Computer Graphics: 7-Polygon Rasterization, Clipping

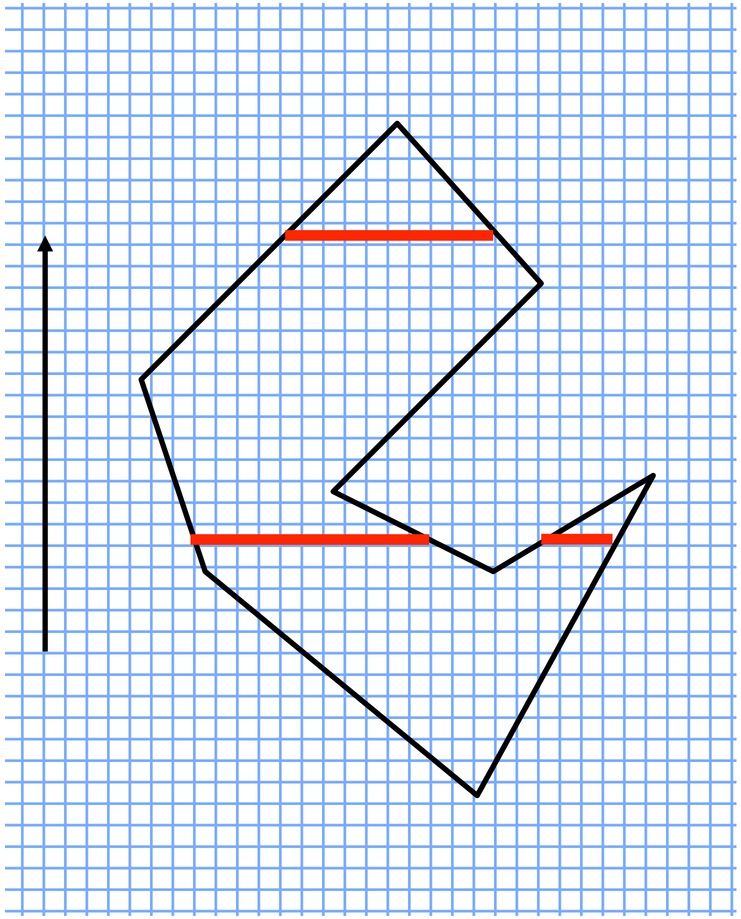
Prof. Dr. Charles A. Wüthrich,
Fakultät Medien, Medieninformatik
Bauhaus-Universität Weimar
caw AT medien.uni-weimar.de

Filling polygons (and drawing them)

- In general, except if we are dealing with wireframes, we would want to draw a filled polygon on our screen.
- The advantage is clear: the polygon acquires thickness and can be use to render surfaces
- The simplest way one would do that is to draw the polygon border and then fill the region delimited by the polygon
- In fact, this is the start point for the real algorithm, the scanline algorithm
- The scanline algorithm combines the advantages of filling algorithms and of line tracing at the borders in a complex but very fast way
- As input one takes an ordered list of points representing the polygon

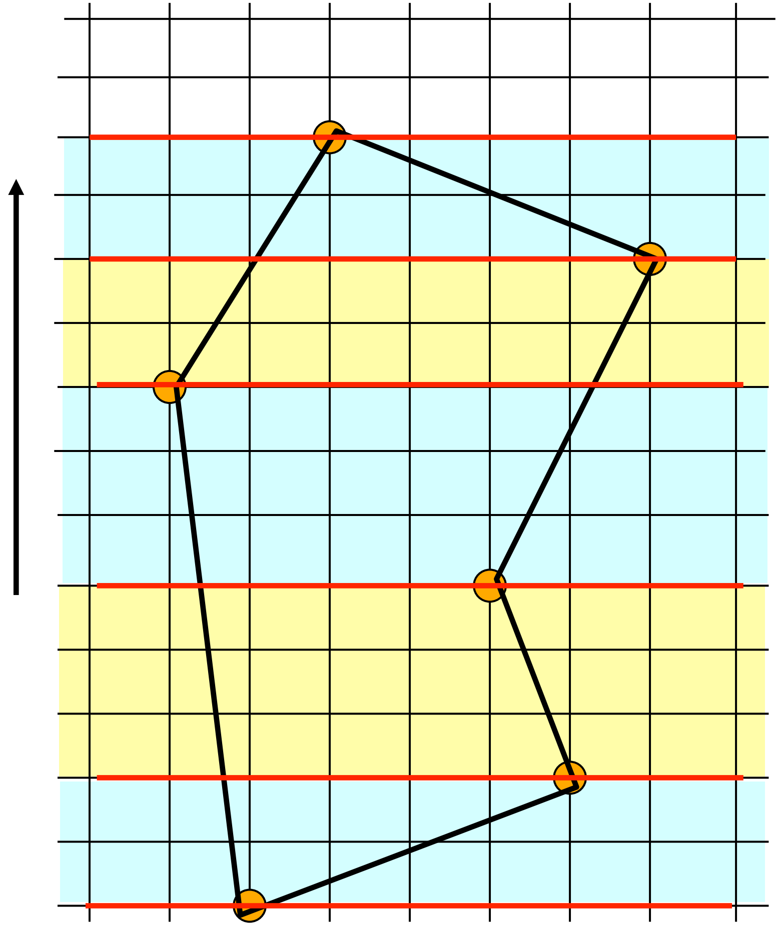
Scanline algorithm

- The basic idea is very simple:
  - A polygon can be filled one scanline at a time, from top to bottom
  - Order therefore polygon corners according to their highest y coordinate
  - Order each horizonal line according to the x coordinate of the edge intersections
  - Fill between pairs of edges, stop drawing until the next edge, and then restart filling again till the next one
  - once finished the edges at current line, restart at next y value
  - Of course, one can also draw upwards



