Computer Graphics (CS 543): 2D Clipping

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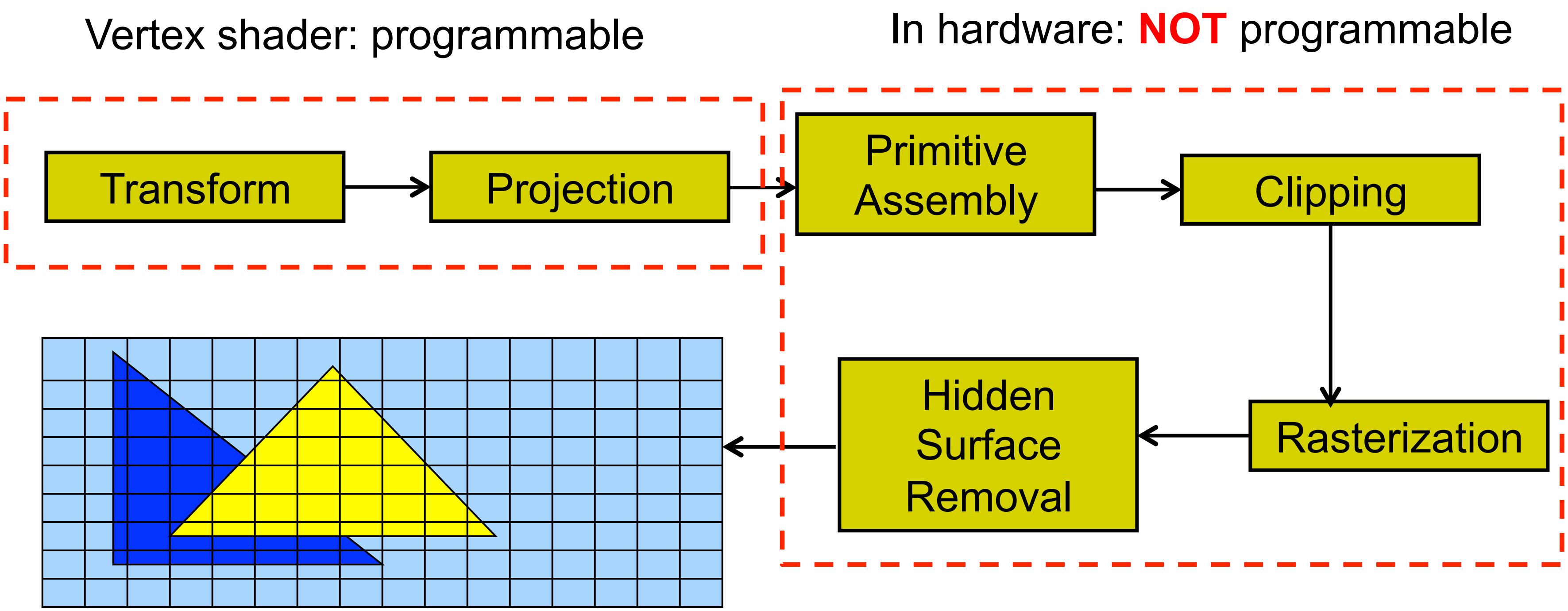
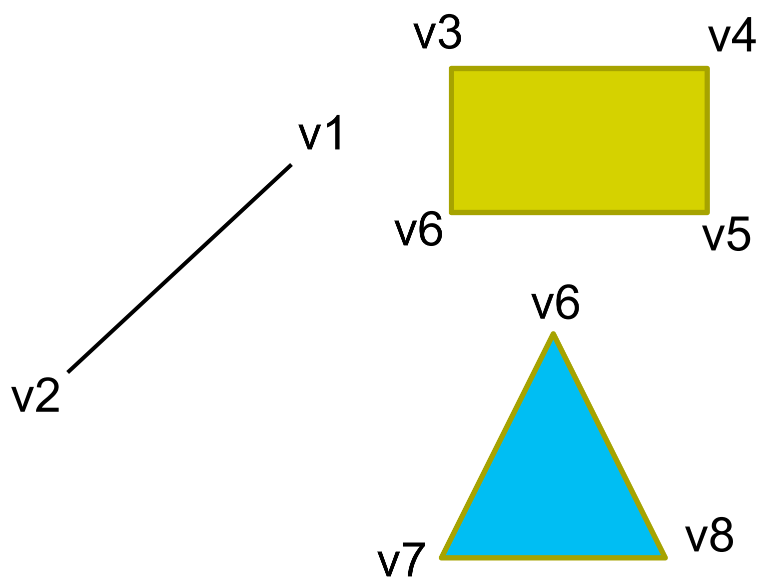
OpenGL Stages

