Clipping, Rasterization

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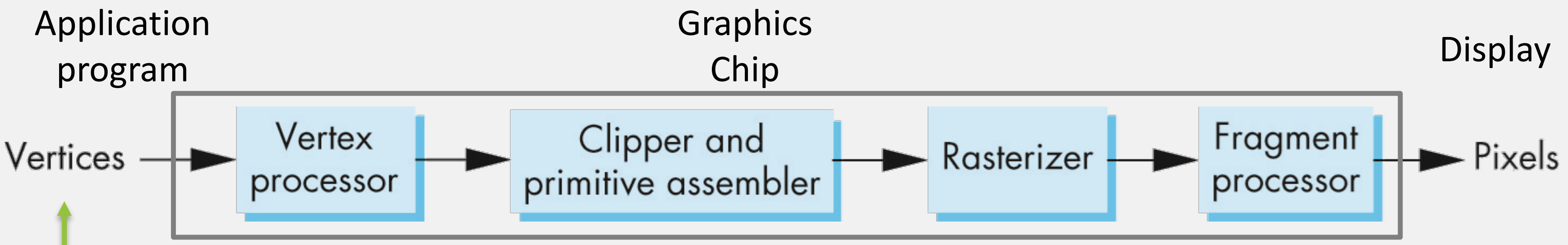
Clipping

Where we are in Rendering Pipeline is …

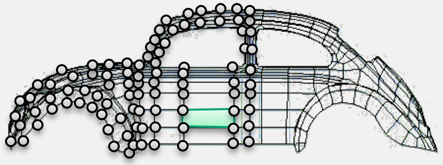
- Pipeline architecture
  - This is everything for interactive computer graphics!
    - First, we focus on the *fixed rendering pipeline*
  - Mechanism: a *state* machine
    - All information for image formations should be specified



Positions: (x, y ,z), …
Normals: (nx, ny, nz), …
Texcoords: (s, t), …
Primitive type: Quads

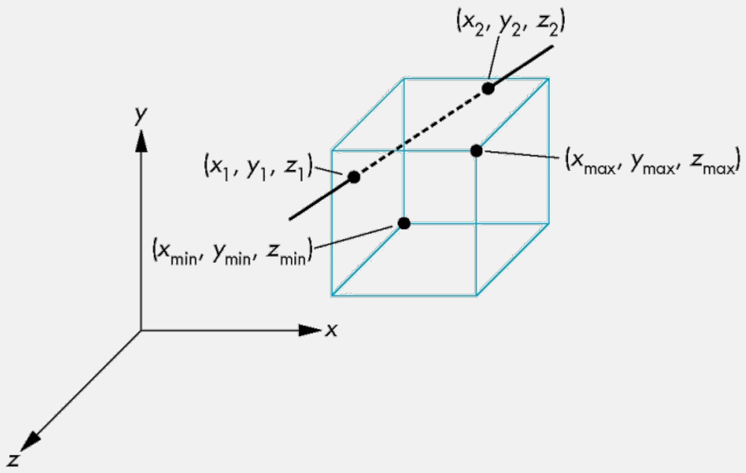
Our input

Our output



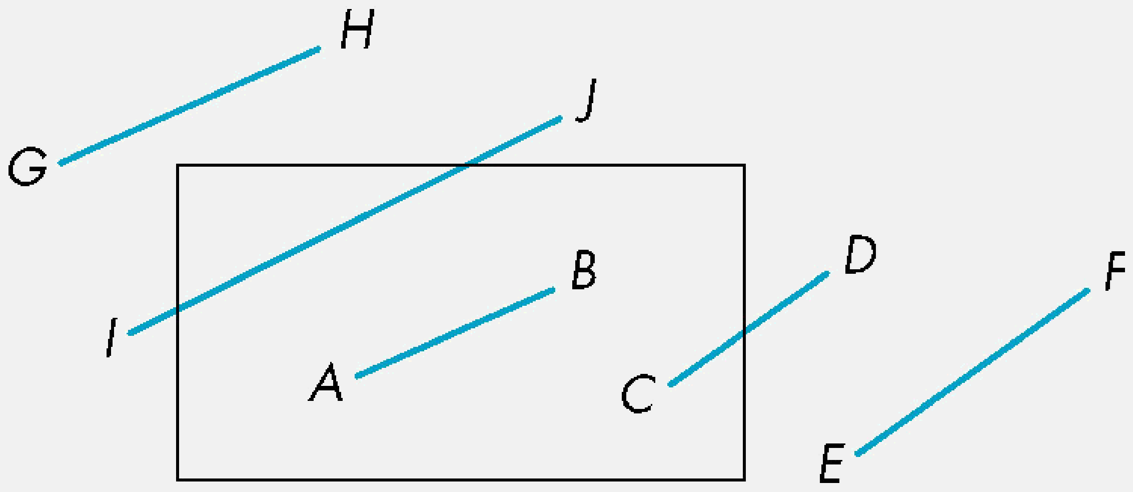
Clipping

- To eliminate objects that lie outside of viewing volume
  - Performed in several places in the pipeline
  - Accept / Reject(or cull)
  - Supported by H/W or S/W



