CS 112 - Clipping

Aditi Majumder, CS 112 Slide 1

Clipping

- Removing primitives (lines, polygons) that are not visible
- Can take place in different stages
  - In image space
    - OpenGL does only this clipping
  - In object space
    - Several methods

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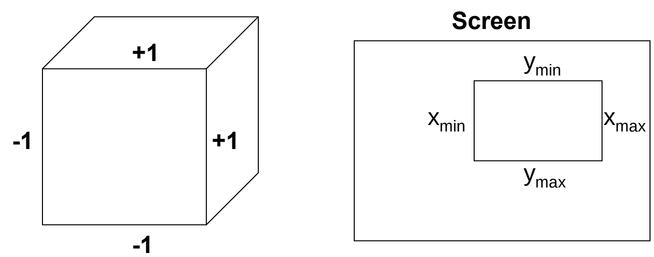
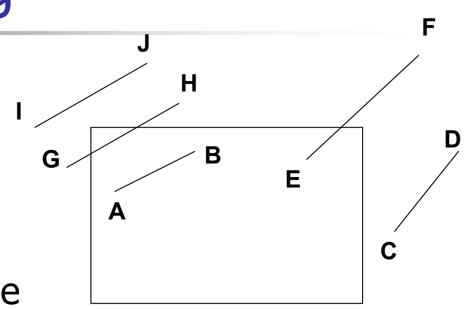
Window Coordinates

- After projection we are in normalized device coordinates
- Convert to window coordinates



Line Clipping

- Accept AB
- Reject (Cull) CD
- Clip EF
  - One endpoint outside the window
- Clip GH
  - Both endpoints outside the window



Cohen-Sutherland Clipping

- Divide the window in nine regions marked by binary codes

$y>y_{max}$	$y<y_{min}$	$x>x_{max}$	$x<x_{min}$
b_1	b_2	b_3	b_4

	$x = x_{min}$		$x = x_{max}$	
	1001	1000	1010
$y = y_{max}$			
	0001	0000	0010
$y = y_{min}$			
	0101	0100	0110

Cohen-Sutherland Clipping

- Find binary codes of two endpoints (C_1, C_2)
  - $C_1 = C_2 = 0$
    - Accept the line, both endpoints inside the window
  - $C_1 = 0$, $C_2 \neq 0$
    - One endpoint outside the window
    - Nonzero bits give the lines with which to intersect
    - Maximum two intersection to get the clipped line

Cohen-Sutherland Clipping

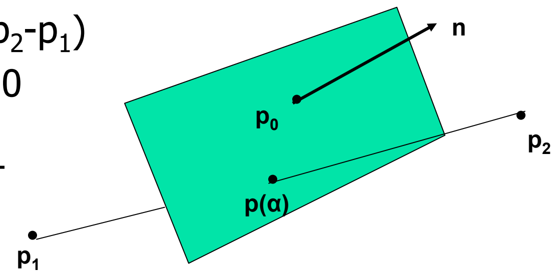
- Find binary codes of two endpoints (C_1, C_2)
  - C_1& $C_2 \neq 0$
    - Both endpoints outside the same edge of the window
    - Cull completely
  - C_1 & C_2= 0
    - Both endpoints outside, but different edges
    - Find the first intersection and find its binary code
    - Apply recursively on this culled line
- All these carried out in order
- Boolean operations, intersections if needed

Cohen-Sutherland Clipping

- Advantage
  - Most lines can be eliminated based on codes
  - Can be easily extended to 3D
  - Plane-line intersection instead if line-line intersection
- Disadvantage
  - Has to be applied recursively

Extending it to 3D

- How many bits for codes? How many codes?
- Plane-line intersection
  - $p(\alpha) = p_1 + \alpha(p_2 - p_1)$
  - $n.(p(\alpha) - p_0) = 0$
  - $\alpha = \dfrac{n.\,(p_1 - p_0)}{n.\,(p_2 - p_1)}$

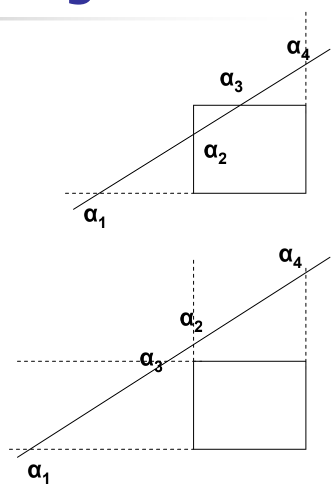


Liang-Barsky Clipping

- Take the parametric equation of the line
- Find intersection with four lines of windows
- Order the alphas

Liang-Barsky Clipping

- $1 > \alpha_4 > \alpha_3 > \alpha_2 > \alpha_1 > 0$
  - Line meets l before t
  - Line between α_2 and α_3 is inside the window
- $1 > \alpha_4 > \alpha_2 > \alpha_3 > \alpha_1 > 0$
  - Line meets t before l
  - Whole line is outside
  - Reject completely