- After projection, several stages before objects drawn to screen
- These stages are non-programmable



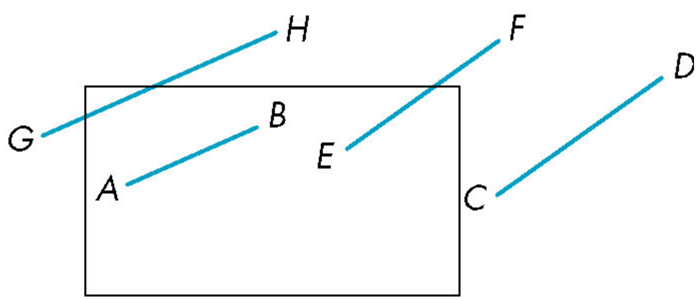
Hardware Stage: Primitive Assembly

- Up until 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

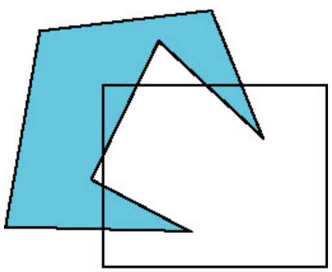


Hardware Stage: Clipping

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



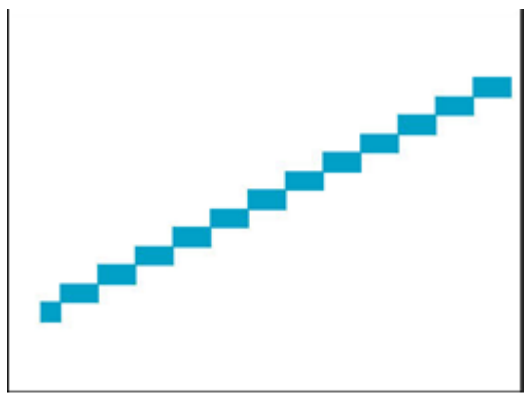
Clipping lines



Clipping polygons

Rasterization

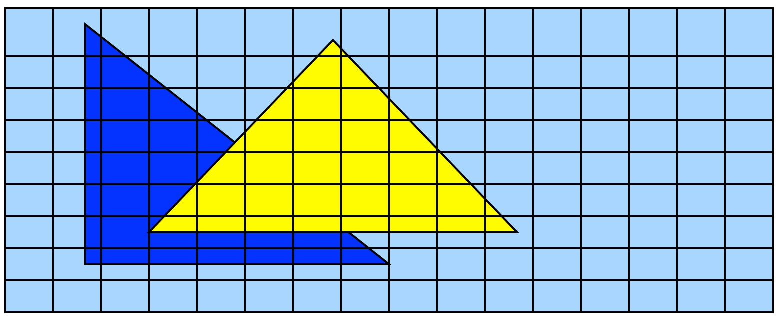
- Determine which pixels that primitives map to
  - Fragment generation
  - Rasterization or scan conversion



