University of British Columbia
CPSC 314 Computer Graphics
Jan-Apr 2013

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Clipping

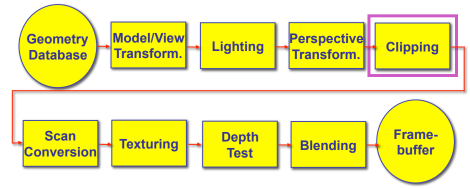
http://www.ugrad.cs.ubc.ca/~cs314/Vjan2013

Reading for Clipping

- FCG Sec 8.1.3-8.1.6 Clipping
- FCG Sec 8.4 Culling
  - (12.1-12.4 2nd ed)

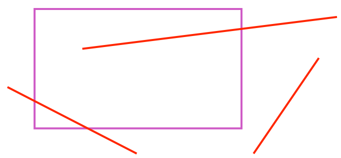
Clipping

Rendering Pipeline



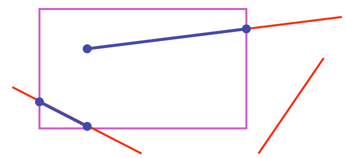
Next Topic: Clipping

- we've been assuming that all primitives (lines, triangles, polygons) lie entirely within the *viewport*
  - in general, this assumption will not hold:



Clipping

- analytically calculating the portions of primitives within the viewport



Why Clip?

- bad idea to rasterize outside of framebuffer bounds
- also, don't waste time scan converting pixels outside window
  - could be billions of pixels for very close objects!

Line Clipping

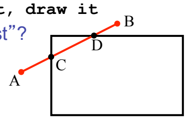
- 2D
  - determine portion of line inside an axis-aligned rectangle (screen or window)
- 3D
  - determine portion of line inside axis-aligned parallelpiped (viewing frustum in NDC)
  - simple extension to 2D algorithms

Clipping

- naïve approach to clipping lines:

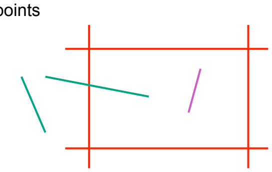
```
for each line segment
    for each edge of viewport
        find intersection point
        pick "nearest" point
    if anything is left, draw it
```

- what do we mean by "nearest"?
- how can we optimize this?



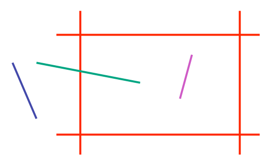
Trivial Accepts

- big optimization: trivial accept/rejects
  - Q: how can we quickly determine whether a line segment is entirely inside the viewport?
  - A: test both endpoints



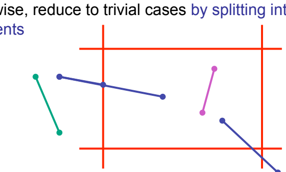
Trivial Rejects

- Q: how can we know a line is outside viewport?
- A: if both endpoints on wrong side of same edge, can trivially reject line



Clipping Lines To Viewport

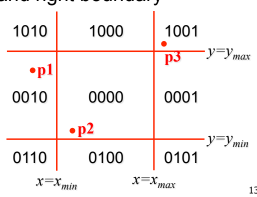
- combining trivial accepts/rejects
  - trivially accept lines with both endpoints inside all edges of the viewport
  - trivially reject lines with both endpoints outside the same edge of the viewport
  - otherwise, reduce to trivial cases by splitting into two segments



Cohen-Sutherland Line Clipping

- outcodes
  - 4 flags encoding position of a point relative to top, bottom, left, and right boundary

- $OC(p1)=0010$
- $OC(p2)=0000$
- $OC(p3)=1001$



Cohen-Sutherland Line Clipping

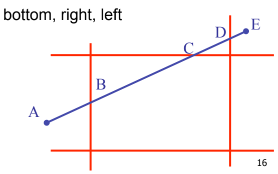
- assign outcode to each vertex of line to test
  - line segment: (**p1**,**p2**)
- trivial cases
  - OC(**p1**)== 0 && OC(**p2**)==0
    - both points inside window, thus line segment completely visible (trivial accept)
  - (OC(**p1**) & OC(**p2**))!= 0
    - there is (at least) one boundary for which both points are outside (same flag set in both outcodes)
    - thus line segment completely outside window (trivial reject)

Cohen-Sutherland Line Clipping

- if line cannot be trivially accepted or rejected, subdivide so that one or both segments can be discarded
- pick an edge that the line crosses (*how?*)
- intersect line with edge (*how?*)
- discard portion on wrong side of edge and assign outcode to new vertex
- apply trivial accept/reject tests; repeat if necessary

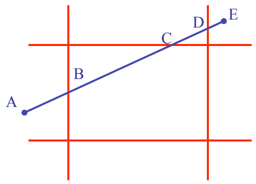
Cohen-Sutherland Line Clipping

- if line cannot be trivially accepted or rejected, subdivide so that one or both segments can be discarded
- pick an edge that the line crosses
  - check against edges in same order each time
    - for example: top, bottom, right, left



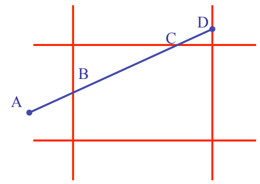
Cohen-Sutherland Line Clipping

- intersect line with edge



Cohen-Sutherland Line Clipping

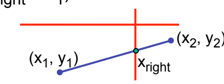
- discard portion on wrong side of edge and assign outcode to new vertex



