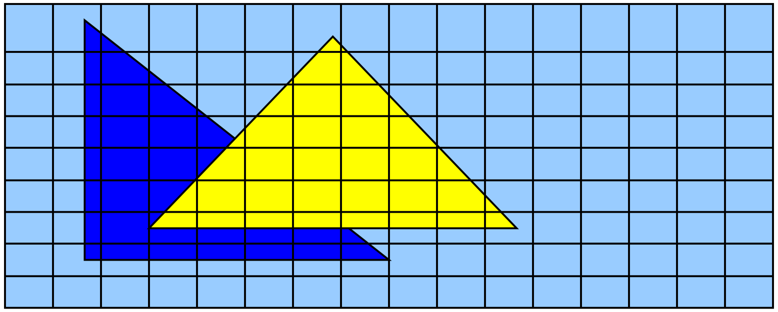
- Determine which pixels that primitives map to
  - Fragment generation
  - Rasterization or scan conversion



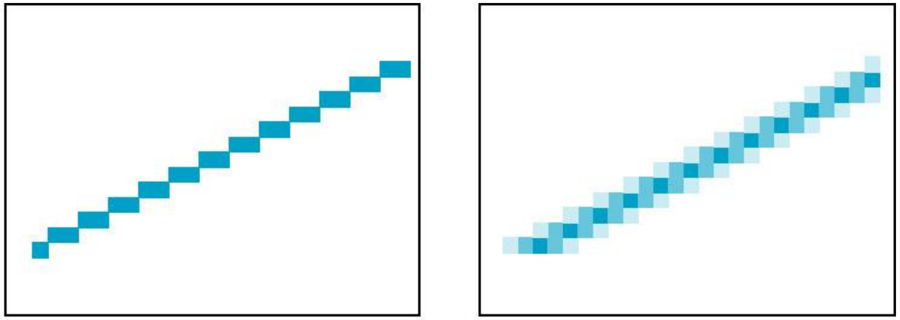
Fragment Processing

- Some tasks deferred until fragment processing

Hidden Surface Removal



Antialiasing

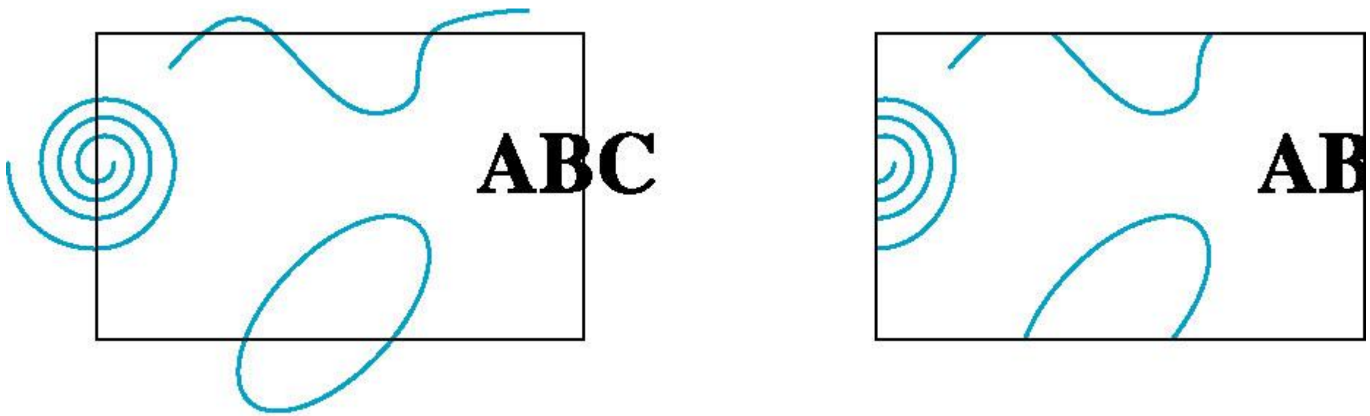


Transformation
Projection

Hidden surface Removal
Antialiasing

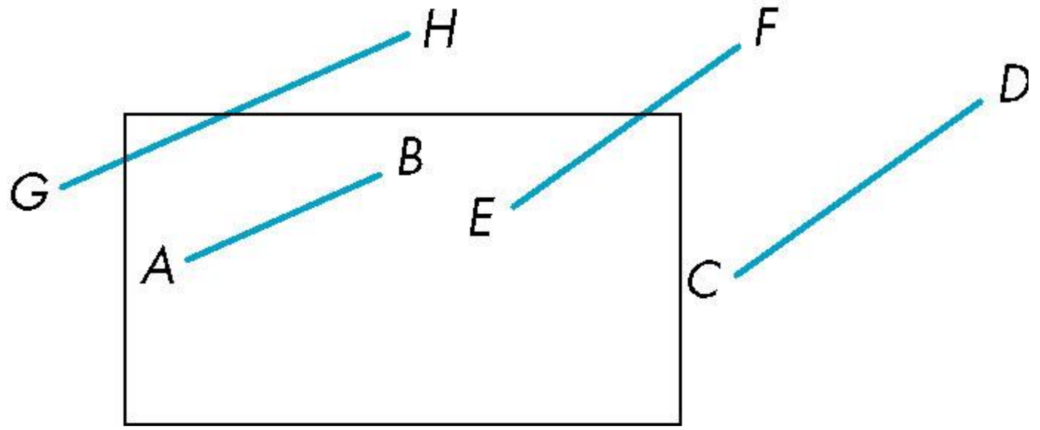
Clipping

- 2D and 3D clipping algorithms
  - 2D against clipping window
  - 3D against clipping volume
- 2D clipping
  - Lines (e.g. dino.dat)
  - Polygons
  - Curves
  - Text