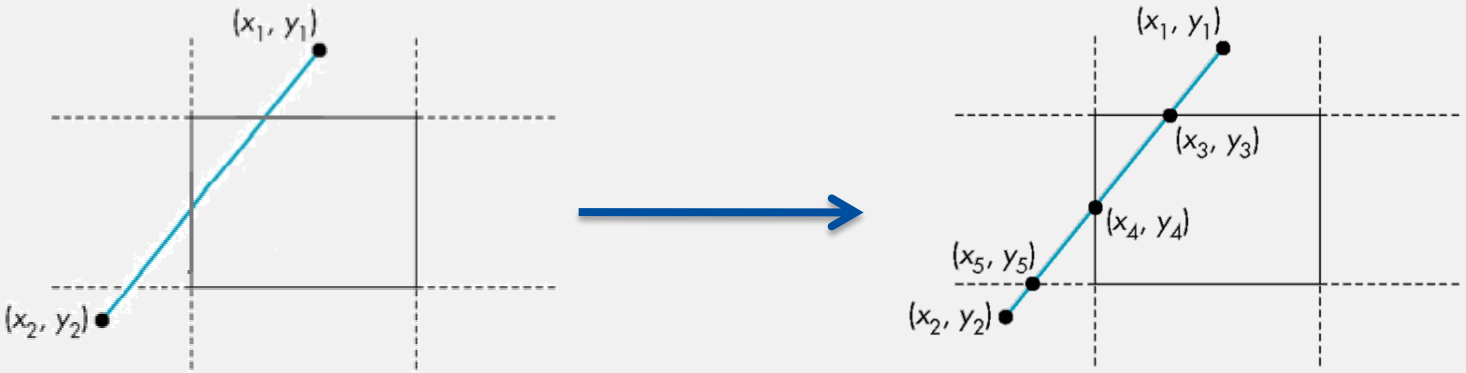
Line-Segment Clipping

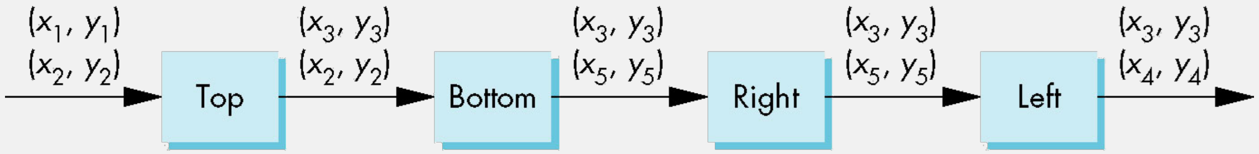
- From an input line, to clip out a portion which passes through the view volume



Line-Segment Clipping

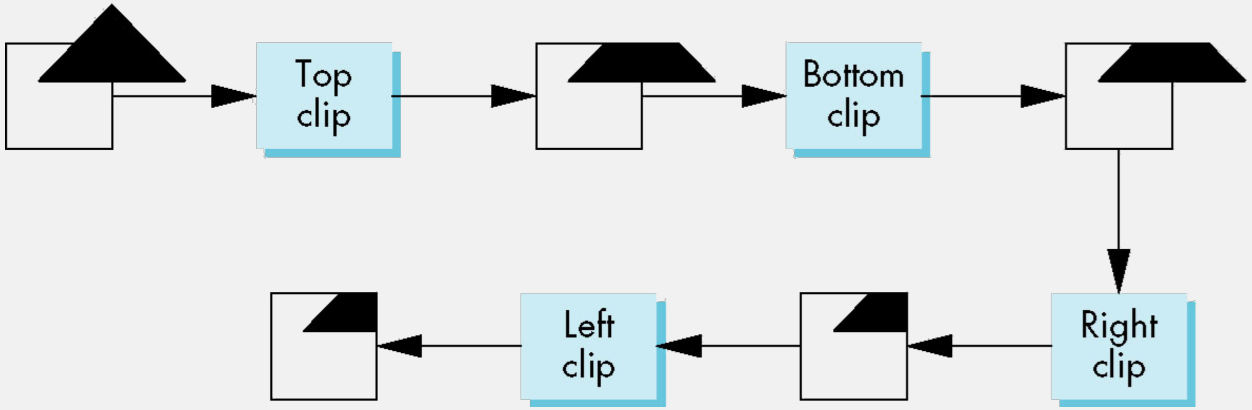
- From an input line, to clip out a portion which passes through the view volume