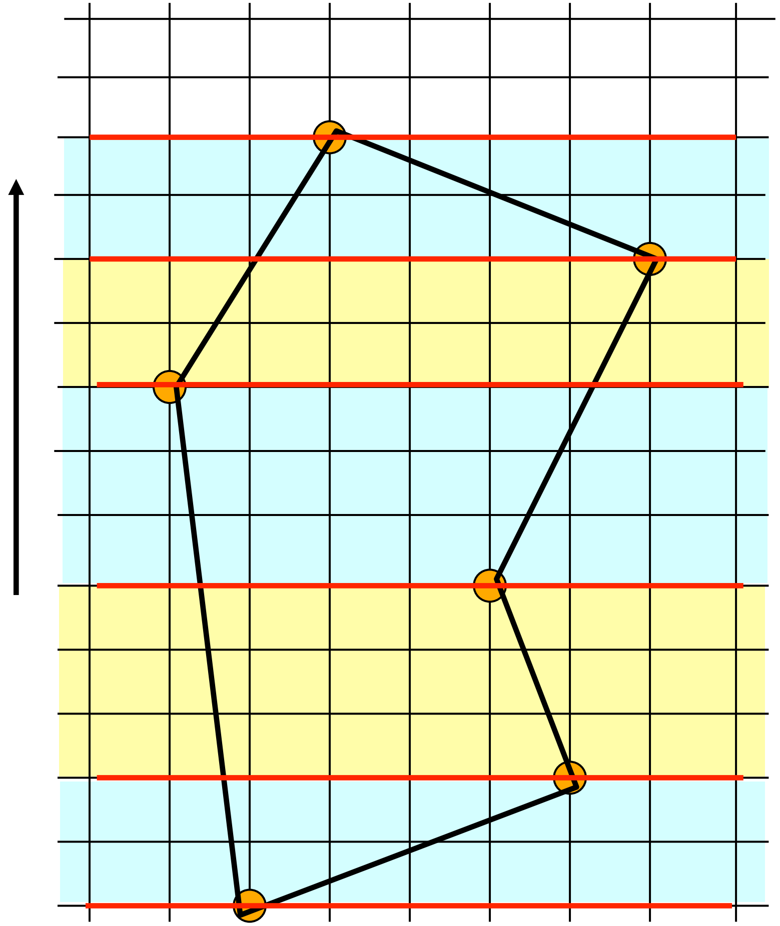
Scanline algorithm

- Notice that the number of edges remains constant between starting and ending points in the horizontal bands.
- Notice also that segments have only a limited contiguous range where they are active
- Notice that while proceeding downwards, borders can use a mirrored DDA to be drawn
- In this way, one can draw line borders and fill between them, after having ordered the border intersections with the current line WRT current coordinate