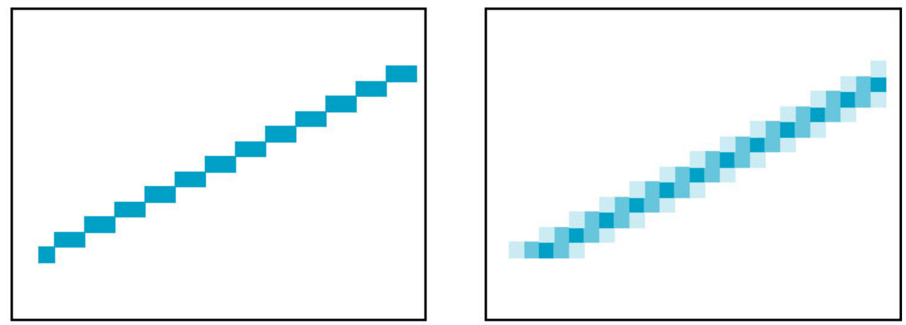
Fragment Processing

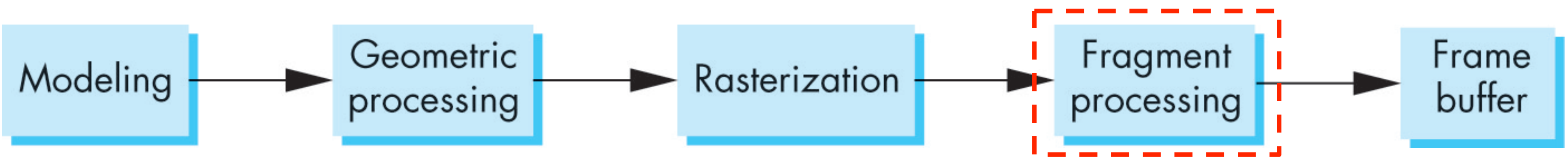
- Some tasks deferred until fragment processing