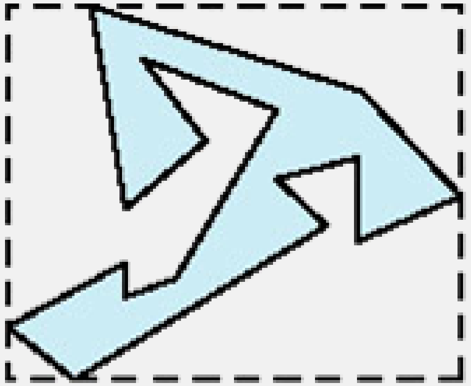
Polygon Clipping

- From a given polygon, to clip out portions which are inside of the view volume



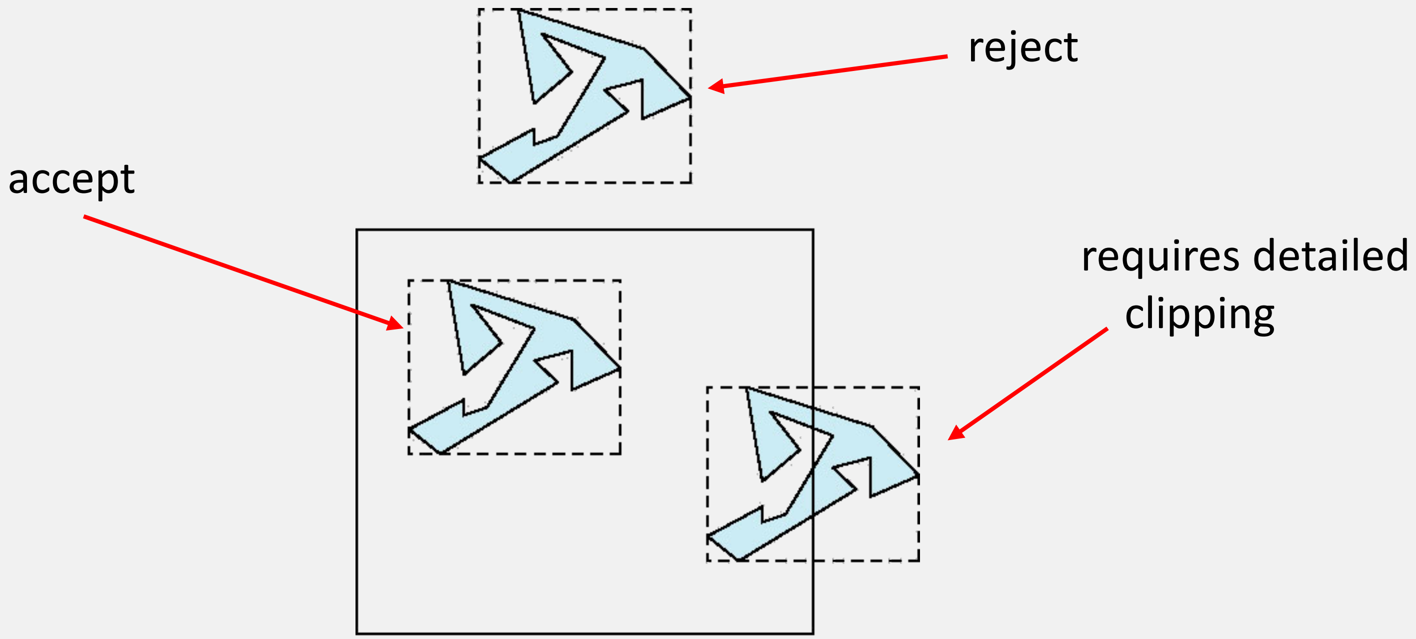
Bounding Boxes and Volumes

- Rather than doing clipping on a complex polygon, we can use an axis-aligned bounding box or extent
  - Usually, used in the game-engine



Bounding Boxes and Volumes

- Determine accept/reject based only on bounding box



Rasterization

Where we are in Rendering Pipeline is …

- Pipeline architecture
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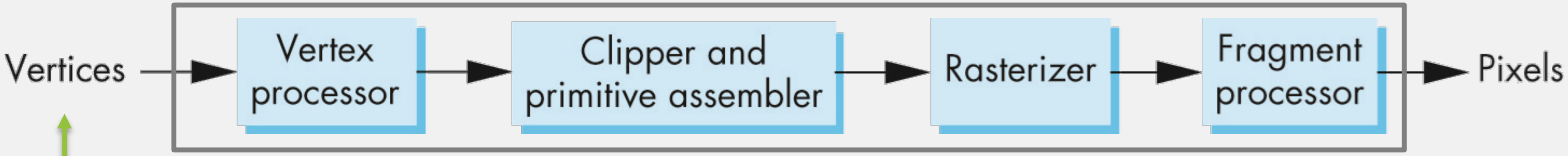
Application program

Graphics Chip

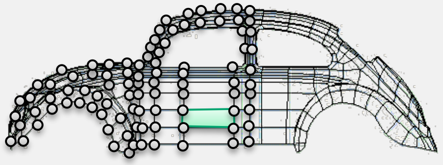
Display



Vertices → Vertex processor → Clipper and primitive assembler → Rasterizer → Fragment processor → Pixels

Positions: (x, y ,z), …
Normals: (nx, ny, nz), …
Texcoords: (s, t), …
Primitive type: Quads