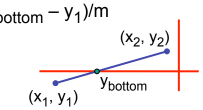
- apply trivial accept/reject tests and repeat if necessary

Viewport Intersection Code

- (x_1, y_1), (x_2, y_2) intersect vertical edge at x_{right}
  - $y_{intersect} = y_1 + m(x_{right} - x_1)$
  - $m=(y_2-y_1)/(x_2-x_1)$



- (x_1, y_1), (x_2, y_2) intersect horiz edge at y_{bottom}
  - $x_{intersect} = x_1 + (y_{bottom} - y_1)/m$
  - $m=(y_2-y_1)/(x_2-x_1)$



Cohen-Sutherland Discussion

- key concepts
  - use opcodes to quickly eliminate/include lines
    - best algorithm when trivial accepts/rejects are common
  - must compute viewport clipping of remaining lines
    - non-trivial clipping cost
    - redundant clipping of some lines
- basic idea, more efficient algorithms exist

Line Clipping in 3D

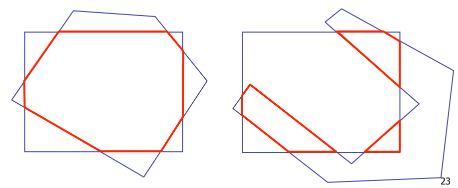
- approach
  - clip against parallelpiped in NDC
    - after perspective transform
  - means that clipping volume always the same
    - xmin=ymin= -1, xmax=ymax= 1 in OpenGL
  - boundary lines become boundary planes
    - but outcodes still work the same way
    - additional front and back clipping plane
      - zmin = -1, zmax = 1 in OpenGL

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

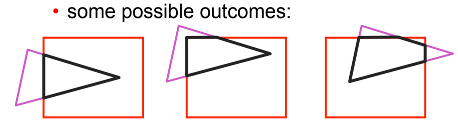
Polygon Clipping

- not just clipping all boundary lines
- may have to introduce new line segments



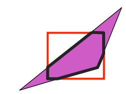
Why Is Clipping Hard?

- what happens to a triangle during clipping?
  - some possible outcomes:



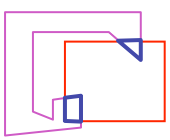
triangle to triangle   triangle to quad   triangle to 5-gon

- how many sides can result from a triangle?
  - seven



Why Is Clipping Hard?

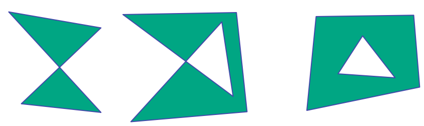
- a really tough case:



concave polygon to multiple polygons

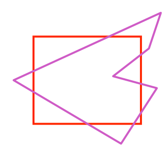
Polygon Clipping

- classes of polygons
- triangles
- convex
- concave
- holes and self-intersection



Sutherland-Hodgeman Clipping

- basic idea:
  - consider each edge of the viewport individually
  - clip the polygon against the edge equation
  - after doing all edges, the polygon is fully clipped



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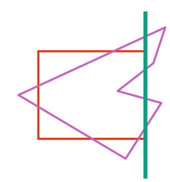

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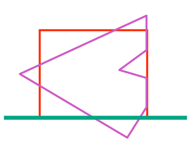

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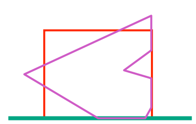

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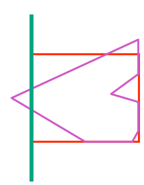

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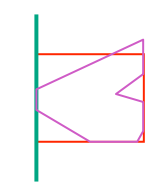

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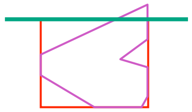

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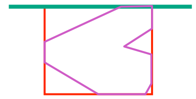

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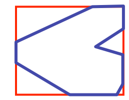
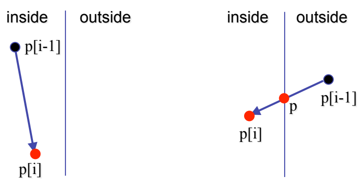


Sutherland-Hodgeman Algorithm

- input/output for whole algorithm
  - input: list of polygon vertices in order
  - output: list of clipped polygon vertices consisting of old vertices (maybe) and new vertices (maybe)
- input/output for each step
  - input: list of vertices
  - output: list of vertices, possibly with changes
- basic routine
  - go around polygon one vertex at a time
  - decide what to do based on 4 possibilities
    - is vertex inside or outside?
    - is previous vertex inside or outside?

Clipping Against One Edge

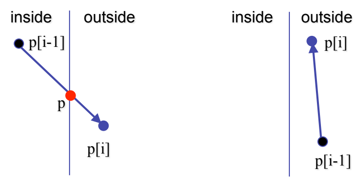
- p[i] inside: 2 cases



output: p[i] output: p, p[i]

Clipping Against One Edge

- p[i] outside: 2 cases

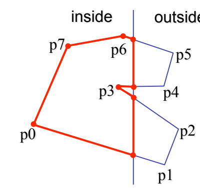


output: p output: nothing

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


Sutherland-Hodgeman Example



Sutherland-Hodgeman Discussion

- similar to Cohen/Sutherland line clipping
  - inside/outside tests: outcodes
  - intersection of line segment with edge: window-edge coordinates
- clipping against individual edges independent
  - great for hardware (pipelining)
  - all vertices required in memory at same time
    - not so good, but unavoidable
    - another reason for using triangles only in hardware rendering