Hidden Surface Removal



Antialiasing



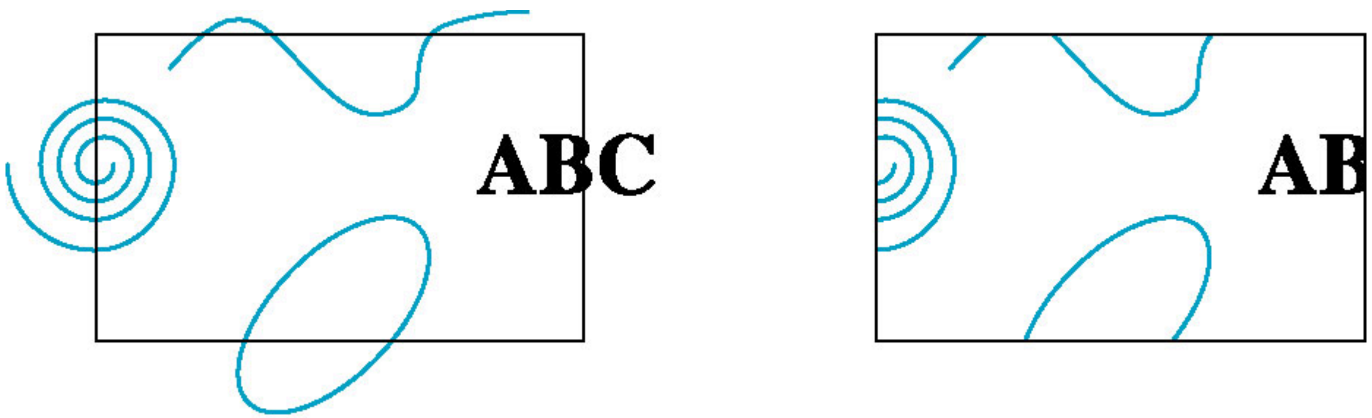


Transformation
Projection

Hidden surface Removal
Antialiasing

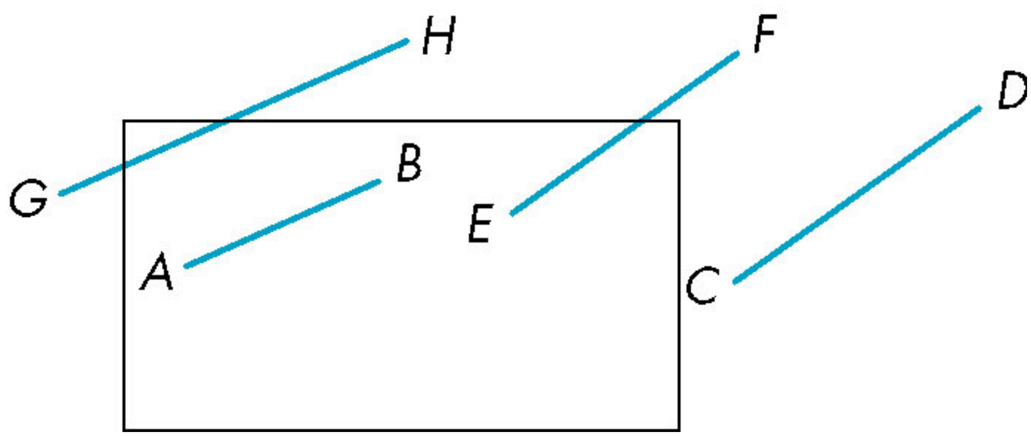
Clipping

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



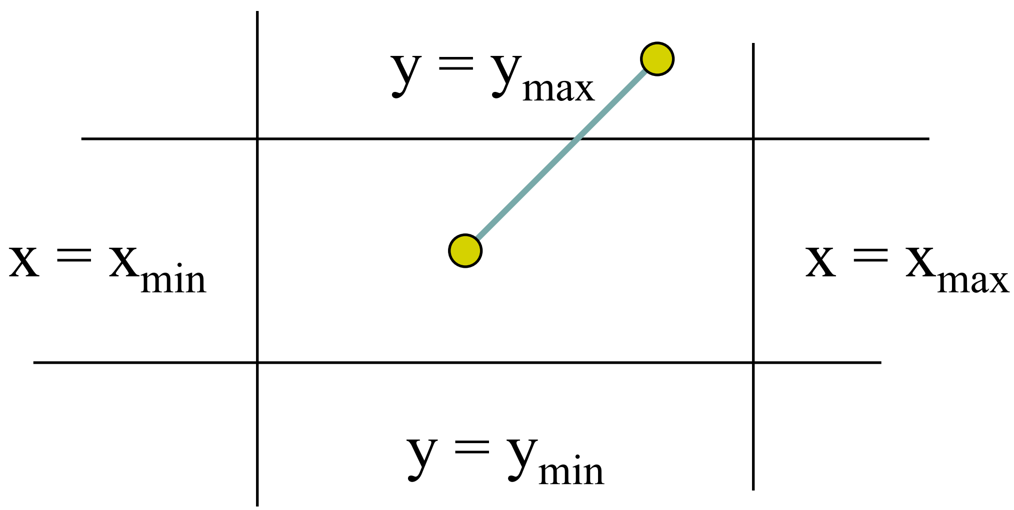
Clipping 2D Line Segments

