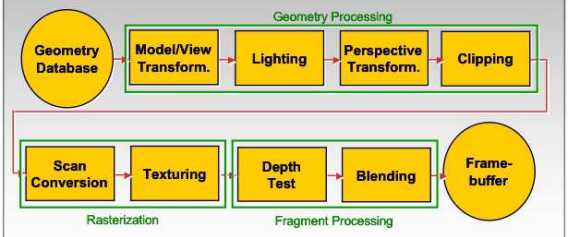
Clipping

CPSC 314

The Rendering Pipeline

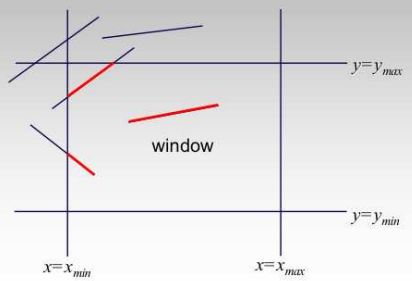


Line Clipping

Purpose

- Originally: 2D
  - *Determine portion of line inside an axis-aligned rectangle (screen or window)*
- 3D
  - *Determine portion of line inside axis-ligned parallelpiped (viewing frustum in NDC)*
  - *Simple extension to the 2D algorithms*

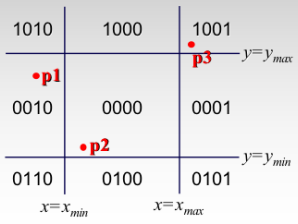
Line Clipping



Line Clipping

Outcodes (Cohen, Sutherland '74)

- 4 flags encoding position of a point relative to top, bottom, left, and right boundary
- E.g.:
  - OC(**p1**)=0010
  - OC(**p2**)=0000
  - OC(**p3**)=1001



Line Clipping

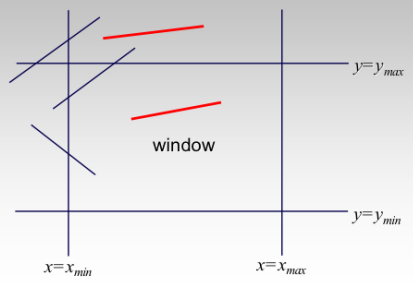
Line segment:

- (**p1**,**p2**)

Trivial cases:

- OC(**p1**)== 0 && OC(**p2**)==0
  - *Both points inside window, thus line segment completely visible (trivial accept)*
- (OC(**p1**) & OC(**p2**))!= 0
  - *There is (at least) one boundary for which both points are outside (same flag set in both outcodes)*
  - *Thus line segment completely outside window (trivial reject)*

Line Clipping



Line Clipping

α-Clipping

- Handling of all the non-trivial cases
- Improvement of earlier algorithms (Cohen/Sutherland, Cyrus/Beck, Liang/Barsky)
- Define *window-edge-coordinates* of a point $\mathbf{p}=(x,y)^T$
  - $WEC_L(\mathbf{p})= x-x_{min}$
  - $WEC_R(\mathbf{p})= x_{max}-x$
  - $WEC_B(\mathbf{p})= y-y_{min}$
  - $WEC_T(\mathbf{p})= y_{min}-y$

Negative if outside!

Line Clipping

α-Clipping

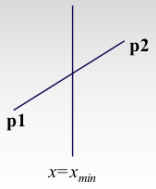
- Line segment defined as: p1+ α(p2-p1)
- Intersection point with one of the borders (say, left):

$$x_1 + \alpha(x_2 - x_1) = x_{min} \Leftrightarrow$$

$$\alpha = \frac{x_{min} - x_1}{x_2 - x_1}$$

$$= \frac{x_{min} - x_1}{(x_2 - x_{min}) - (x_1 - x_{min})}$$

$$= \frac{\mathrm{WEC}_L(x_1)}{\mathrm{WEC}_L(x_1) - \mathrm{WEC}_L(x_2)}$$



Line Clipping

α-Clipping: algorithm

```
alphaClip( p1, p2, window ) {
    Determine window-edge-coordinates of p1, p2
    Determine outcodes OC(p1), OC(p2)

    Handle trivial accept and reject

    α1= 0; // line parameter for first point
    α2= 1; // line parameter for second point
    …
```


Line Clipping

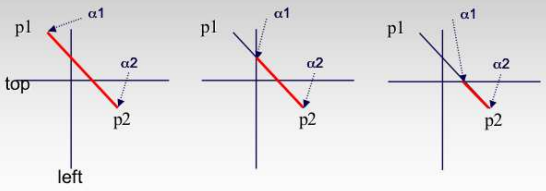
α-Clipping: algorithm (cont.)

```
    …
    // now clip point p1 against all edges
    if( OC(p1) & LEFT_FLAG ) {
        α= WEC_L(p1)/(WEC_L (p1) - WEC_L (p2));
        α1= max(α1, α );
    }

    Similarly clip p1 against other edges
    …
```


Line Clipping

α-Clipping: example for clipping p1



Start configuration | After clipping to left | After clipping to top

Line Clipping

α-Clipping: algorithm (cont.)