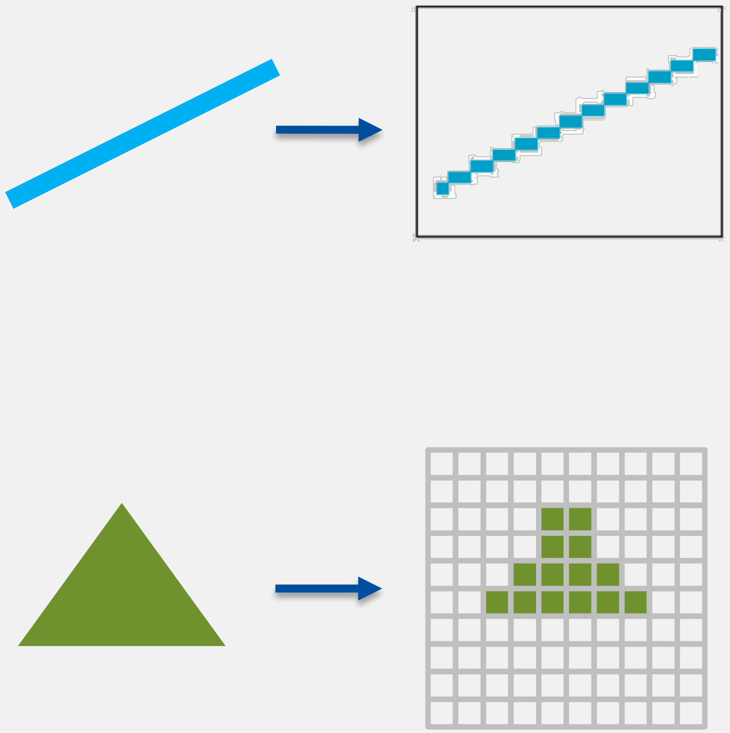
Our input



Our output

Rasterization

- Rasterization (Scan conversion)
  - The process of converting a primitive into a set of pixels
  - It computes
    - Fragment location
      - Which pixels that are inside primitive specified by a set of vertices
    - Per-fragment attributes
      - Attributes, such as color and texture coordinates are determined by interpolating values at vertices

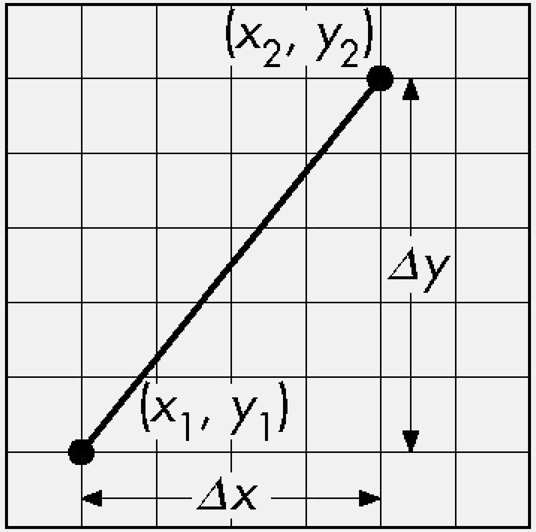


Line Rasterization

- DDA algorithm
  - With a given line equation (i.e., *y* = *mx* + *h*), compute *y* by increasing x by Δx