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

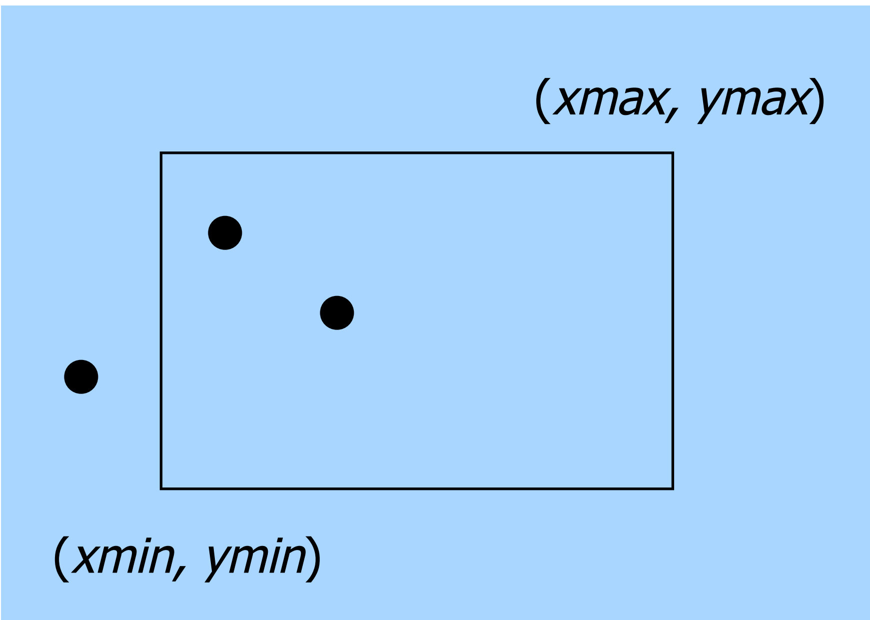


2D Clipping

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



Clipping Points

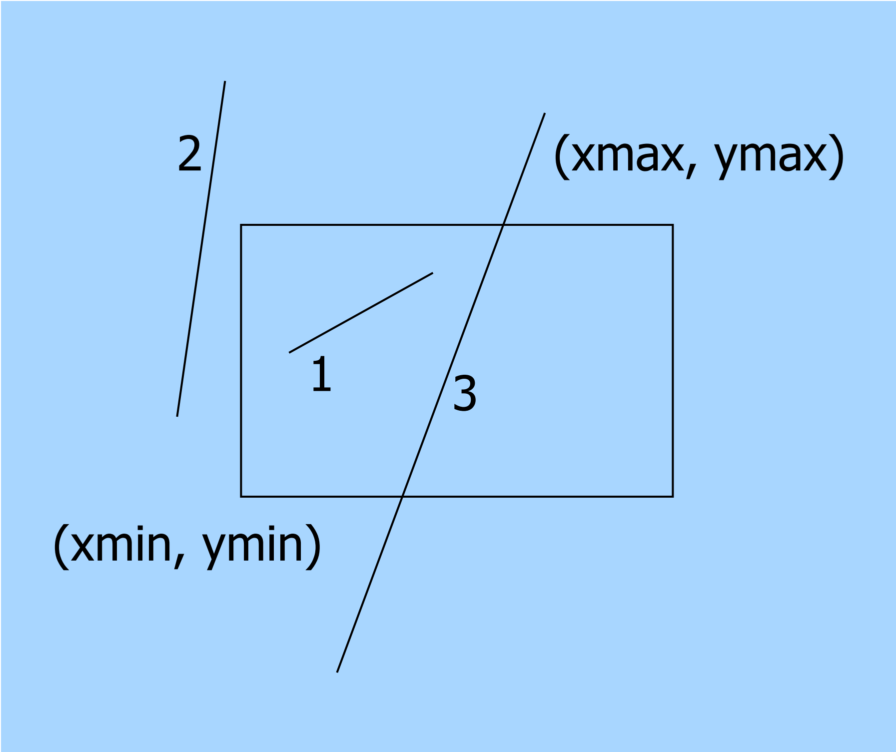


Determine whether a point (x,y) is inside or outside of the world window?

