Computer Graphics (CS 543)
Lecture 11 (Part 2): Clipping

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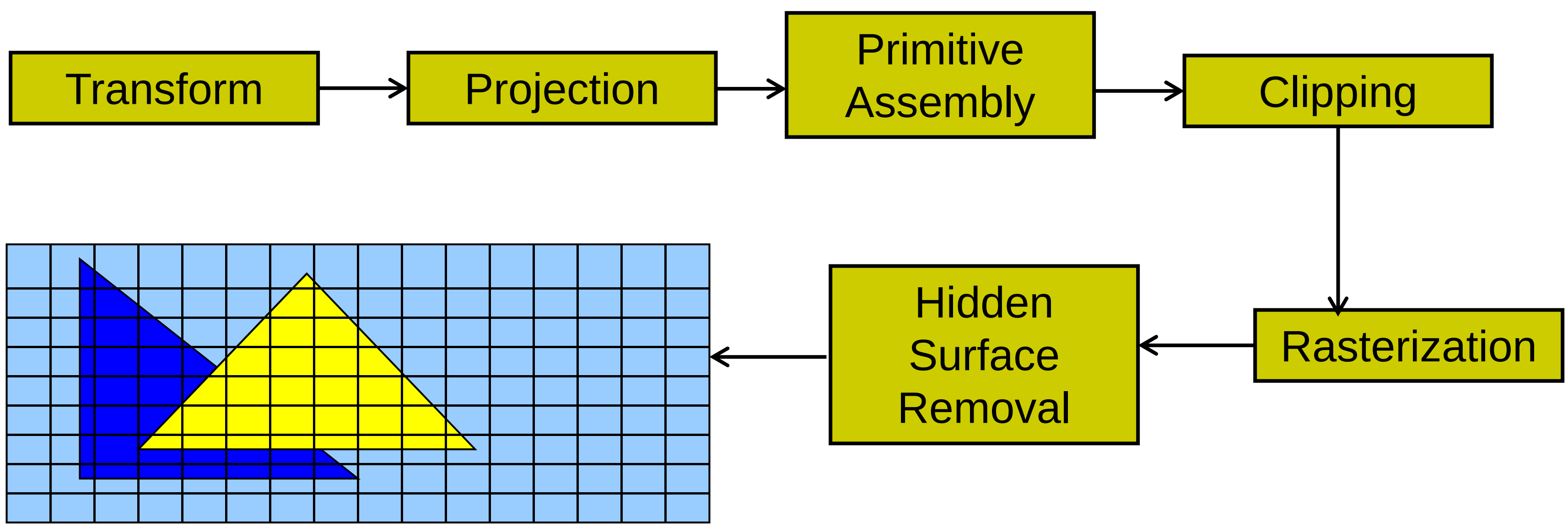
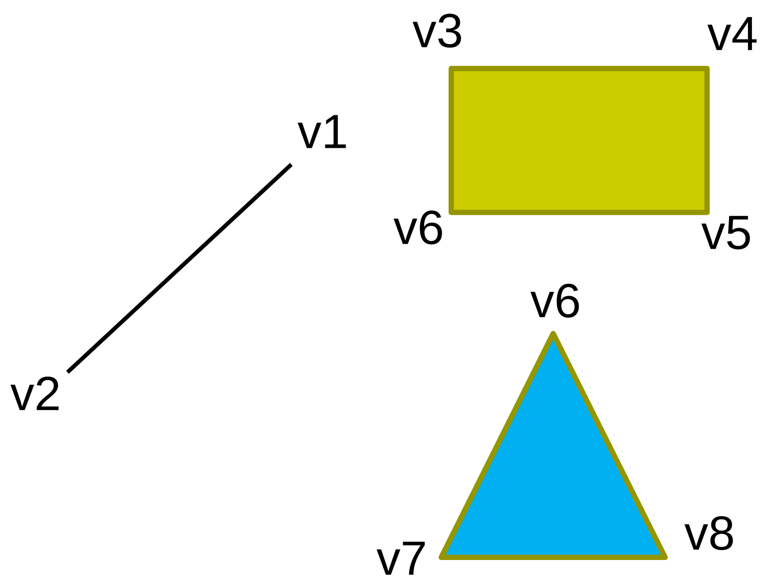
OpenGL Stages