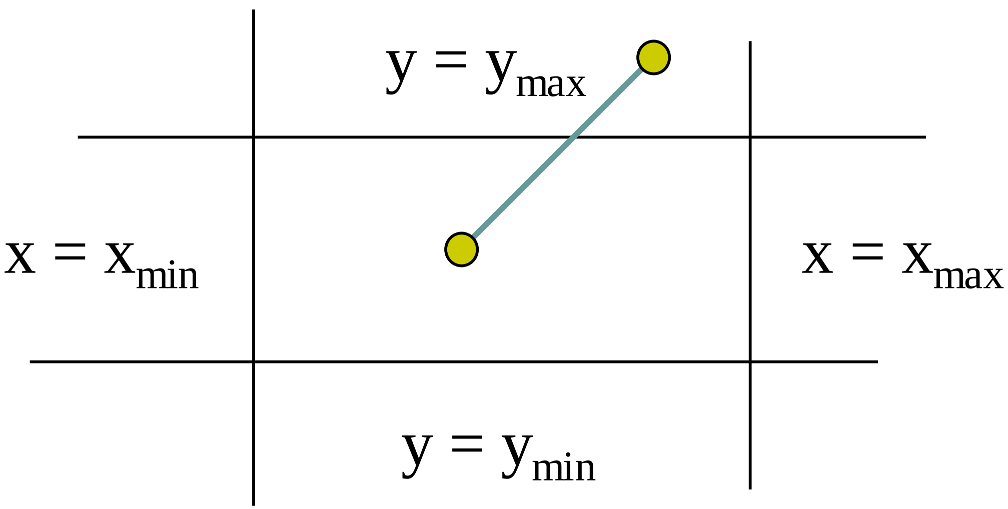
Clipping 2D Line Segments

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

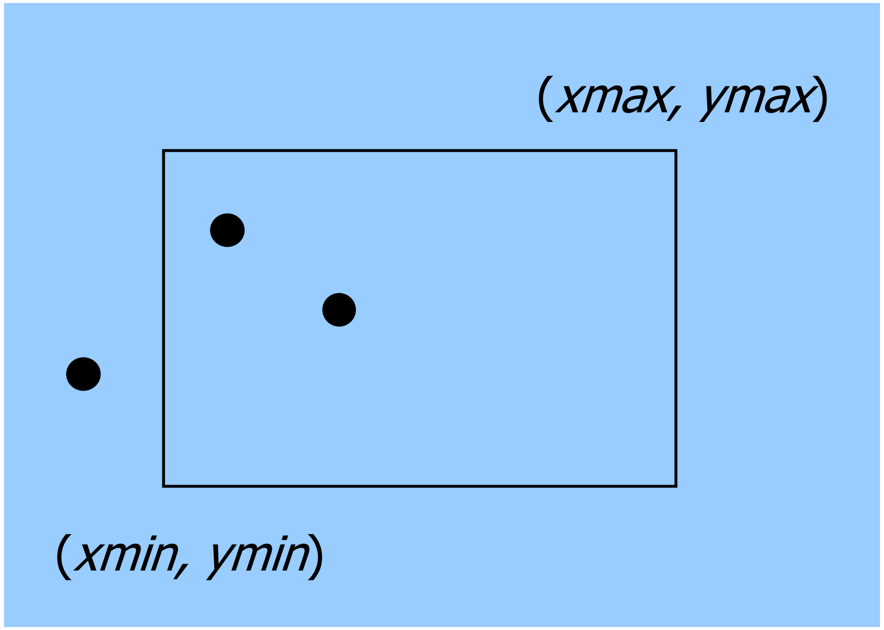


2D Clipping

- **Better Idea:** eliminate as many cases