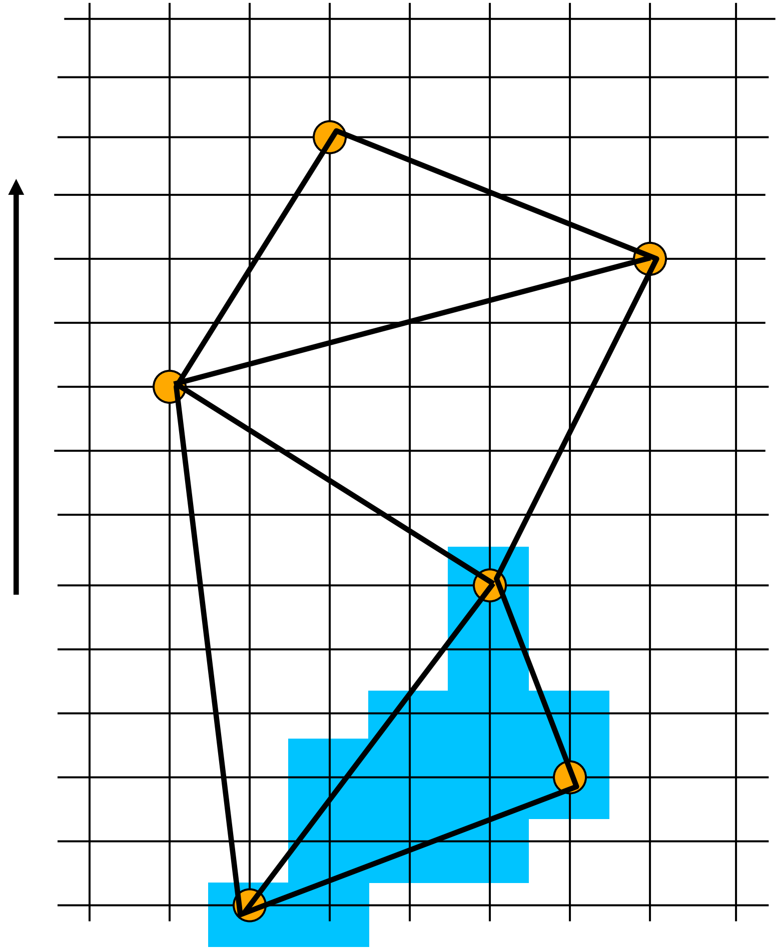
Scanline algorithm

- Polygon drawing starts at the bottom.
- Out of the edges list the ones with lowest starting point are chosen.
- These will remain part of the „active edge“ list until their end is met
- When they end, they are removed and replaced by new starting edges
- This until there is no edge left among the active edge
- At each value of the y variable, the edge rasterization is computed, and edges are ordered by growing x
- Colour is then filled between sorted pairs of edge rasterizations.



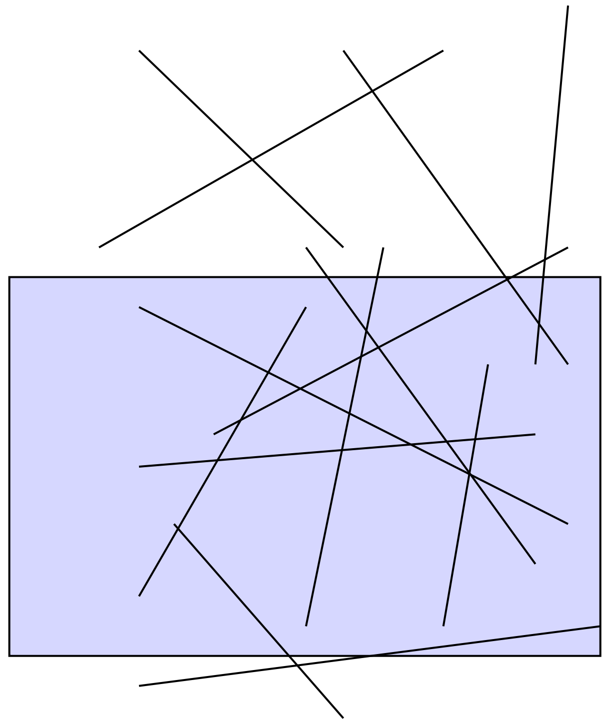
Triangle rasterization

- Modern graphics cards accept only triangles at the rasterization step
- Polygons with more edges are simply triangularized
- Obviously, the rasterization of a triangle is much easier
- This because a triangle is convex, and therefore a horizontal line has just the left and the right hand borders
- Filling is then done between the left side and the right side



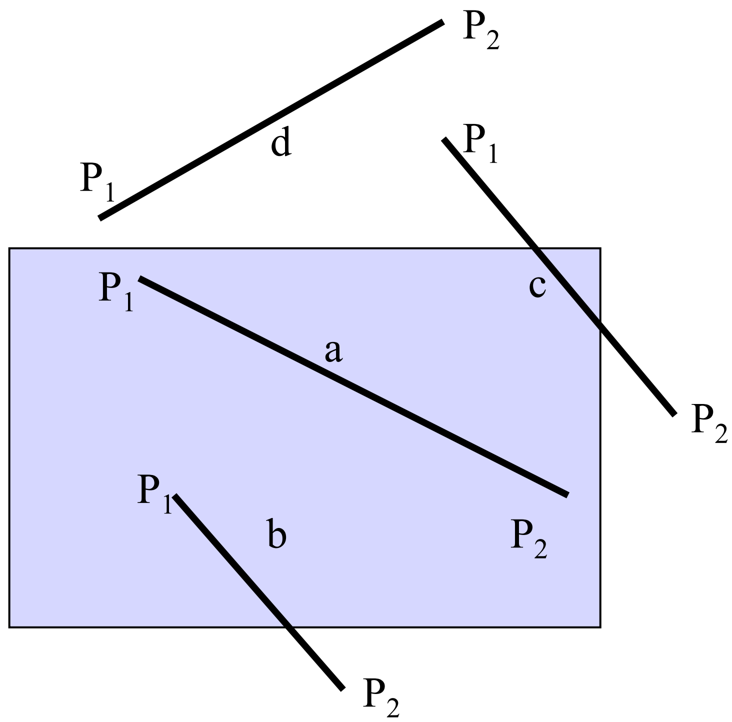
Clipping: motivation

- Often in 2D we have drawings that are bigger than a screen
- To save drawing complexity, it is good to be able to cut the drawings so that only screen objects are drawn
- Also, one needs to protect other (invisible) regions while working on a complex drawing
- The question is how is this done
- Problem: Given a segment in the plane, clip it to a rectangular segment