…
// now clip point p2 against all edges
if(OC(p2) & LEFT_FLAG) {
    $\alpha = WEC_L(p2)/(WEC_L(p1) - WEC_L(p2))$;
    α2= min(α2, α);
}

Similarly clip p1 against other edges
…

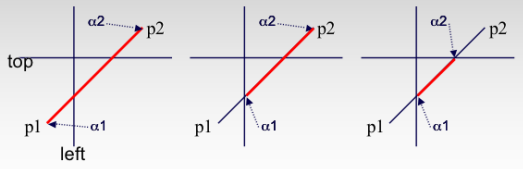
Line Clipping

α-Clipping: algorithm (cont.)

...
// wrap-up
if(α1 > α2)
    no output;
else
    output line from p1+α1(p2-p1) to p1+α2(p2-p1)
} // end of algorithm

Line Clipping

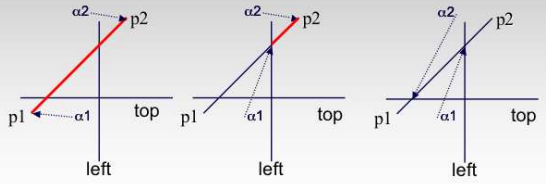
Example



Start configuration | After clipping p1 | After clipping p2

Line Clipping

Another Example



Start configuration | After clipping p1 | After clipping p2

Line Clipping in 3D

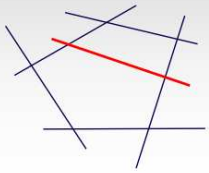
Approach:

- Clip against parallelpiped in NDC (*after* perspective transform)
- Means that the clipping volume is always the same!
  - OpenGL: $x_{min}=y_{min}= -1$, $x_{max}=y_{max}= 1$
- Boundary lines become boundary planes
  - *But outcodes and WECs still work the same way*
  - *Additional front and back clipping plane*
    - $z_{min}=0$, $z_{max}=1$ in OpenGL

Line Clipping

Extensions

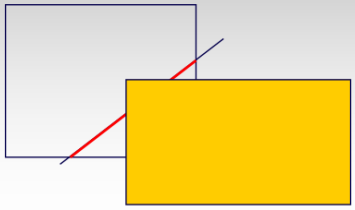
- Algorithm can be extended to clipping lines against
  - *Arbitrary convex polygons (2D)*
  - *Arbitrary convex polytopes (3D)*



Line Clipping

Non-convex clipping regions

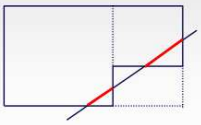
- E.g.: windows in a window system!



Line Clipping

Non-convex clipping regions

- Problem: arbitrary number of visible line segments
- Different approaches:
  - *Break down polygon into convex parts*
  - *Scan convert for full window, and discard hidden pixels*



Polygon Clipping

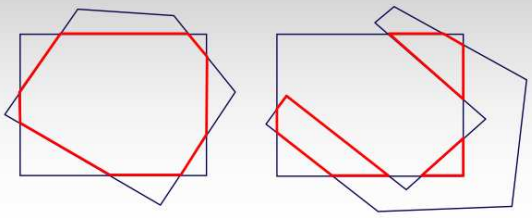
Objective

- 2D: clip polygon against rectangular window
  - *Or general convex polygons*
  - *Extensions for non-convex or general polygons*
- 3D: clip polygon against parallelpiped

Polygon Clipping

Not just clipping all boundary lines

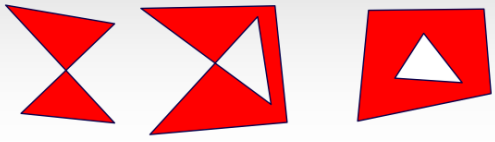
- May have to introduce new line segments