as possible without computing intersections
- Cohen-Sutherland Clipping algorithm



Clipping Points

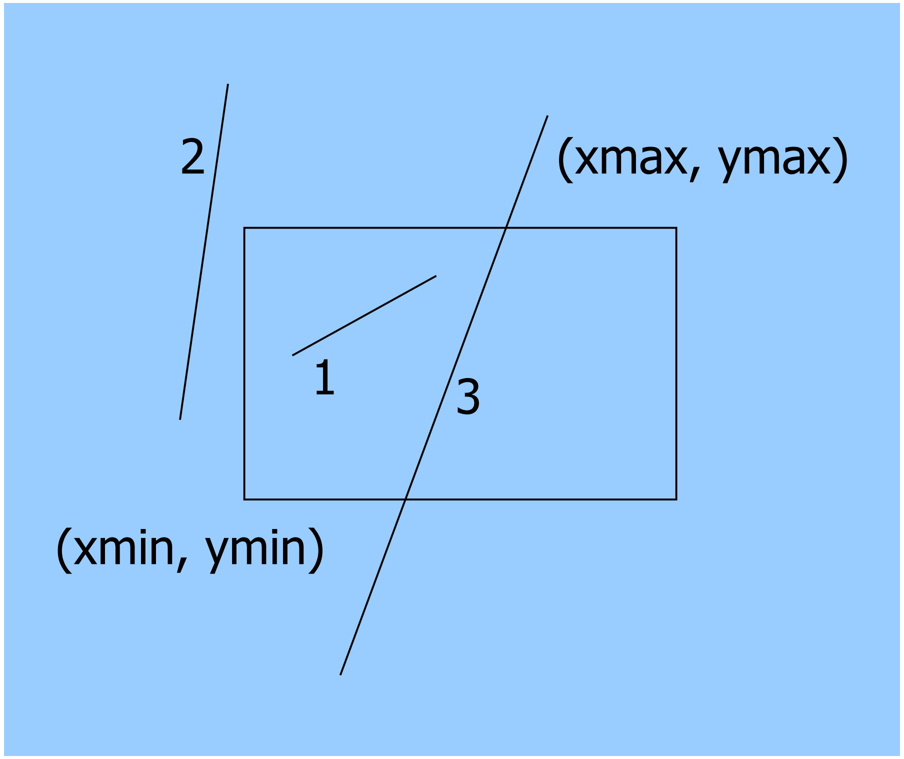


Determine whether a point (x,y) is inside or outside of the world window?