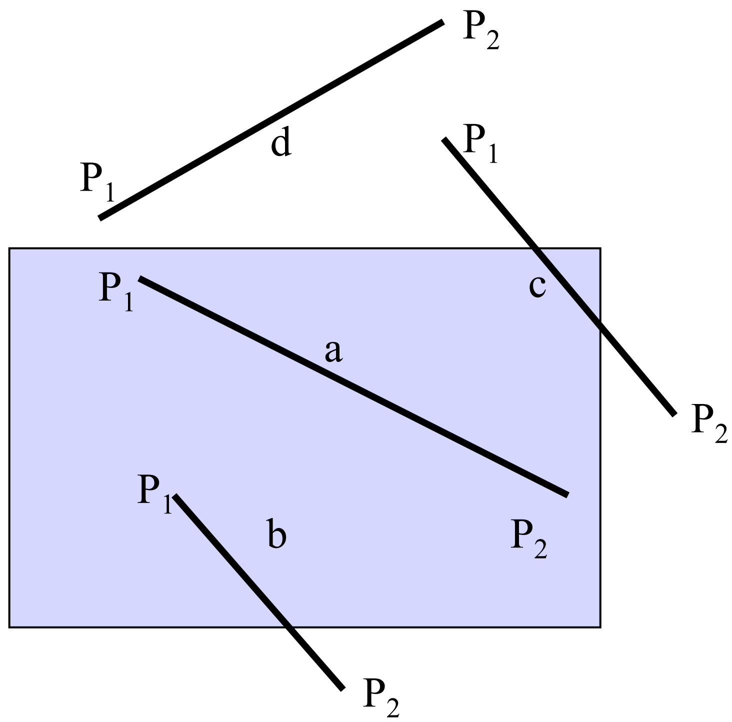
Line clipping

- Let B be the screen, and let P_1P_2 be the endpoints of the segment to be drawn
- There are four possible cases available:
  a) Whole line is visible
     $P_1, P_2 \in B$
  b) Line is partially visible
     $P_1 \in B$, $P_2 \in B$, P_1P_2 intersects screen borders
  c) Line partially visible
     $P_1, P_2 \notin B$, but P_1P_2 intersects screen borders
  d) Line not visible
     $P_1, P_2 \notin B$



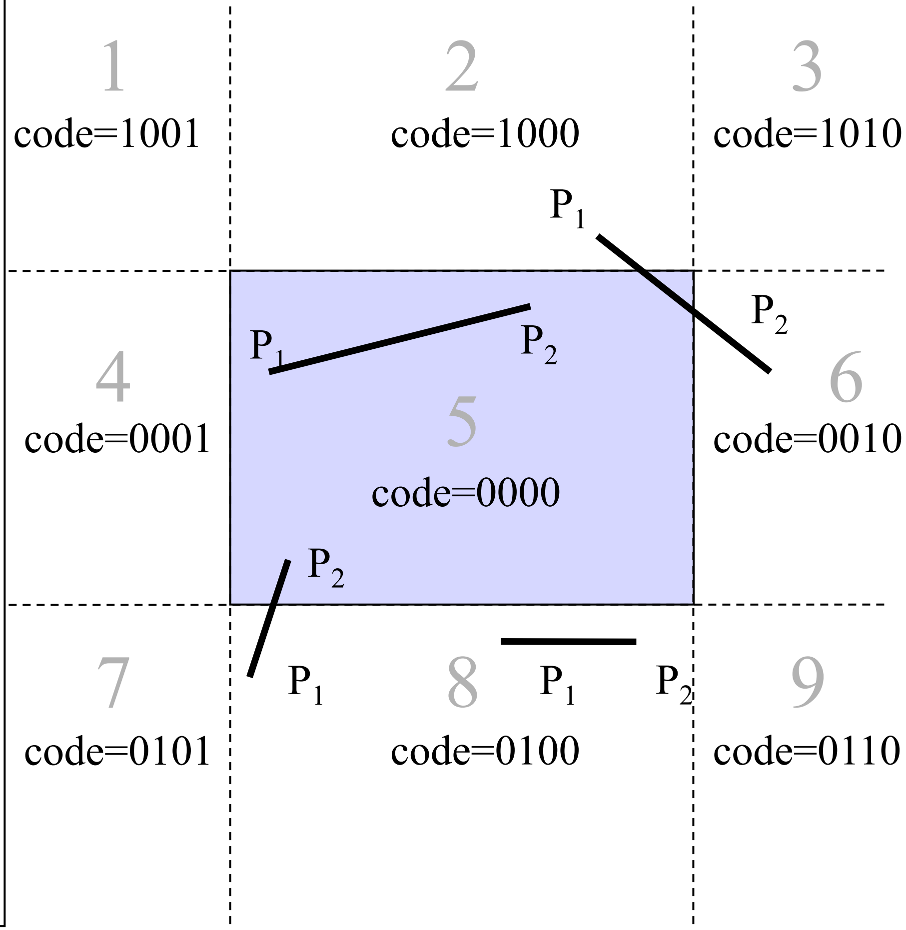
Line clipping Algorithm

```
IF (P1,P2∈B)            /* a */
   DrawLine(P1,P2)
ELSE IF                 /* b */
   (((P1∈B)AND NOT(P2∈B)) OR
   ((P2∈B)AND NOT(P1∈B)))
   compute I=(P1P2∩borders)
   IF(P1ÎB)
      Drawline(I,P1)
   ELSE
      DrawLine(I,P2)
ELSE                    /* c,d */
   compute I1,I2=
           (P1P2∩ borders)
   IF I1,I2 exist
      Drawline (I1,I2)
END
```

