Introduction to Computer Graphics

2016 Spring

National Cheng Kung University

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Presentation

- Read and present at least one paper from:
  - http://kesen.realtimerendering.com/sig2015.html
  - http://kesen.realtimerendering.com/egsr2015Papers.htm
  - http://kesen.realtimerendering.com/i3d2016Papers.htm
- 3~4 members per team
- Presentation dates:
  - 5/3, 5/10, 5/24, 5/31, 6/7, 6/14
  - 3 teams per week
  - 10 minutes per team

Outline of your presentation

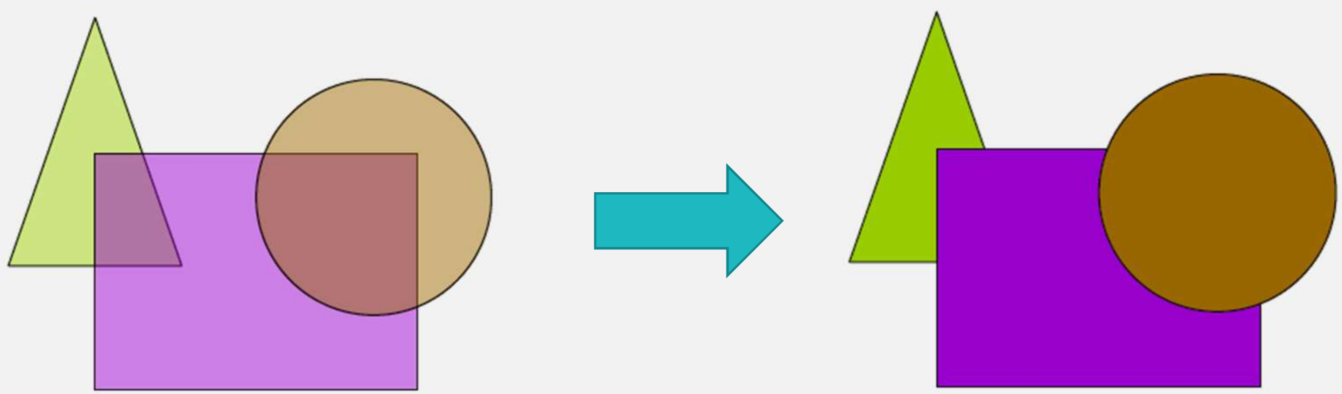
- Motivation of this work (20%)
  - You can play demo video to briefly show the concept, but the video should be no more than 1 minute
- Related work (20%)
  - Briefly compare previous work and show the strength/weakness of them
- Main idea/methodology (20%)
  - You do not have to understand all details/equations (just try your best), but you have to figure out why the proposed method works better
- Results & discussion (20%)
  - Show the results and point out what can be done to make the work better
- Studying experience sharing (20%)

Your score will be your Team Score ±5 (based on your performance)

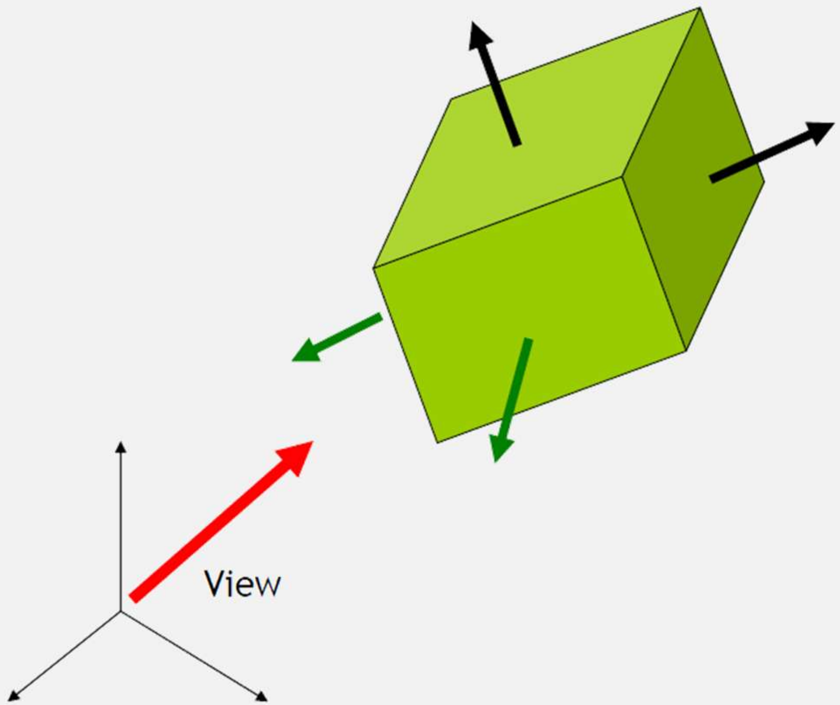
Hidden Surface Removal (HSR) & Culling

Objectives

- In 3D wireframe displayer, we can simply draw the line segments between projected point pairs.
- To fill projected polygons, we have to remove "hidden surfaces".