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

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

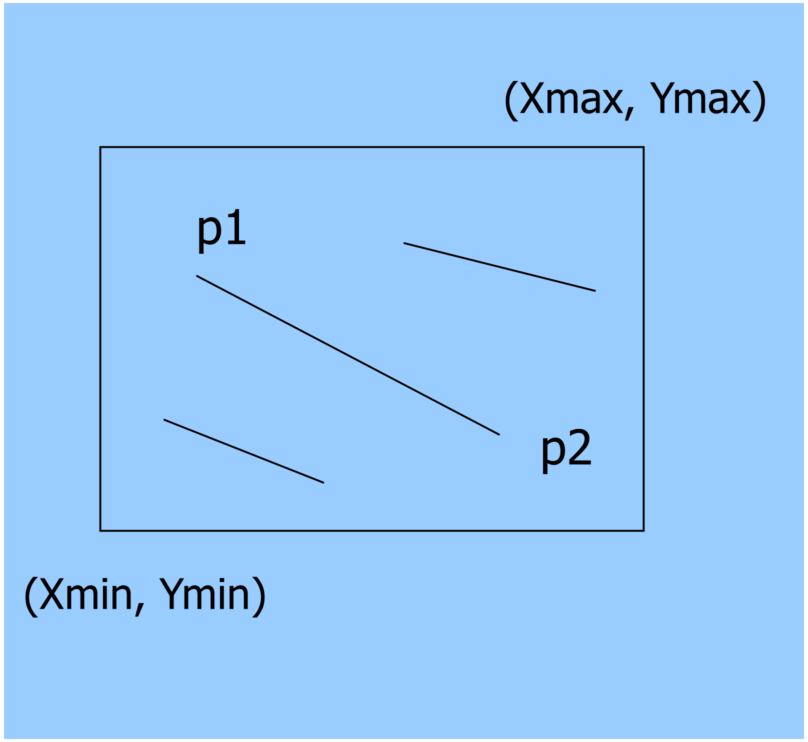
Clipping Lines



3 cases:

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

Clipping Lines: Trivial Accept



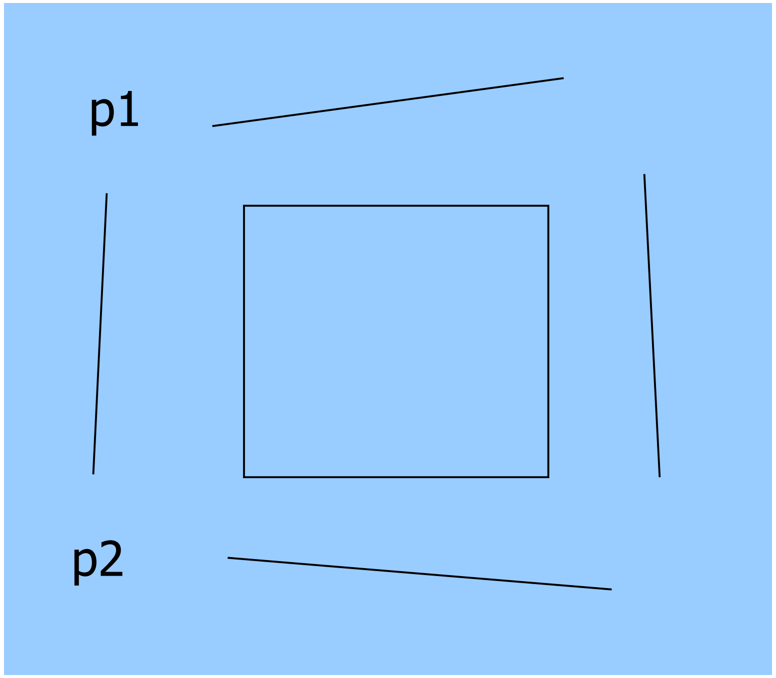
Case 1: All of line in
Test line endpoints:

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



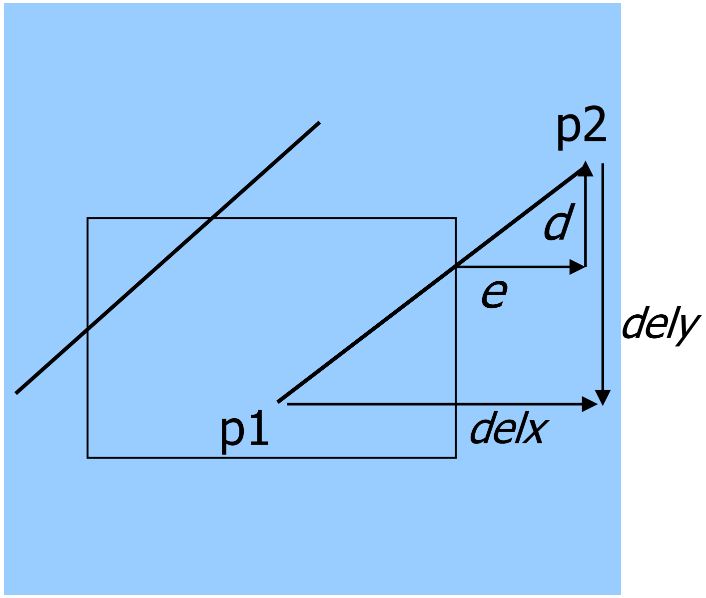
Case 2: All of line out
Test line endpoints:

- ***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

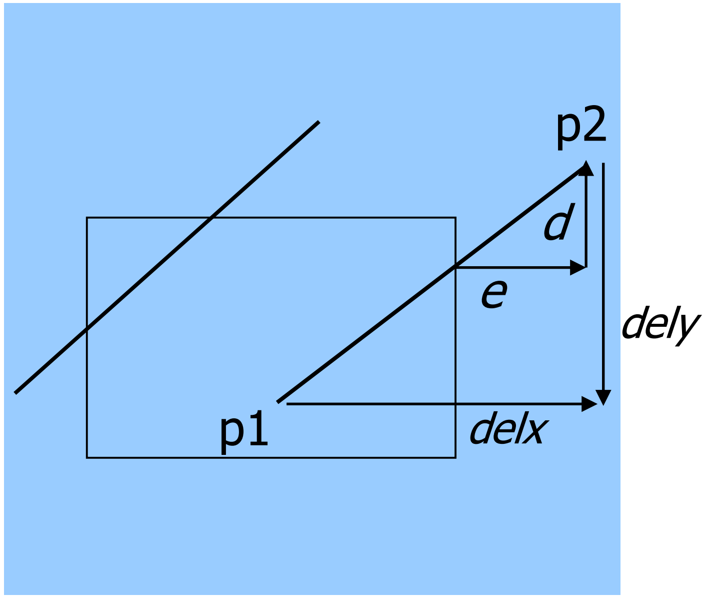
Both points out, but part of line cuts through viewport

Need to find inside segments

Use similar triangles to figure out length of inside segments

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

Clipping Lines: Calculation example



If chopping window has
(left, right, bottom, top) = (30, 220, 50, 240),
what happens when the following lines are chopped?

(a) p1 = (40,140), p2 = (100, 200)

(b) p1 = (20,10), p2 = (20, 200)

(c) p1 = (100,180), p2 = (200, 250)

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

Cohen-Sutherland pseudocode (Hill)

```
int clipSegment(Point2& p1, Point2& p2, RealRect W)
{
   do{
        if(trivial accept) return 1; // whole line survives
        if(trivial reject) return 0;  // no portion survives
        // now chop
        if(p1 is outside)
        //  find surviving segment
        {
            if(p1 is to the left) chop against left edge
            else if(p1 is to the right) chop against right edge
            else if(p1 is below) chop against the bottom edge
           else if(p1 is above) chop against the top edge
        }
```