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



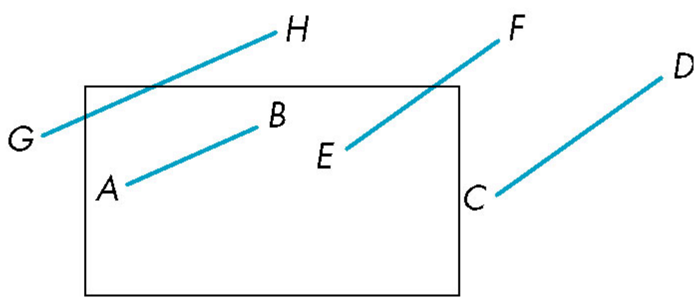
Primitive Assembly

- 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

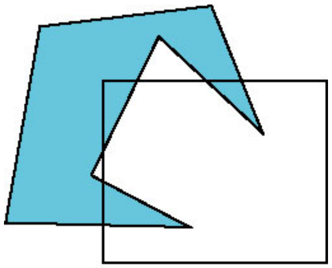


Clipping

- Subsequent operations necessary before display occur per-primitive
- **Clipping:** Remove primitives (lines, polygons, text, curves) outside view frustum



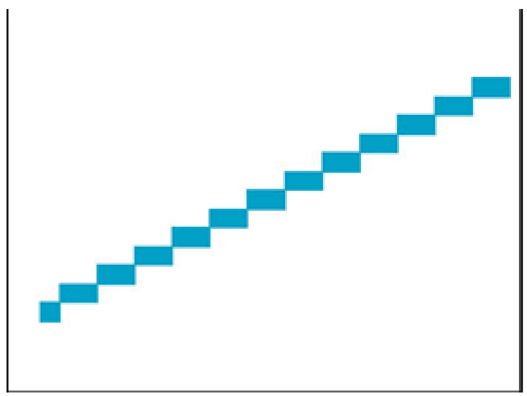
Clipping lines



Clipping polygons

Rasterization

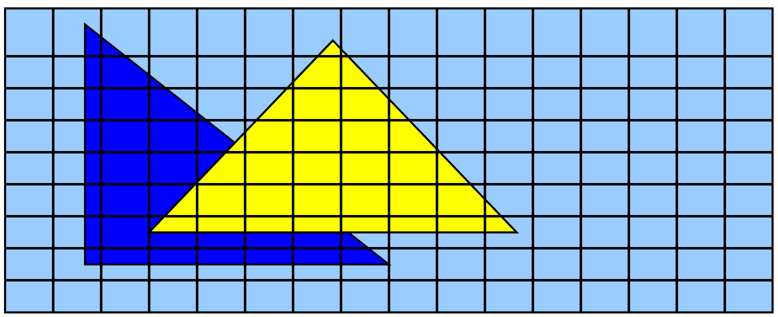
- Determine which pixels that primitives map to
  - Fragment generation
  - Rasterization or scan conversion