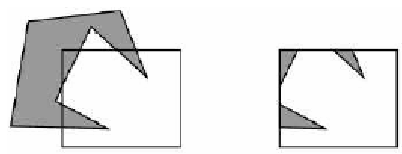
Efficiency Improvements

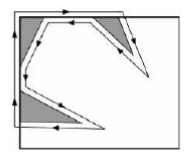
- Compute intersections one by one
  - May need less than four intersections to reject
- Compare without floating point division
  - If $(\alpha_2 < \alpha_3)$ then $(y_{max}-y_1)(x_2-x_1) < (x_{min}-x_1)(y_2-y_1)$

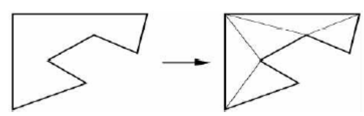
$$y_{max} = (1-\alpha_3)y_1 + \alpha_3 y_2$$
$$x_{min} = (1-\alpha_2)x_1 + \alpha_2 x_2$$
$$\alpha_3 = \frac{y_{max}-y_1}{y_2-y_1} \qquad \alpha_2 = \frac{x_{min}-x_1}{x_2-x_1}$$

Polygon Clipping

- Convex polygons clipped to a single polygon
- Concave polygons
  - Clip and join to a single polygon
  - Tessalate and clip triangles

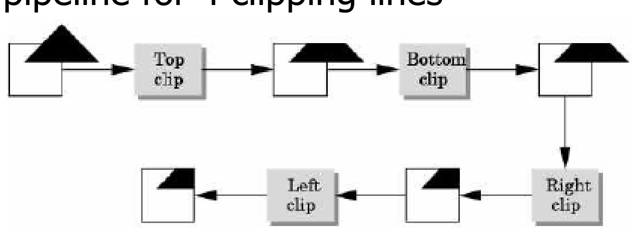






Clipping Convex Polygons

- Sutherland Hodgeman
- Subproblem
  - Input: vertex list (polygon) and a clipping line
  - Output: vertex list (clipped polygon)
- In a pipeline for 4 clipping lines

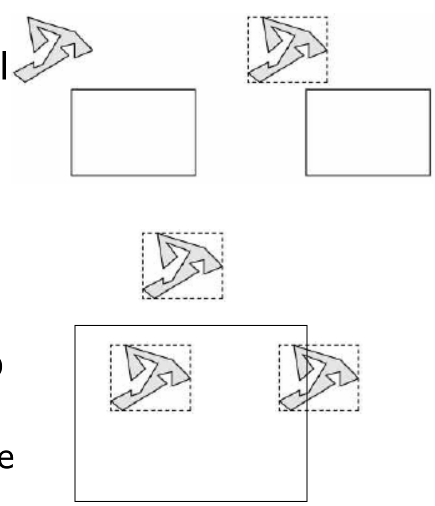


Sutherland Hodgeman

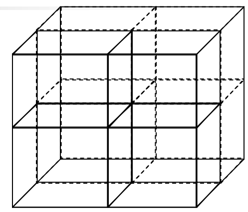
- To clip vertex list against the line
  - Test first vertex, Output if inside else skip
  - Then loop through the list, testing transitions
    - In-to-out: Output intersection
    - In-to-in: Output vertex
    - Out-to-in: Output intersection and vertex
    - Out-to-out: Output nothing
- Can form a pipeline
  - Process vertex list concurrently
- Can be extended to 3D easily (line-plane intersection)

Bounding Boxes and Volumes

- Polygon clipping is overkill if entire polygon outside the window
- Maintain a bounding box
  - Axis-aligned
- Can be a big savings
- Can be easily extended to 3D
  - For volumes in object-space



View Frustum Culling



- Preprocessing: Spatial Subdivision
  - Octree subdivision:Hierarchical Structure
  - Each box has a list of polygons inside it
  - An empty box is the leaf node
- If completely inside the view frustum
  - Accept
- If completely outside the view frustum
  - Reject
- If intersects the view frustum
  - Go through the children recursively

View Frustum Culling

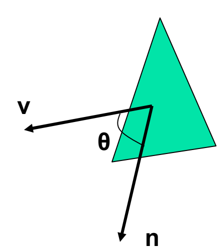
- What happens when a triangle spans across a box?
  - Split the triangle
  - Include it in both boxes
    - Screen space clipping takes care of it
- Octree is suboptimal division
  - Other methods control depth of the tree

Hidden Surface Removal

- Object Space Approach
  - Back Face Culling
  - Painter's Algorithm
- Image Space Approach
  - Z-buffer algorithm

Back Face Culling

- Do not want to render back facing polygons
- If the normal is pointed towards the viewer
  - $-90 \leq \theta \leq 90$
  - $\cos(\theta) \geq 0$
  - $n.v \geq 0$
- Viewing in -z
  - Culled if normal has negative z



Painter's Algorithm

- Depth Sort
  - For back to front rendering
- Problems when polygons overlap in z
  - Can check overlap in x and y direction using bounding boxes
  - Order can be found if no such overlap
- If also overlaps in x and y
  - Split polygons

Z-buffer

- Store z in screen space during projection
- Interpolate 1/z during rasterization
- Find reciprocal to get correct them
- Check less than
- Then overwrite pixel if true