Cohen-Sutherland pseudocode (Hill)

```
        else // p2 is outside
               // find surviving segment
        {
            if(p2 is to the left) chop against left edge
          else if(p2 is to right) chop against right edge
          else if(p2 is below) chop against the bottom edge
          else if(p2 is above) chop against the top edge
        }
    }while(1);
}
```

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3D Clipping

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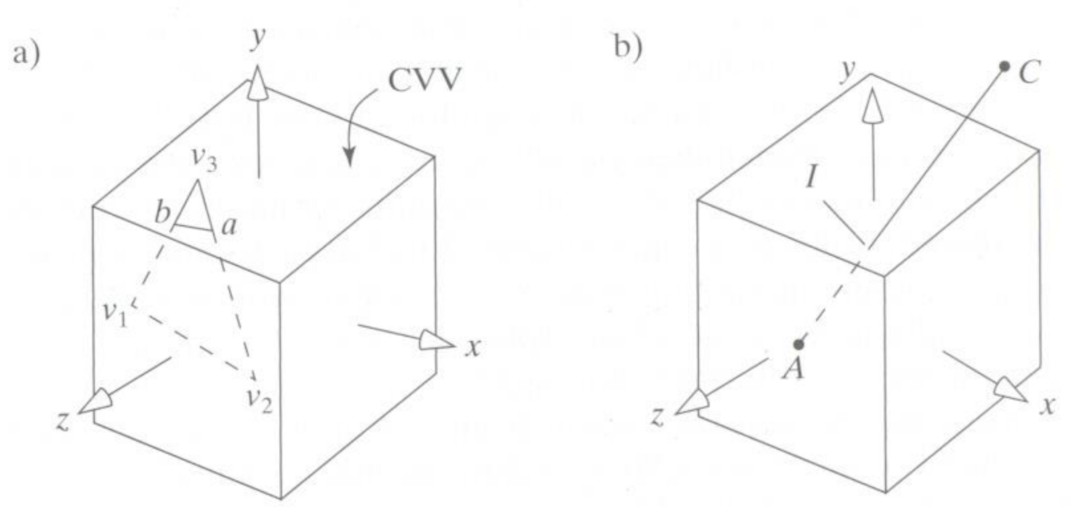
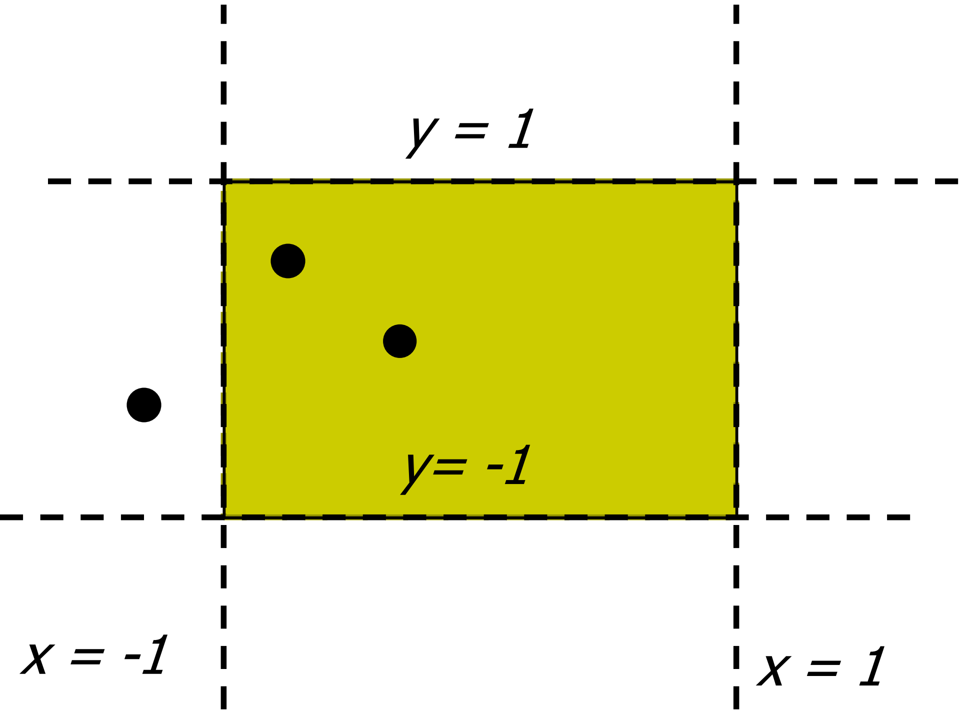
Liang-Barsky 3D Clipping