Polygon Clipping

Classes of Polygons

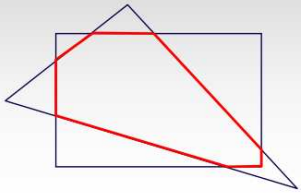
- Triangles
- Convex
- Concave
- Holes and self-intersection



Polygon Clipping

Sutherland/Hodgeman Algorithm ('74)

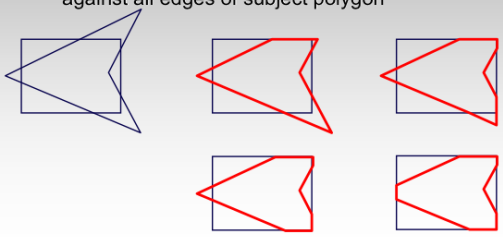
- Arbitrary convex or concave *object polygon*
  - *Restriction to triangles does not simplify things*
- Convex *subject polygon* (window)



Polygon Clipping

Sutherland/Hodgeman Algorithm ('74)

- Approach: clip object polygon independently against all edges of subject polygon



Polygon Clipping

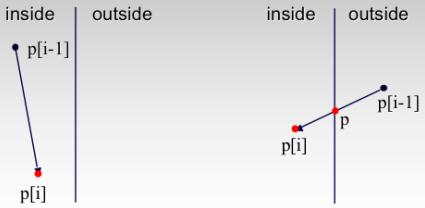
Clipping against one edge:

```
clipPolygonToEdge( p[n], edge ) {
    for( i= 0 ; i< n ; i++ ) {
        if( p[i] inside edge ) {
            if( p[i-1] inside edge ) // p[-1]= p[n-1]
                output p[i];
            else {
                p= intersect( p[i-1], p[i], edge );
                output p, p[i];
            }
        } else…
```


Polygon Clipping

Clipping against one edge (cont)

- p[i] inside: 2 cases



Polygon Clipping

Clipping against one edge (cont)

```
…
else {              // p[i] is outside edge
    if( p[i-1] inside edge ) {
        p= intersect(p[i-1], p[I], edge );
        output p;
    }
} // end of algorithm
```

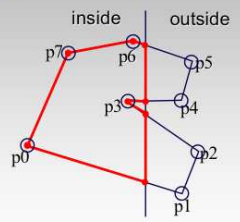

Polygon Clipping

Clipping against one edge (cont)

- p[i] outside: 2 cases

Polygon Clipping

Example



Polygon Clipping

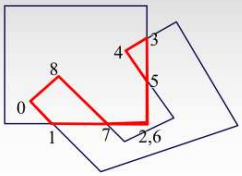
Sutherland/Hodgeman Algorithm

- Inside/outside tests: outcodes
- Intersection of line segment with edge: window-edge coordinates
- Similar to Cohen/Sutherland algorithm for line clipping

Polygon Clipping

Sutherland/Hodgeman Algorithm

- Discussion:
  - *Works for concave polygons*
  - *But generates degenerate cases*



Polygon Clipping

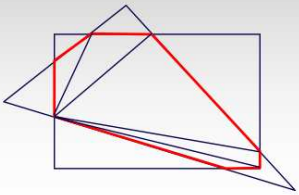
Sutherland/Hodgeman Algorithm

- Discussion:
  - *Clipping against individual edges independent*
    - Great for hardware (pipelining)
  - *All vertices required in memory at the same time*
    - Not so good, but unavoidable
    - Another reason for using triangles only in hardware rendering

Polygon Clipping

Sutherland/Hodgeman Algorithm

- For Rendering Pipeline:
  - *Re-triangulate resulting polygon (can be done for every individual clipping edge)*

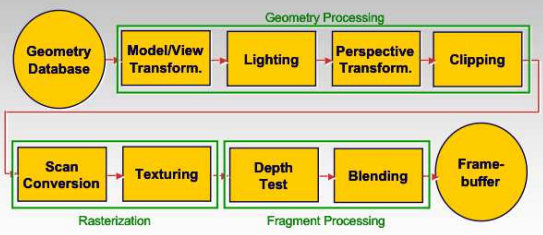


Polygon Clipping

Other Polygon Clipping Algorithms

- Weiler/Aetherton '77:
  - *Arbitrary concave polygons with holes both as subject and as object polygon*
- Vatti '92:
  - *Self intersection allowed as well*
- … many more
  - *Improved handling of degenerate cases*
  - *But not often used in practice due to high complexity*

The Rendering Pipeline



Coming Up:

Tuesday, Oct 9:

- Hidden surface removal / visibility

Thursday, Oct 11:

- Scan Conversion