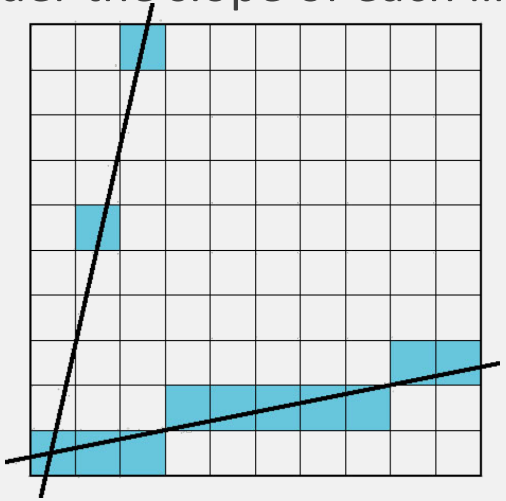
$$y = mx + h$$

$$m = \frac{\Delta y}{\Delta x}$$

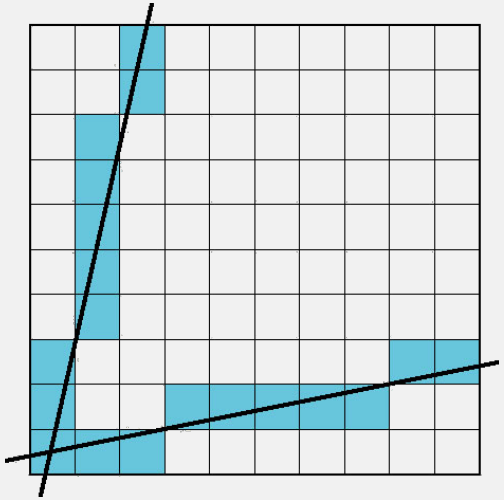


Line Rasterization

- DDA algorithm
  - We have to consider the slope of each line



DDA Algorithm w/o considering slopes

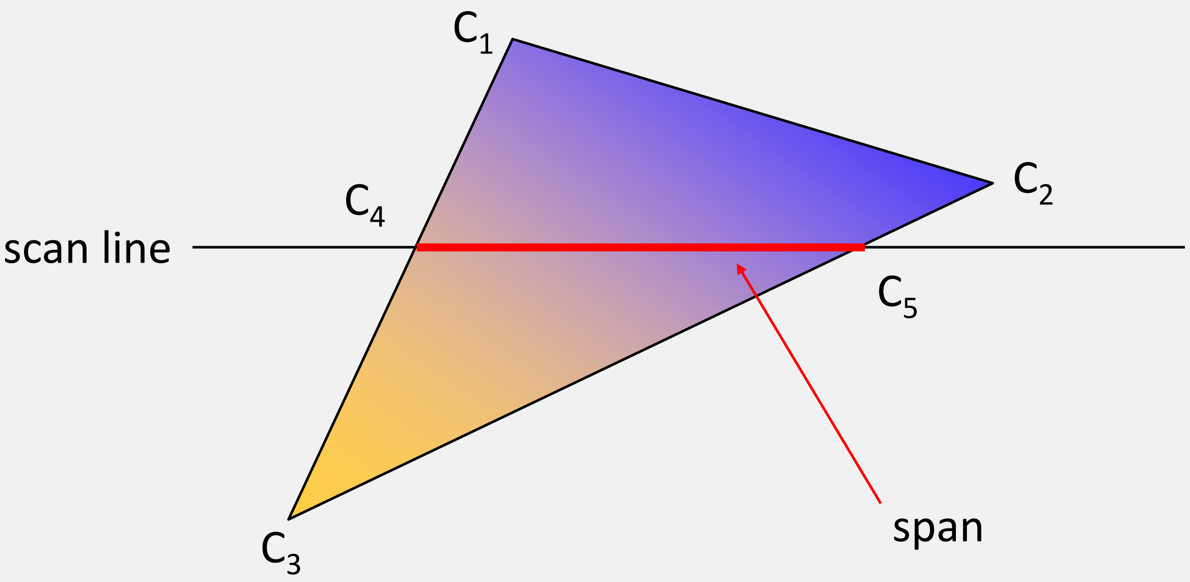


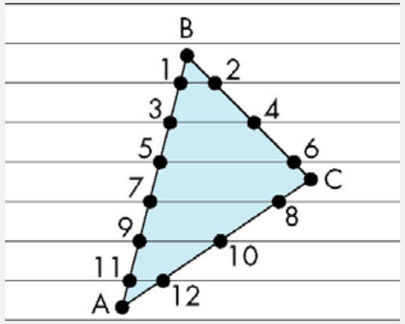
DDA Algorithm w considering slopes

- Bresenham's line algorithm is implemented in graphics HW, in practice

Polygon Rasterization

- Bilinear interpolation
  - First, colors on the line is interpolated
  - Second, colors on each scan line interpolated
- Here, several attributes are interpolated over the fragments in a triangle