- **Goal:** Clip object edge-by-edge against Canonical View volume (CVV)
- **Problem:**
  - 2 end-points of edge: **A = (Ax, Ay, Az, Aw)** and **C = (Cx, Cy, Cz, Cw)**
  - If edge intersects with CVV, compute intersection point **I =(Ix,Iy,Iz,Iw)**



Determining if point is inside CVV



- **Problem:** Determine if point (x,y,z) is inside or outside CVV?

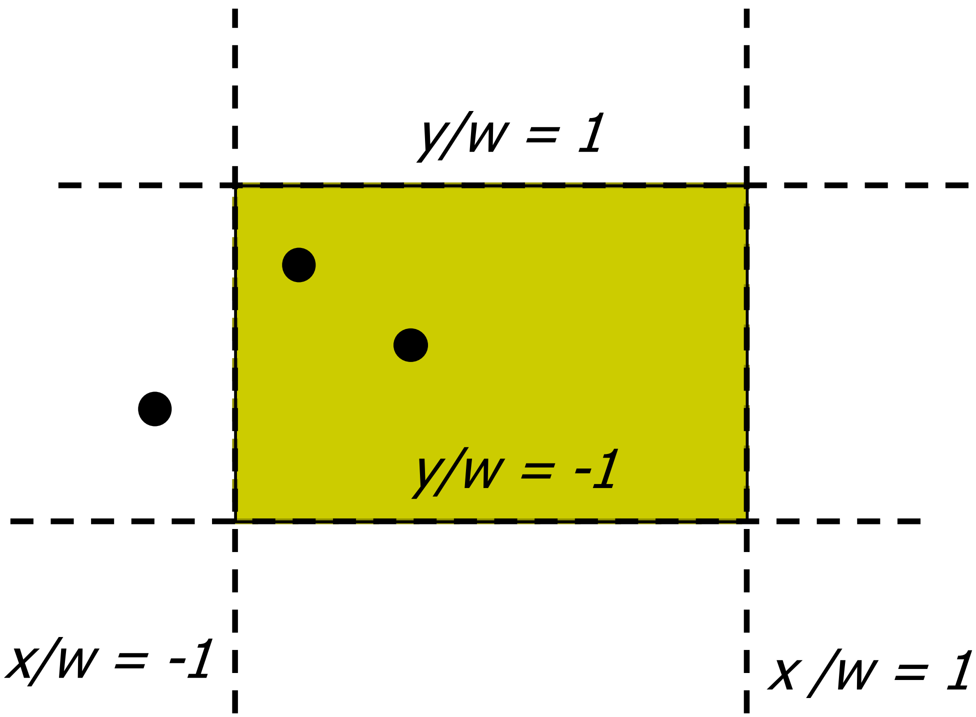
Point (x,y,z) is **inside CVV if**

(-1 <= x <= 1)
and (-1 <= y <= 1)
and (-1 <= z <= 1)