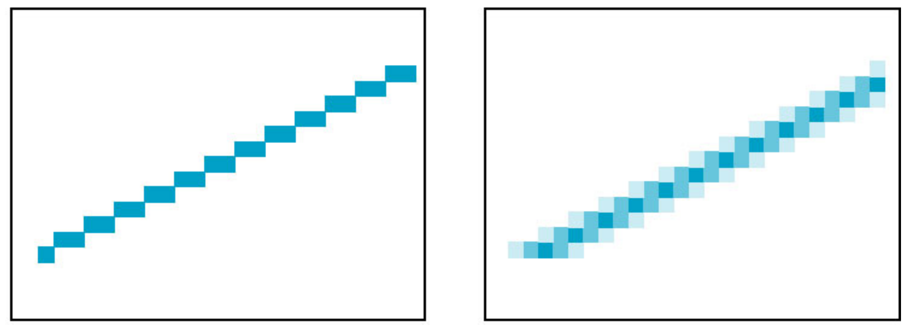
Fragment Processing

- Some tasks deferred until fragment processing

Hidden Surface Removal



Antialiasing

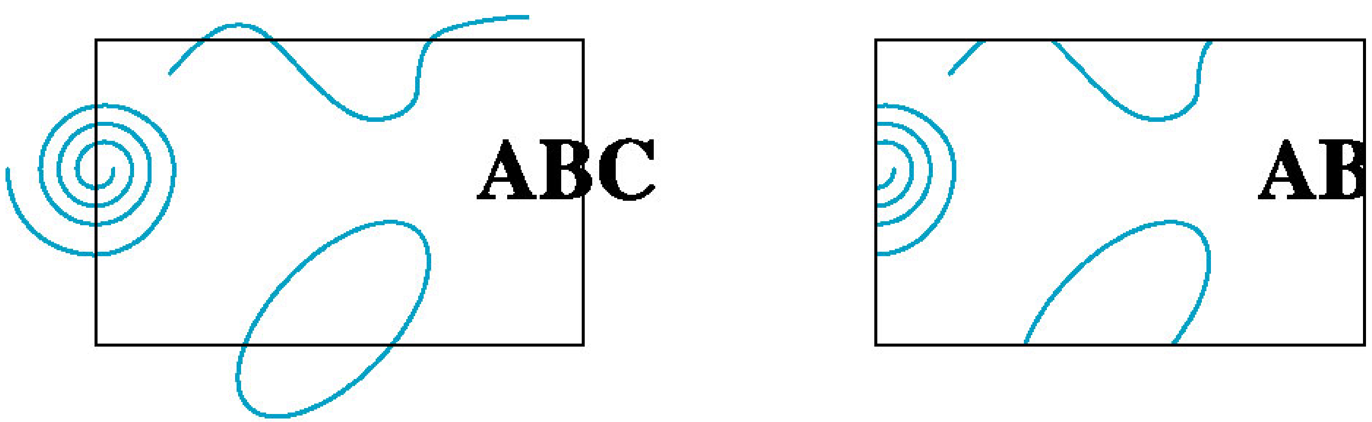


Transformation
Projection

Hidden surface Removal
Antialiasing

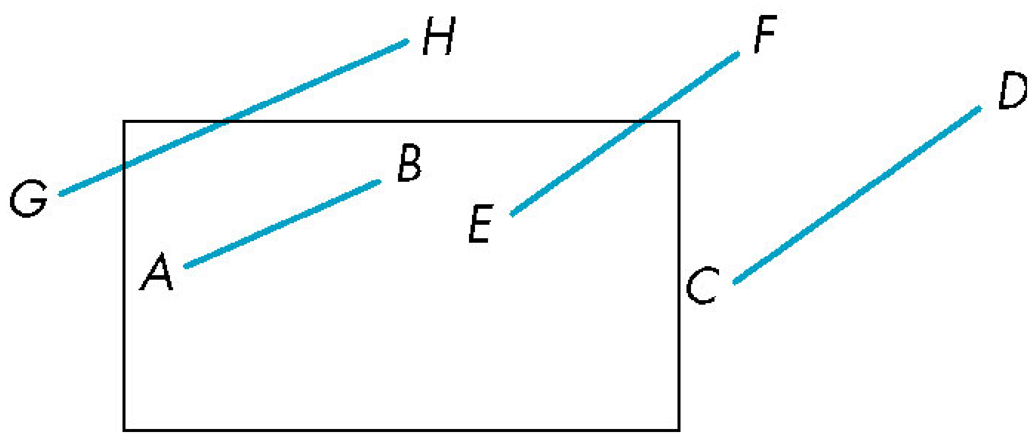
Clipping

- 2D and 3D clipping algorithms
  - 2D against clipping window
  - 3D against clipping volume
- 2D clipping
  - Lines
  - Polygons
  - Curves
  - Text