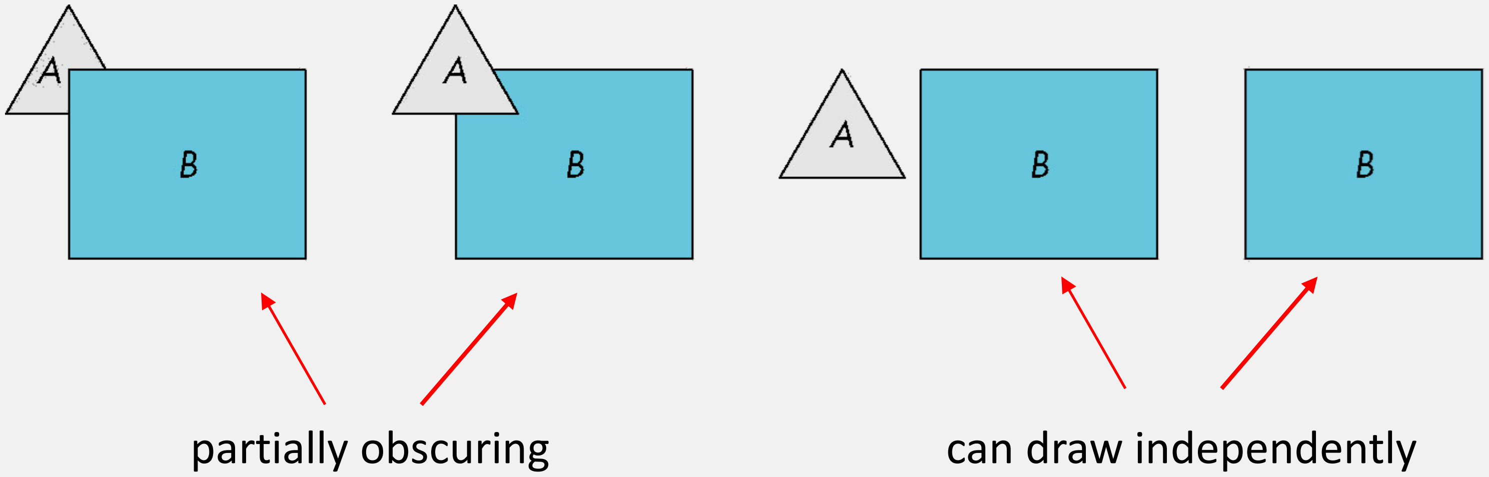




Hidden Surface Removal

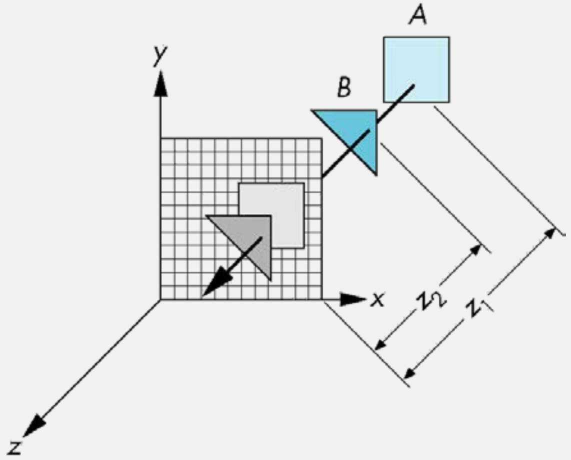
Hidden Surface Removal

- General concept



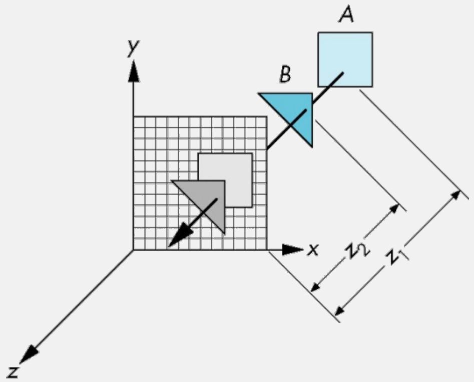
Hidden Surface Removal – z-buffer Algorithm

- z-buffer (or depth-buffer) algorithm
  - It uses a buffer called z- or depth-buffer to store the depth of the closest object at each pixel found so far
  - As we render each polygon, compare the depth of each pixel to depth in z-buffer
  - If less, place shade of pixel in color buffer and update z-buffer



Hidden Surface Removal – z-buffer Algorithm

- z-buffer (or depth-buffer) algorithm
  - We have an additional buffer whose size is identical to the color buffer
  - Each pixel in the depth buffer keeps a depth-value, which is the sitance to the point on the nearest object from the synthetic camera



			🟩	🟩			
			🟩	🟩			
		🟩	🟩	🟩	🟩		
	🟩	🟩	🟩	🟩	🟩	🟩	

Color buffer

			0.7	0.6			
			0.8	0.7			
		1.0	0.9	0.8	0.7		
	1.2	1.1	1.0	0.9	0.8	0.7	

Depth buffer

Hidden Surface Removal – z-buffer Algorithm

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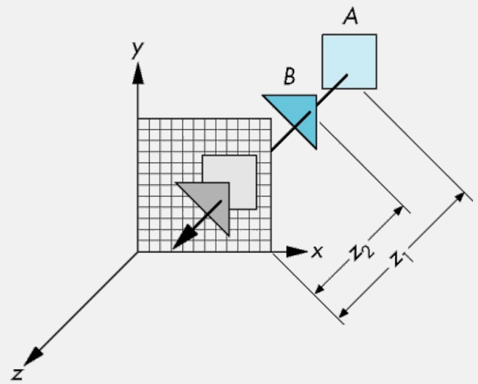
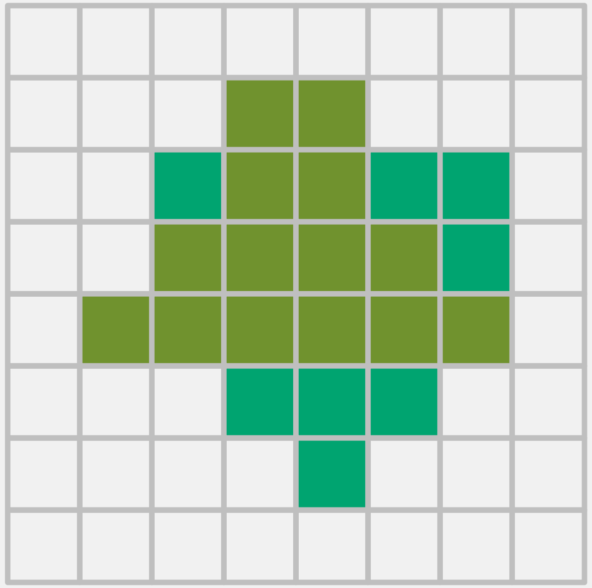




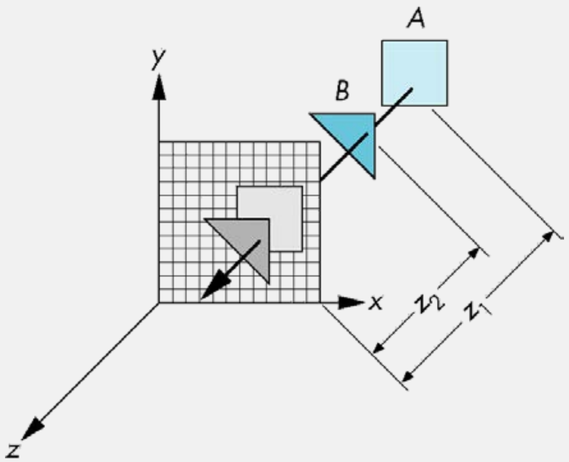
Color buffer

			0.7	0.6			
		2.5	0.8	0.7	2.8	2.9	
		1.0	0.9	0.8	0.7	2.9	
	1.2	1.1	1.0	0.9	0.8	0.7	
			2.5	2.6	2.7		
				2.5			