else point **is outside CVV**

- **CVV == 6 infinite planes (x=-1,1; y=-1,1; z=-1,1)**

Determining if point is inside CVV



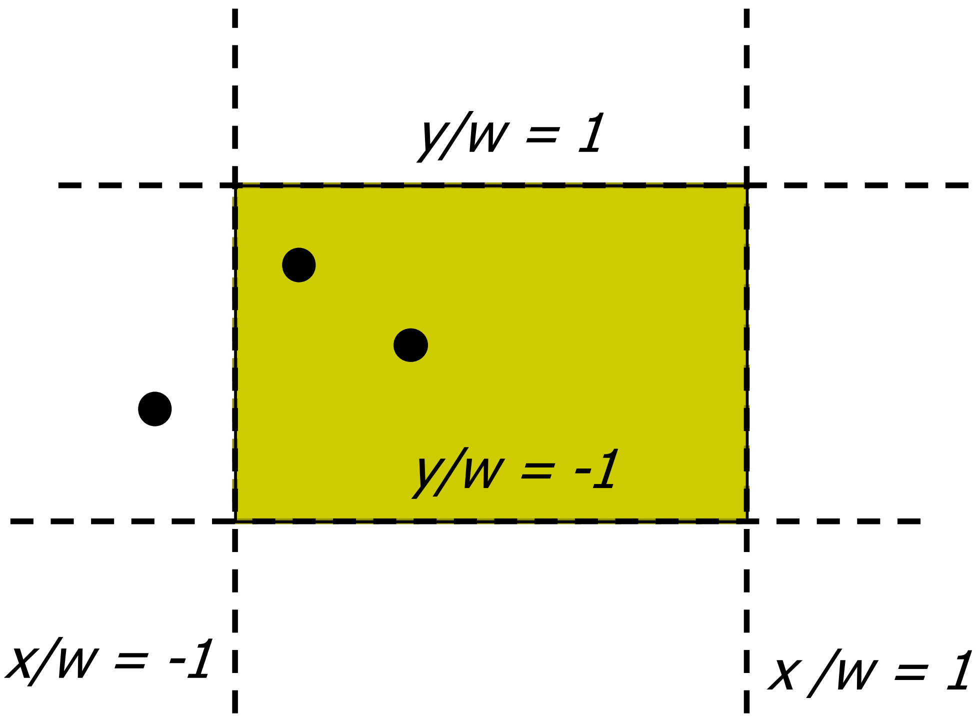
- If point specified as (x,y,z,w)
- **Test (x/w, y/w , z/w)!**

Point (x/w, y/w, z/w) is inside CVV

if (-1 <= **x/w** <= 1)
and (-1 <= **y/w** <= 1)
and (-1 <= **z/w** <= 1)

else point is outside CVV

Modify Inside/Outside Tests Slightly



Our test: (-1 < **x/w** < 1)

Point (x,y,z,w) inside plane x = 1 if

x/w < 1

=> **w – x > 0**

Point (x,y,z,w) inside plane x = -1 if

-1 < x/w

=> **w + x > 0**

Numerical Example: Inside/Outside CVV Test

- Point (x,y,z,w) is
  - inside plane x=-1 **if w+x > 0**
  - inside plane x=1 **if w – x > 0**

- Example Point (0.5, 0.2, 0.7) inside planes (x = -1,1) because - 1 <= 0.5 <= 1

- If w = 10,   (0.5, 0.2, 0.7) = (5, 2, 7, 10)
- Can either **divide by w** then test: – 1 <= 5/10 <= 1 **OR**

To test if inside   x = - 1,   **w + x** =   10 + 5 = 15   >   0

To test if inside   x = 1,   **w - x** =   10 - 5 = 5   >   0

3D Clipping

- Do same for y, z to form boundary coordinates for 6 planes as:

Boundary coordinate (BC)	**Homogenous coordinate**	**Clip plane**	**Example (5,2,7,10)**
BC0	w+x	x=-1	15
BC1	w-x	x=1	5
BC2	w+y	y=-1	12
BC3	w-y	y=1	8
BC4	w+z	z=-1	17
BC5	w-z	z=1	3

- **Consider line that goes from point A to C**
  - **Trivial accept:** 12 BCs (6 for pt. A, 6 for pt. C) > 0
  - **Trivial reject:** Both endpoints outside (-ve) for same plane

References

- Angel and Shreiner, Interactive Computer Graphics, 6th edition
- Hill and Kelley, Computer Graphics using OpenGL, 3rd edition