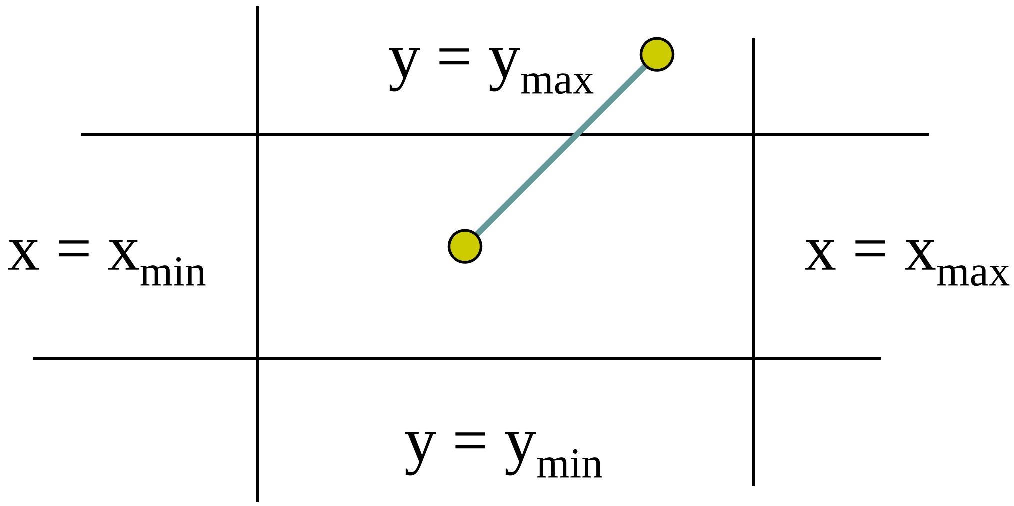
Clipping 2D Line Segments

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

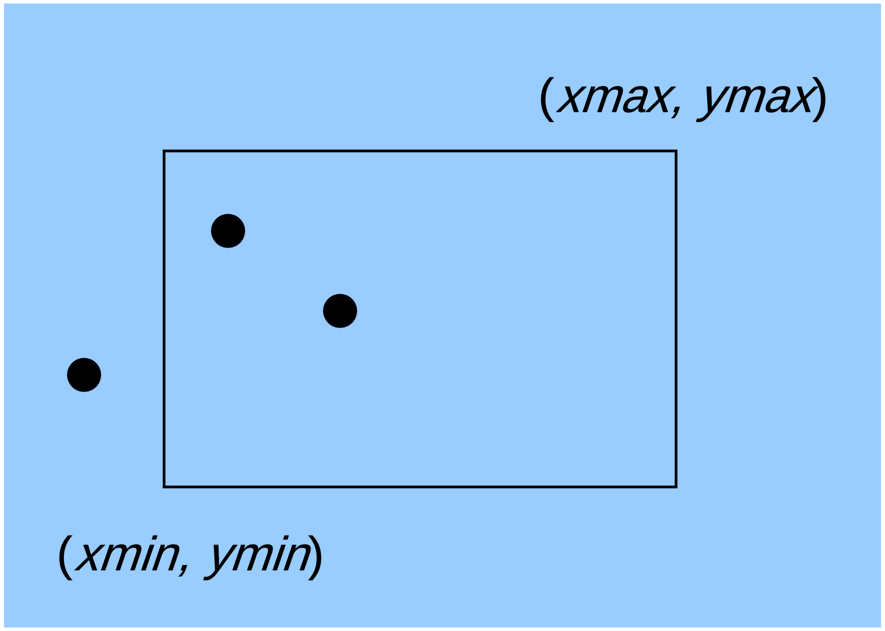


2D Clipping: Cohen-Sutherland Algorithm

- Idea: eliminate as many cases as possible without computing intersections
- Start with four lines that determine the sides of the clipping window



Clipping Points

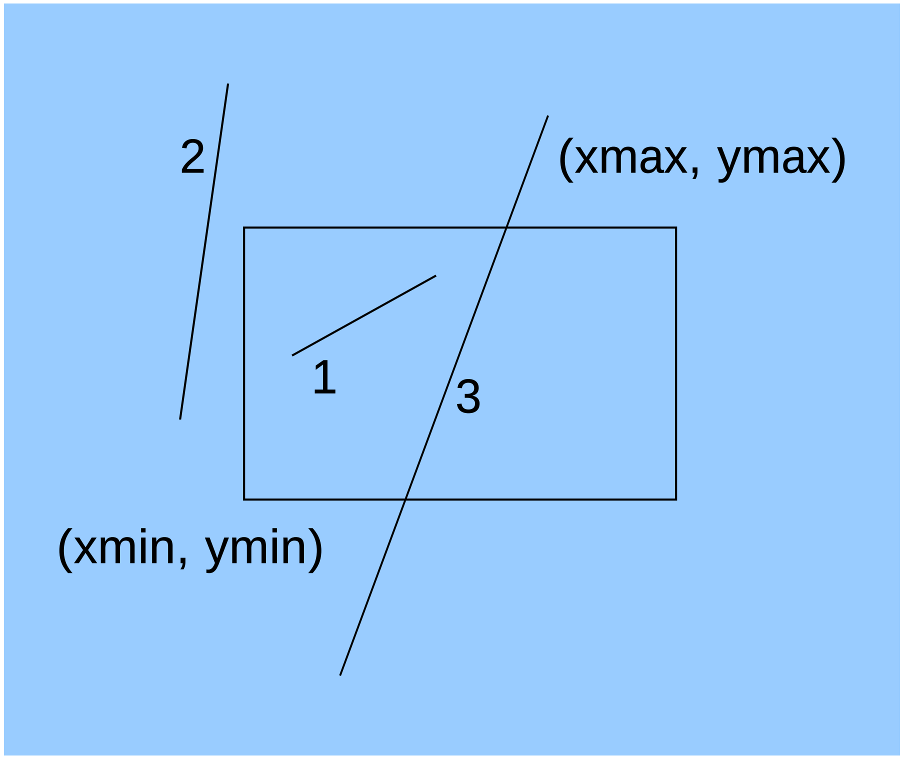


Determine whether a point (x,y) is inside or outside of the world window?