Depth buffer

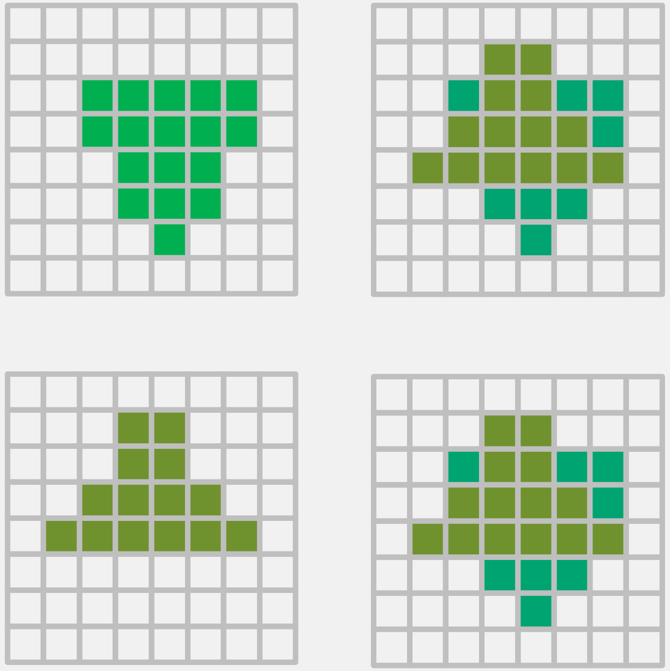
Hidden Surface Removal – z-buffer Algorithm

- Advantages
  - The programmer do not need to care about the rendering order of objects in a scene
    - A → B
    - B → A



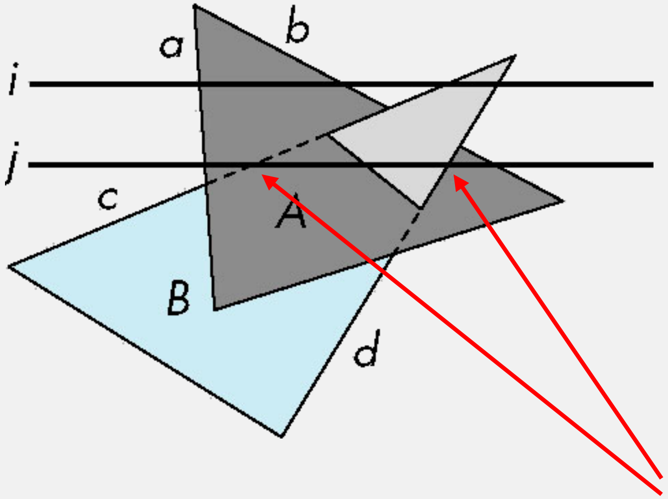
A → B

B → A



Hidden Surface Removal – z-buffer Algorithm

- Advantage
  - Z-buffer algorithm can combine shading and hiddn surface removal through scan line algorithm

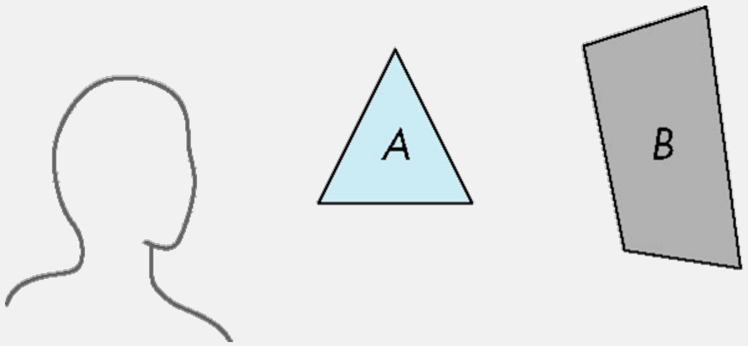


scan line *i*: no need for depth information, can only be in no or one polygon

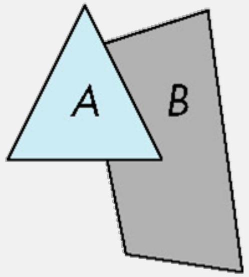
scan line *j*: need depth information only when in more than one polygon

Hidden Surface Removal – Painter's Algorithm

- A kind of S/W approach
- Render polygons a back to front order so that polygons behind others are simply painted over
  - We need to perform a sorting algorithm