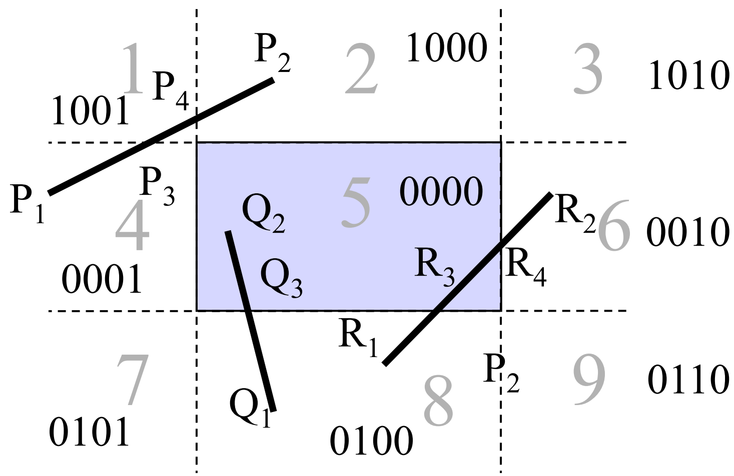


Examples: Cohen-Sutherland algo.

```
Code points according to
     characteristics:
  Bit 0=1 if x_P<x_min else 0
  Bit 1=1 if x_P>x_max else 0
  Bit 2=1 if y_P<y_min else 0
  Bit 3=1 if y_P>y_max else 0

Use bitwise operations:
  code(P1) AND code(P2)!= 0
       trivial case, line not
       on screen
  code(P1) OR code(P2)  == 0
       trivial case, line
       on screen
  ELSE
  - compute line-borders intersection
     (one at time) and set their code
     as above
  - redo clipping with shortened line
Note: before new intersection, at least
     one endpoint is outside WRT the
     border you clipped against, thus
     one subseg is trivially out (all
     left or right or up or down of
     screen)
```



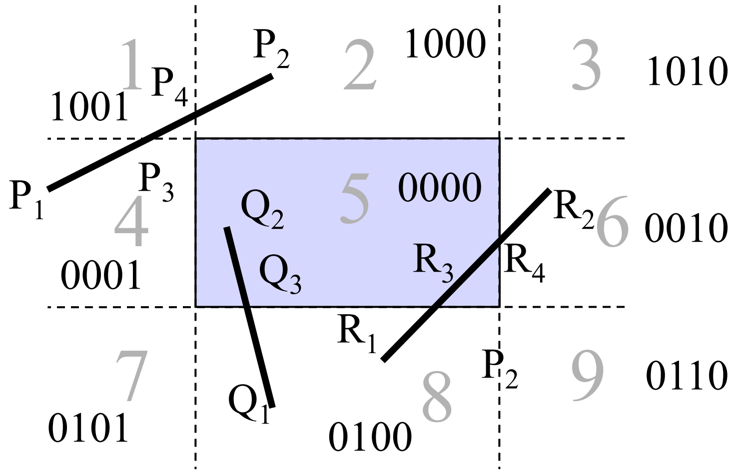
Algorithm Examples



Algorithm examples

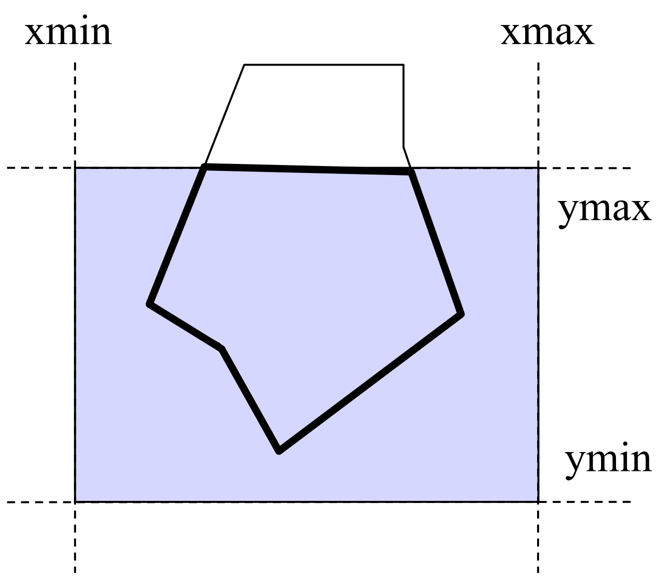
```
P1P2: P1=0001, P2=1000
      P1 AND P2= 0000
      P1 OR P2=1001
      Subdivide against left,
      Pick P2, find P4
new line P2P4
P2P4: P2=1000, P4=1000
      P2 AND P4: 1000 outside!
      Draw nothing

Q1Q2: Q1=0100, Q2=0000
      Q1 AND Q2:0000
      Q1 OR Q2: 0100
      Subdivide, Pick Q2, find Q3
new line Q2Q3
Q2Q3: Q2=0000, Q3=0000
      Q2 AND Q3: 0000
      Q1 OR Q3: 0000 inside!
      Draw Q3Q2
Q3Q2: Q3=0100

~
```