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

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

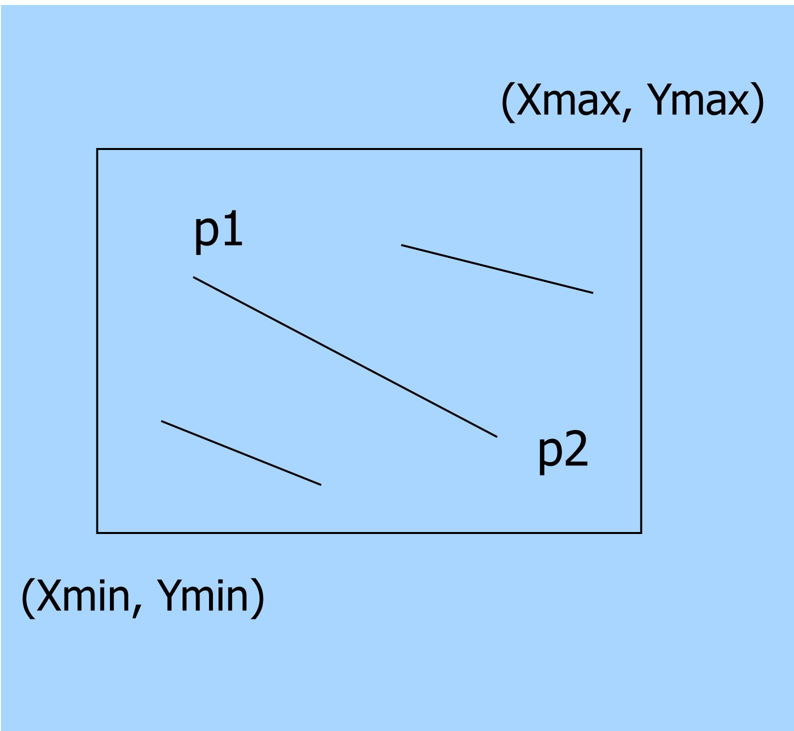
Clipping Lines



3 cases:

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

Clipping Lines: Trivial Accept



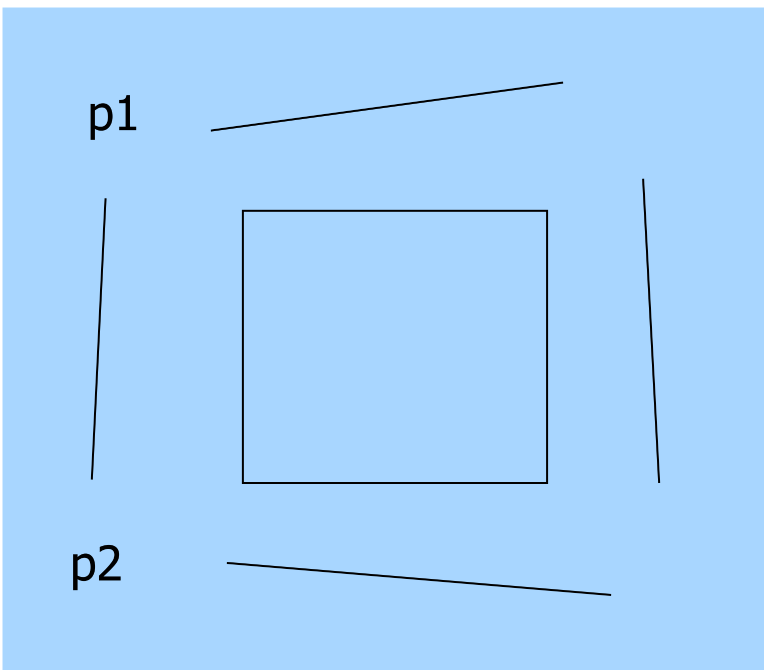
Case 1: All of line in
Test line endpoints:

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



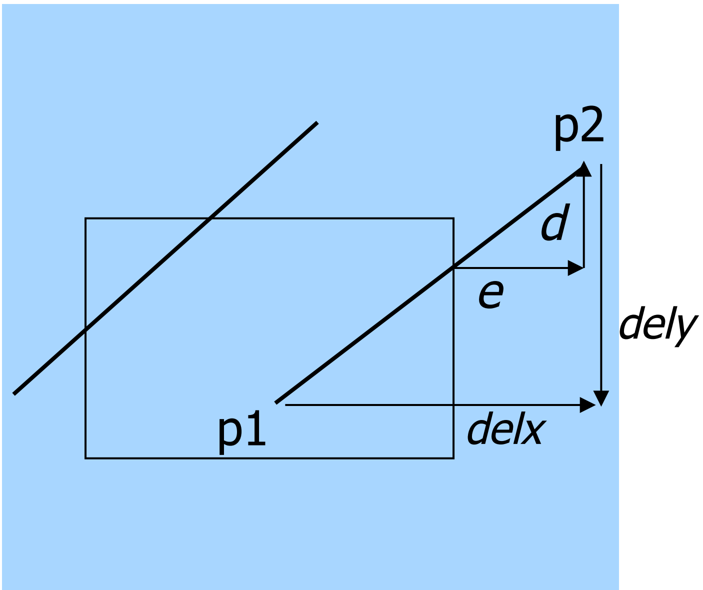
Case 2: All of line out
Test line endpoints:

- ***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:

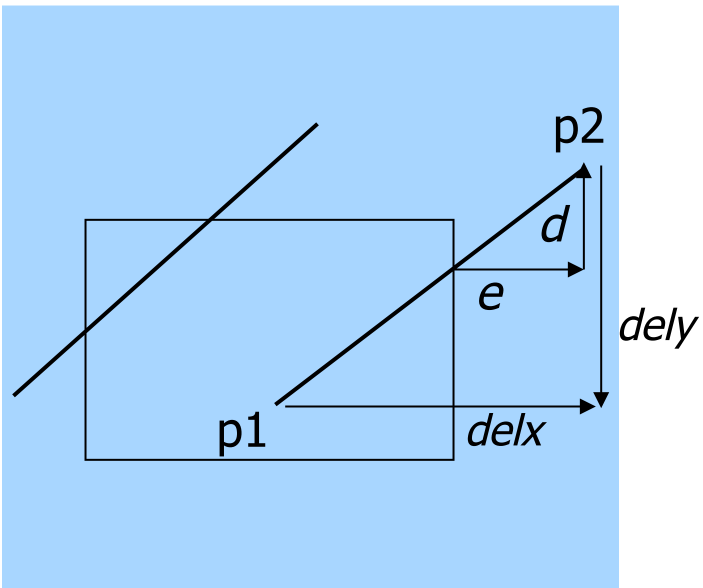
- One point in, other out
- Both points out, but part of line cuts through viewport

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



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

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)

Cohen-Sutherland Pseudocode

```
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
        // Otherwise 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

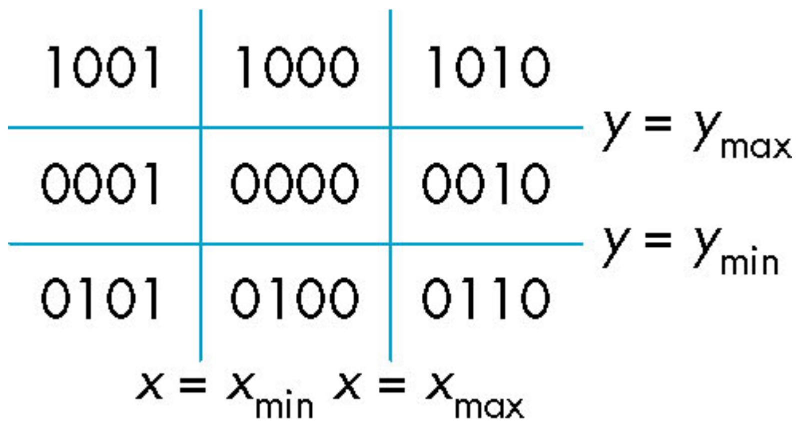
```
        else // p2 is outside
        // find surviving segment
        {
             if( p2 is to the left ) chop against left edge
             else if( p2 is to right ) chop against right edge
             else if( p2 is below ) chop against the bottom edge
             else if( p2 is above )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

Using Outcodes to Speed Up Comparisons

- Encode each endpoint into outcode (what quadrant)

$$b_0b_1b_2b_3$$

$$b_0 = 1 \text{ if } y > y_{max}, \text{ 0 otherwise}$$
$$b_1 = 1 \text{ if } y < y_{min}, \text{ 0 otherwise}$$
$$b_2 = 1 \text{ if } x > x_{max}, \text{ 0 otherwise}$$
$$b_3 = 1 \text{ if } x < x_{min}, \text{ 0 otherwise}$$



- Outcodes divide space into 9 regions
- Trivial accept/reject becomes bit-wise comparison

References

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