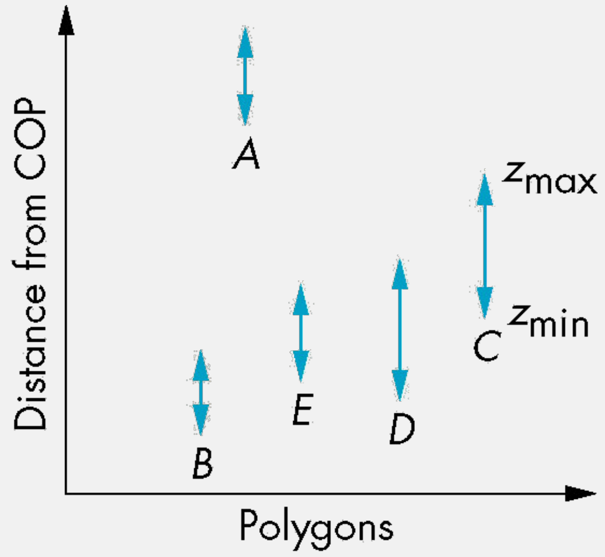
B behind A as seen by viewer



1) Fill B
2) Fill A

Hidden Surface Removal – Painter's Algorithm

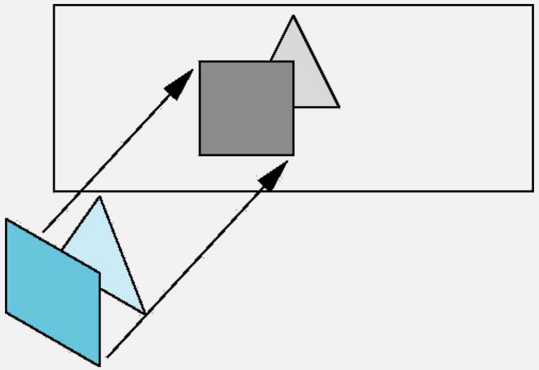
- Requires ordering of polygons first
  - O(*n*log*n*) caculation for ordering
  - Not every polygon is eithter in front or behind all other polygons



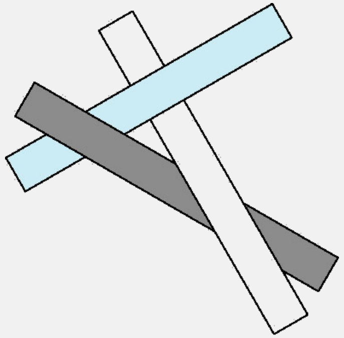
Polygons sorted by distance from COP

Hidden Surface Removal – Painter's Algorithm

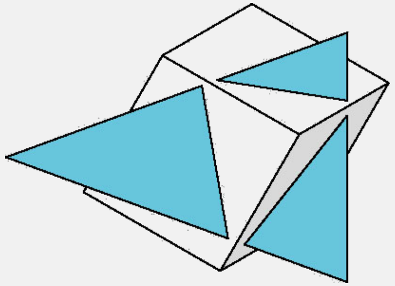
- There are non-trivial cases exist for depth sorts
- Why?



Overlap in all directions
but can one is fully on
one side of the other



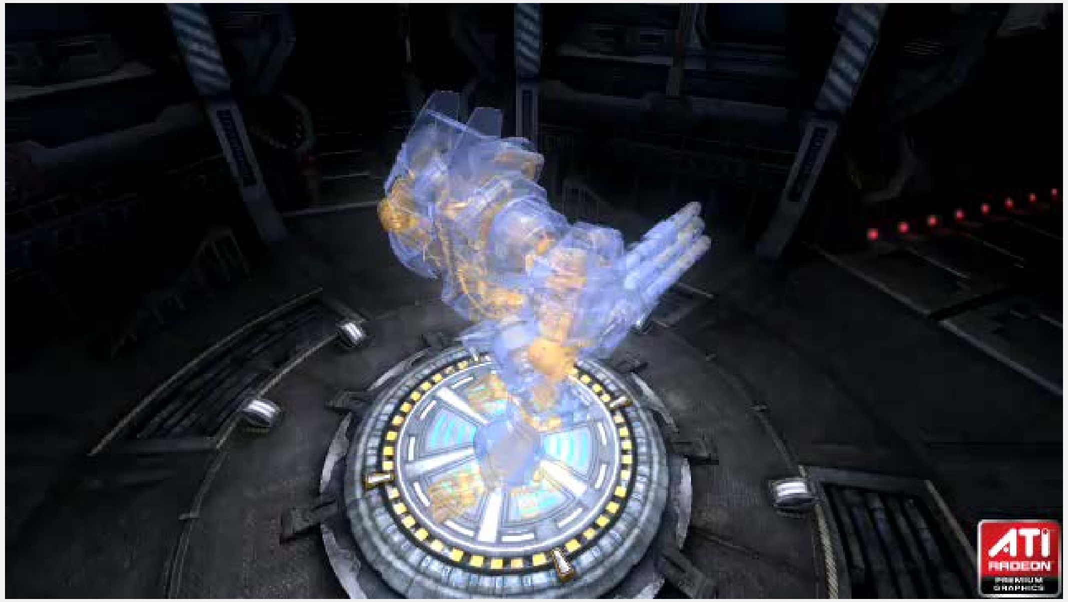
cyclic overlap



penetration

Hidden Surface Removal – Painter’s Algorithm

- Why we should learn about painter’s algorithm, even though graphics HW supports the z-buffer algorithm
  - For using alpha blending, we have to render polygons a back to front order



[AMD DirectX 11 Demo for H/W accelerated alpha blending]
(video, youtube)

Hidden-Surface Removal – Back-face Removal

- Back-face removal (culling) algorithm
  - Face is visible iff $90 \geq \theta \geq -90$
    - equivalently $\cos\theta \geq 0$ or $\mathbf{v} \bullet \mathbf{n} \geq 0$
  - Recall that you always send the vertices in a polygon in the order of CCW.
    - Simply, almost 50% polygons are culled from the back-face removal