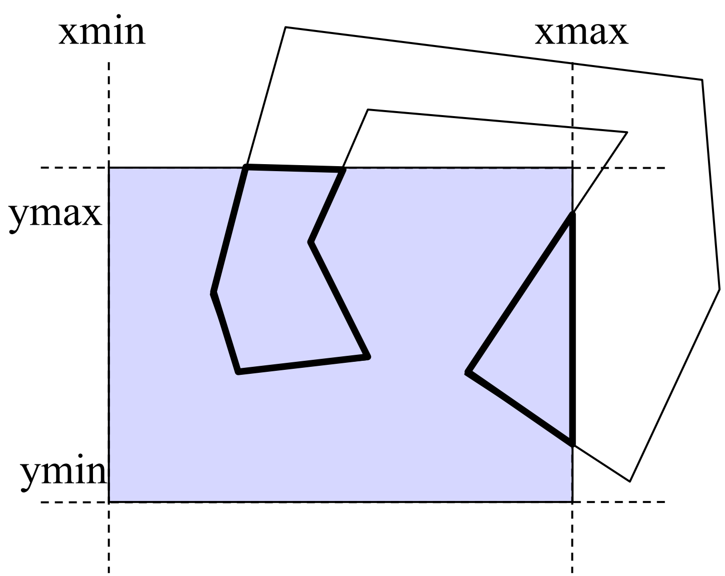
```
R1R2: R1=0100, R2=0010
       R1 AND R2= 0000
       R1 OR R2= 0110
       Subdivide, Pick R1, find R4
new line R1R4
       R1=0100, R4=0000
       R1 AND R4= 0000
       R1 OR R4= 0100
       Subdivide, Pick R4, find R3
new line R3R4
       R3=0000 R4=0000
       R3 AND R4=0000
       draw R3R4
```



Clipping polygons

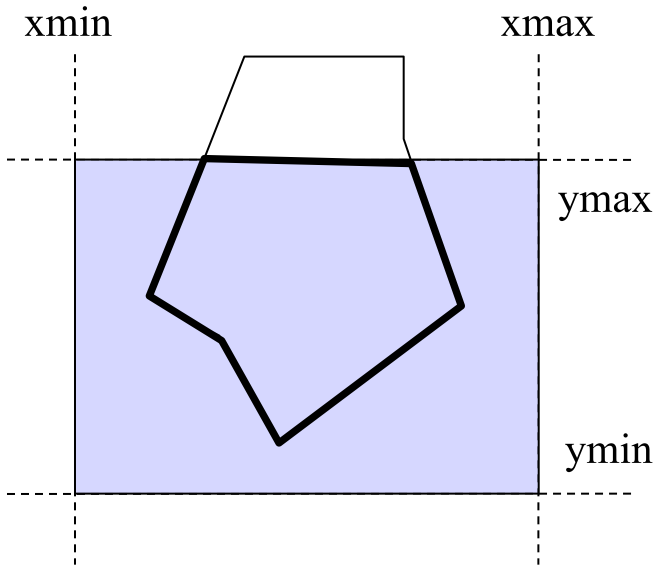
- The task is similar, but it is more complicated to achieve
- Polygon clipping may result into disjunct polys

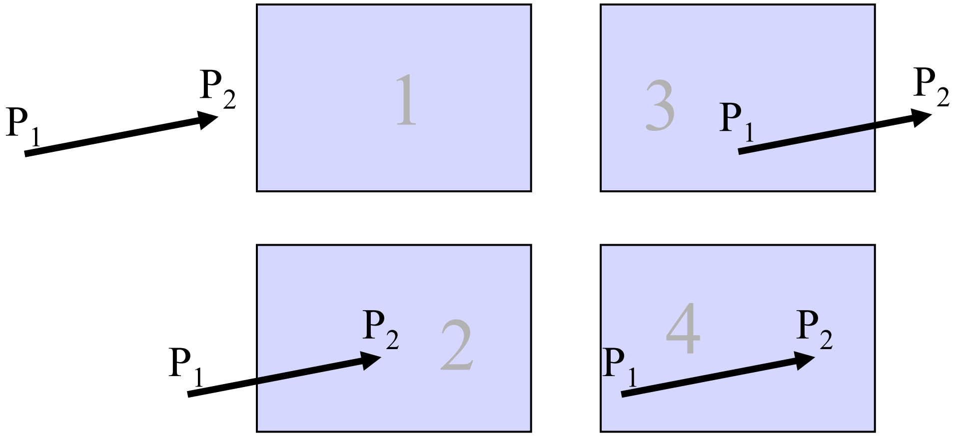




Sutherland Hodgeman Algorithm

- Clearly, drawing polygons is a more complicated issue
- Idea: one could follow the polygon border, and switch to following the border when the polygon leaves the screen until it re-enters it
- This means creating a new polygon, which is trimmed to the screen
- While following an edge, four cases are possible:

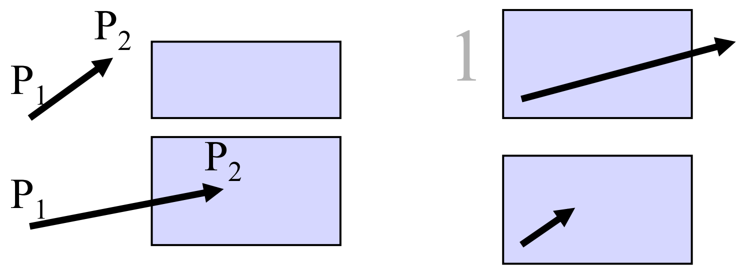




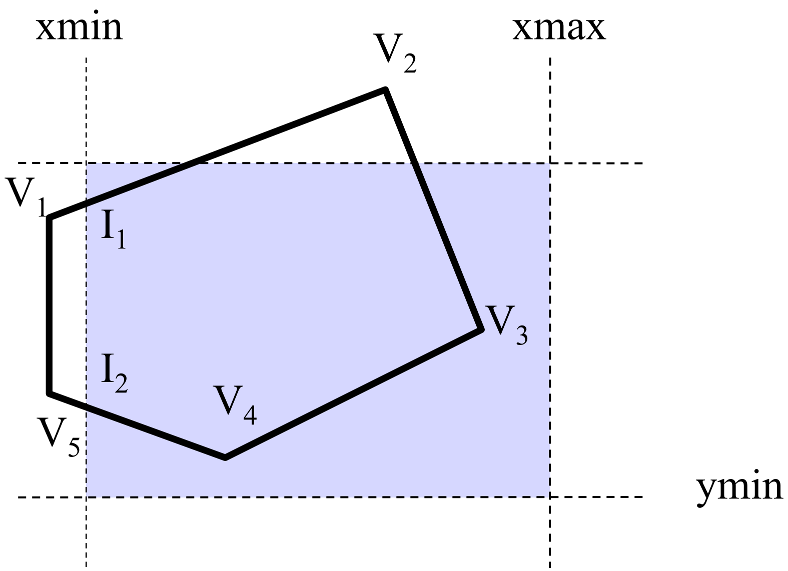
Sutherland-Hodgeman Algorithm

- The algorithm works considering polygons as lists of edges
- Input is a list L of polygon edges
- Output wil be a new list L´ of polygon edges
- The polygon is clipped against ALL screen borders one at a time

```
FOR all screen borders DO:
  FOR all lines in polygons
   DO:
    FOR all points P in L DO
      Compute intersection I
       of line with current
       border
      IF (case 1):
        Do Nothing
      IF (case 2):
        Add (I,Succ(P))to L´
      IF (case 3):
        Add (I) to L´
      IF (case 4):
        Add (succ(P)) to L´
    END
  END
END
```



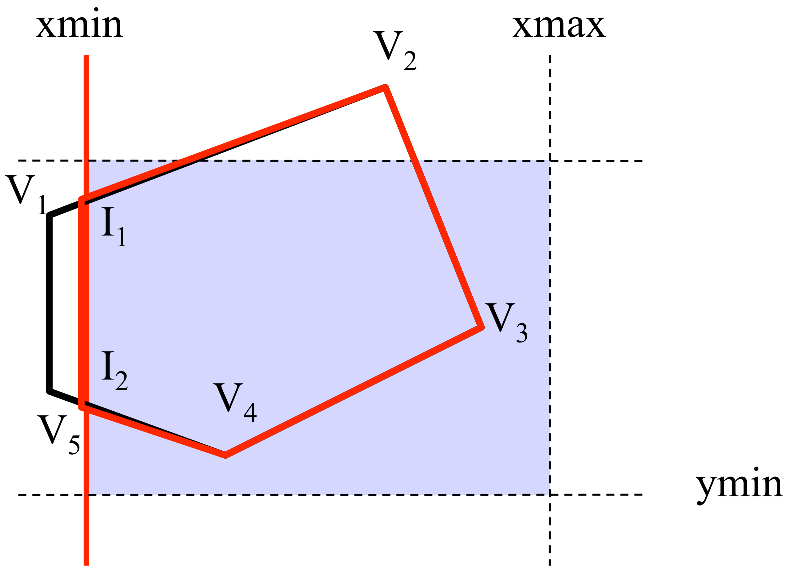
Example

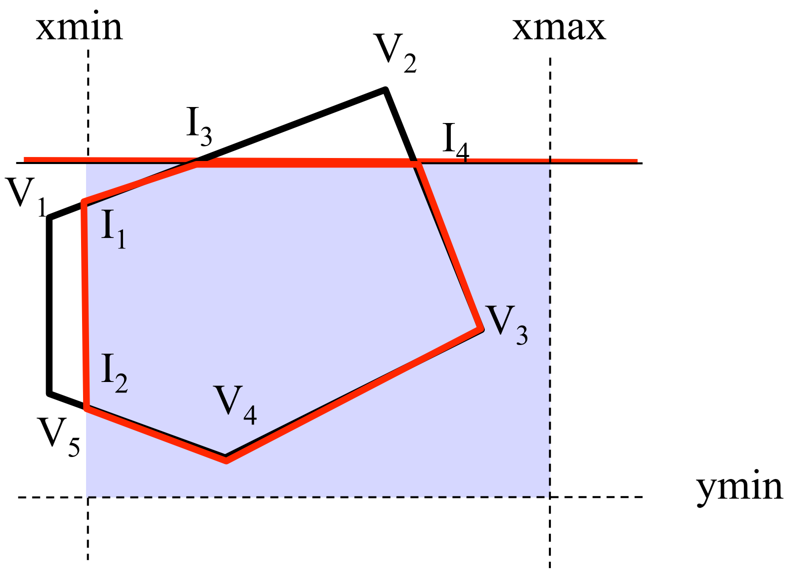


Example

- Left border
  Input: $\{V_1, V_2, V_3, V_4, V_5\}$
  Output: $\{I_1, V_2, V_3, V_4, Í_2\}$