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

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

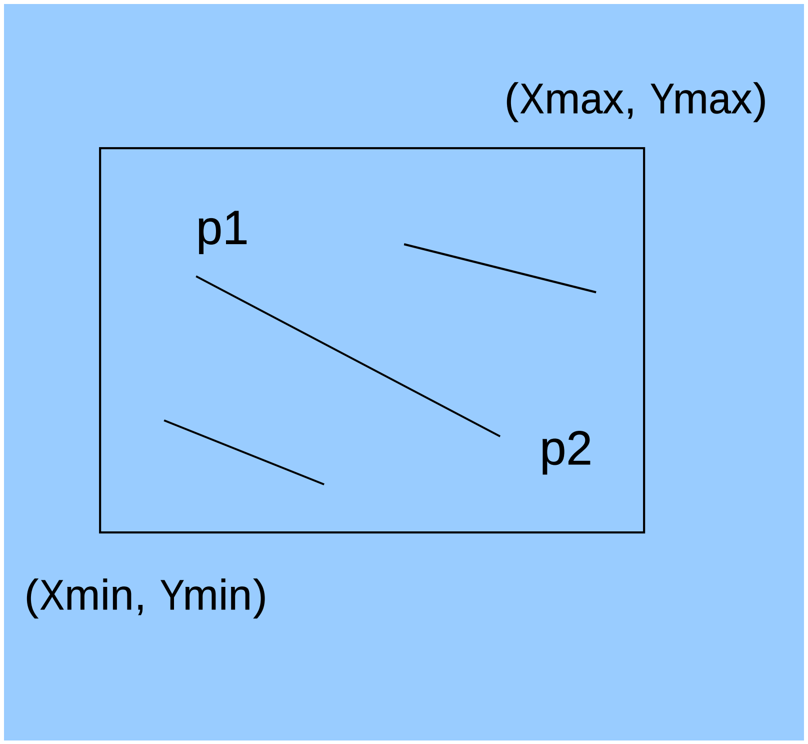
Clipping Lines



3 cases:

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

Clipping Lines: Trivial Accept



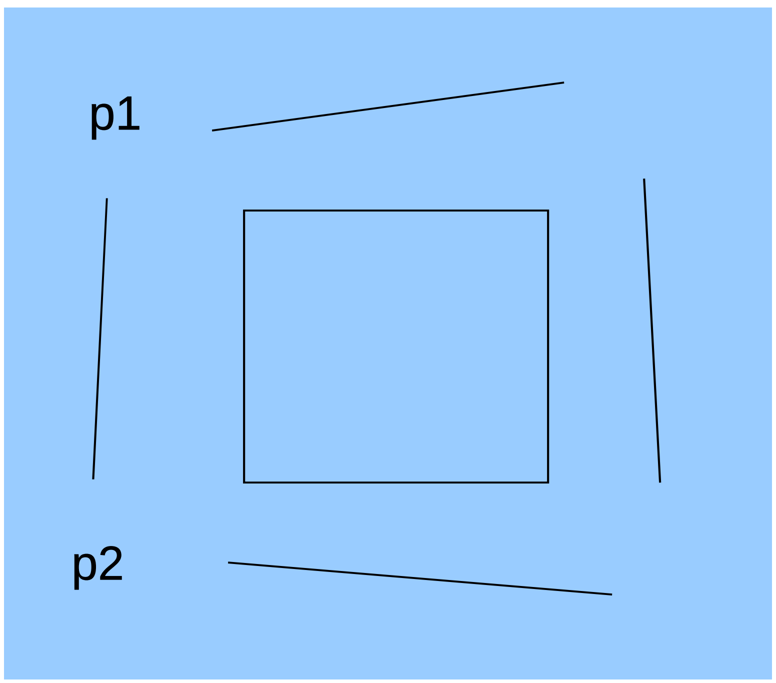
Case 1: All of line in
Test line endpoints:

> ***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



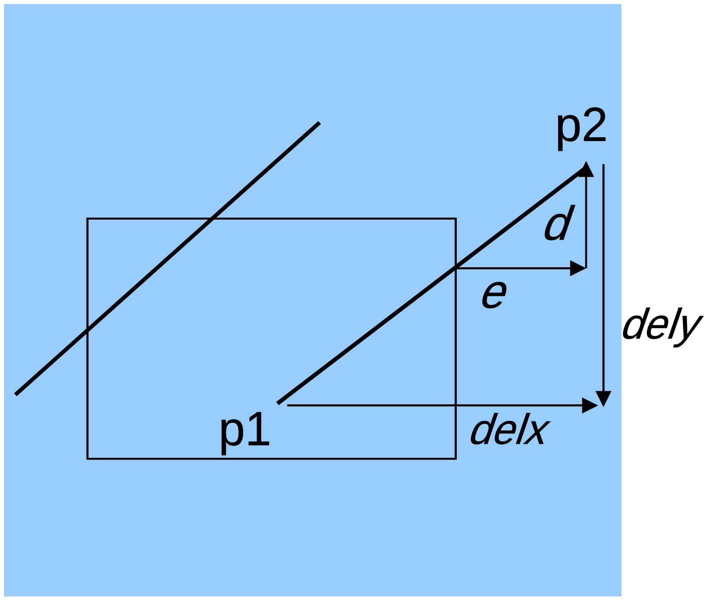
Case 2: All of line out
Test line endpoints:

- ***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

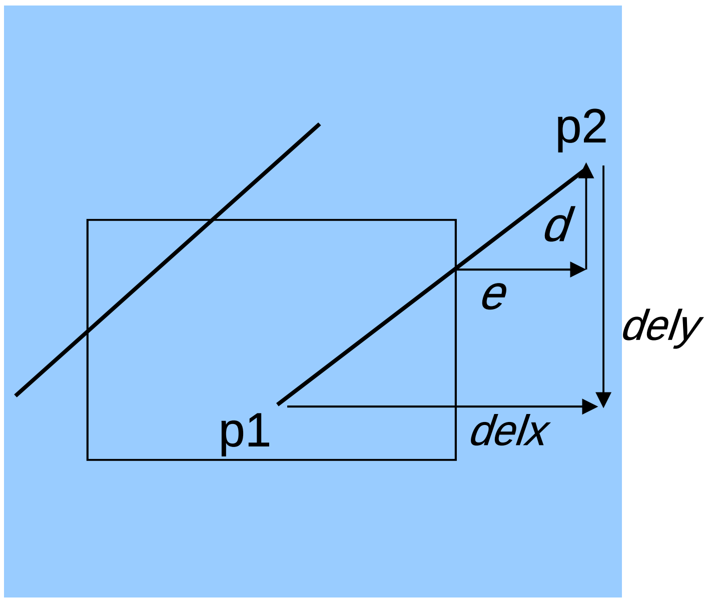
Both points out, but part of line cuts through viewport

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)

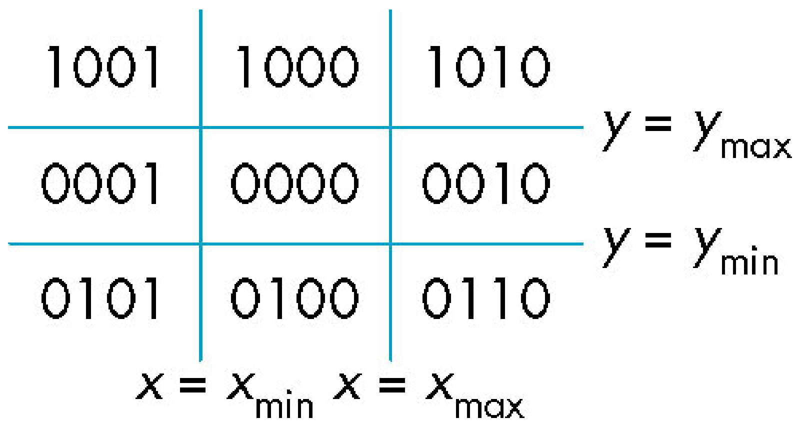
```
        else // p2 is outside
                // find surviving segment
        {
            if(p2 is to the left) chop against left edge
          else if(p2 is to right) chop against right edge
          else if(p2 is below) chop against the bottom edge
          else if(p2 is above) chop against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

Using Outcodes to Speed Up Comparisons

- For each endpoint, define an outcode

$$b_0b_1b_2b_3$$

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