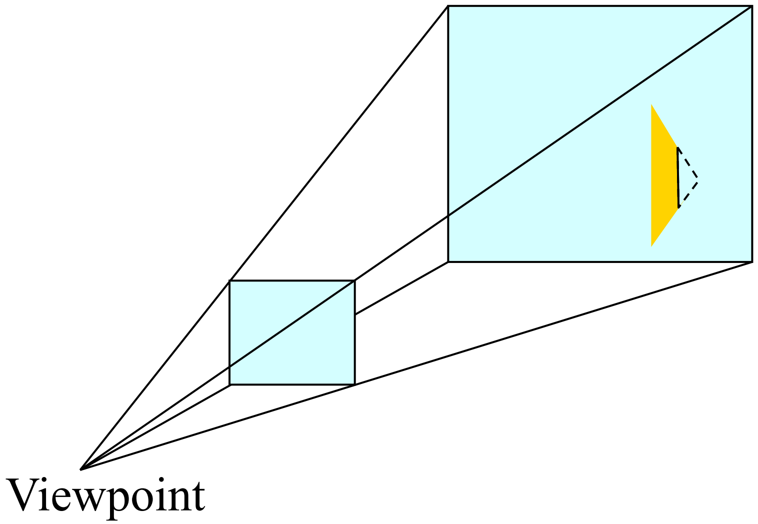
- Top Border
  Input: $\{I_1, V_2, V_3, V_4, I_2\}$
  Output: $\{I_1, I_3, I_4, V_3, V_4, I_2\}$





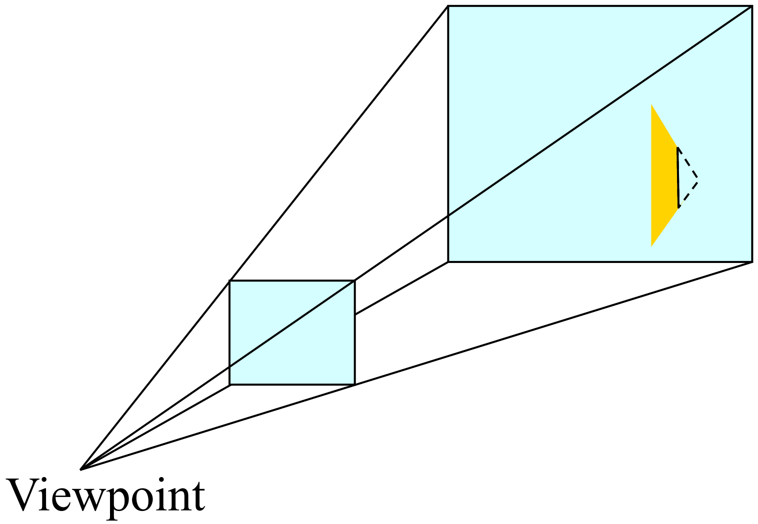
Clipping in 3D

- Remember the near and far clipping planes of the view frustum?
- How do I clip a polygon against them?



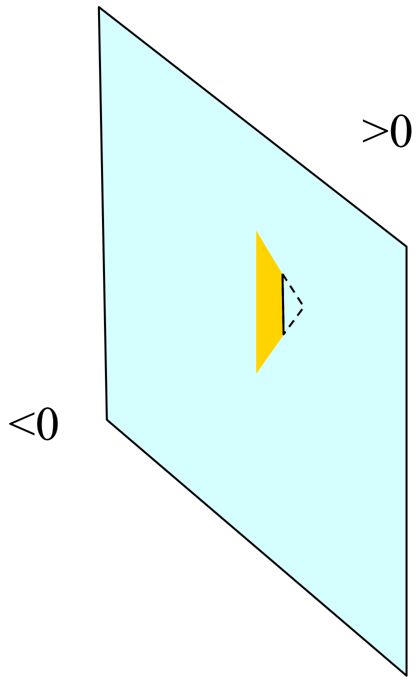
Clipping in 3D

- Remember the near and far clipping planes of the view frustum?
- How do I clip a polygon against them?
- As a matter of fact, it is not so different!
- The problem can be reduced to the same as in 2D, with a few differences



Clipping in 3D

- Let us consider a the far plane and a polygon
- Substitute the coordinates of the vertices of the triangle into the plane equation:
  - Front: <0
  - Back: >0
  - Plane: =0
- So we can follow the vertices exactly like in Cohen-Sutherland to clip against the plane
- A similar method can be applied for an arbitrary plane
- For the frustum planes one can do clipping one plane at a time, like in 2D (except they are 6 now)



End

+++ Ende - The end - Finis - Fin - Fine +++ Ende - The end - Finis - Fin - Fine +++