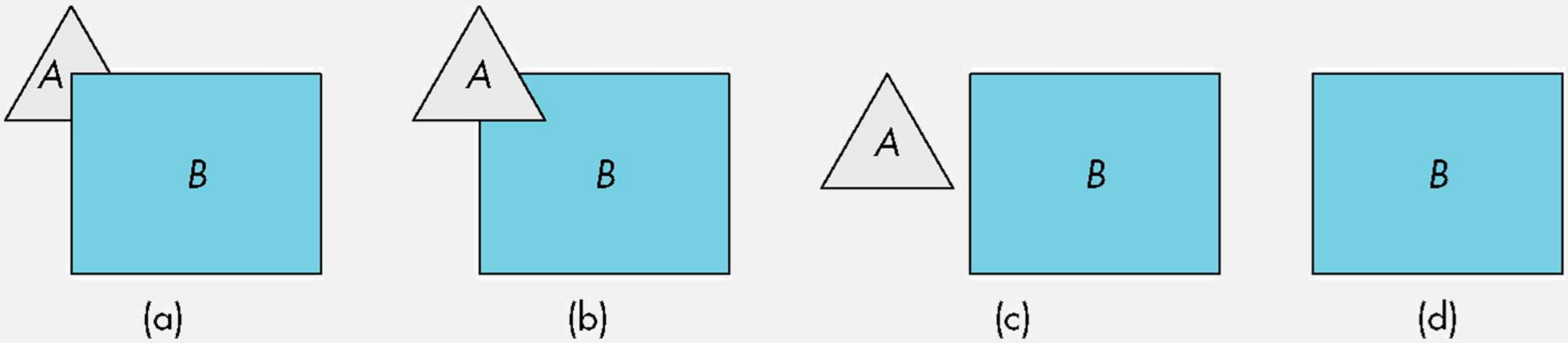


Backface Culling



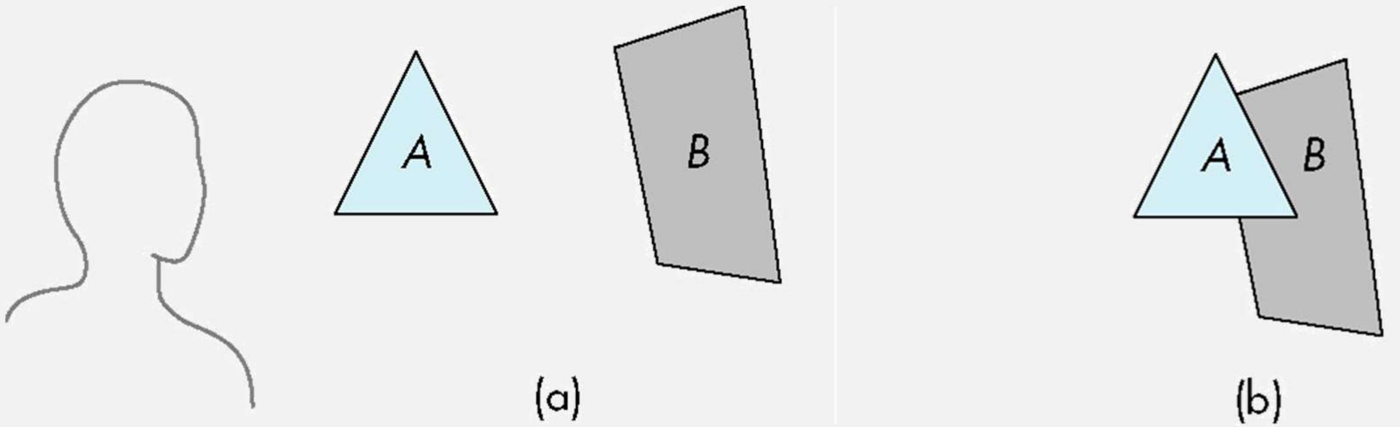
Hidden Surface Removal

- Object-space approach: use pairwise testing between polygons (objects)
- Worst case complexity O(n^2) for n polygons



Painter's Algorithm

- Render polygons in a back to front order so that polygons behind others are simply painted over

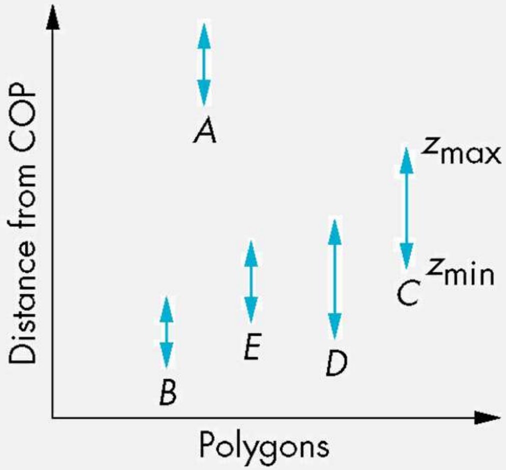


B behind A as seen by the viewer

Fill B then A

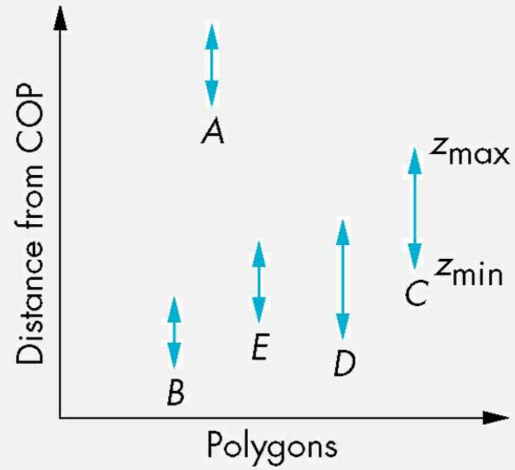
Depth Sort

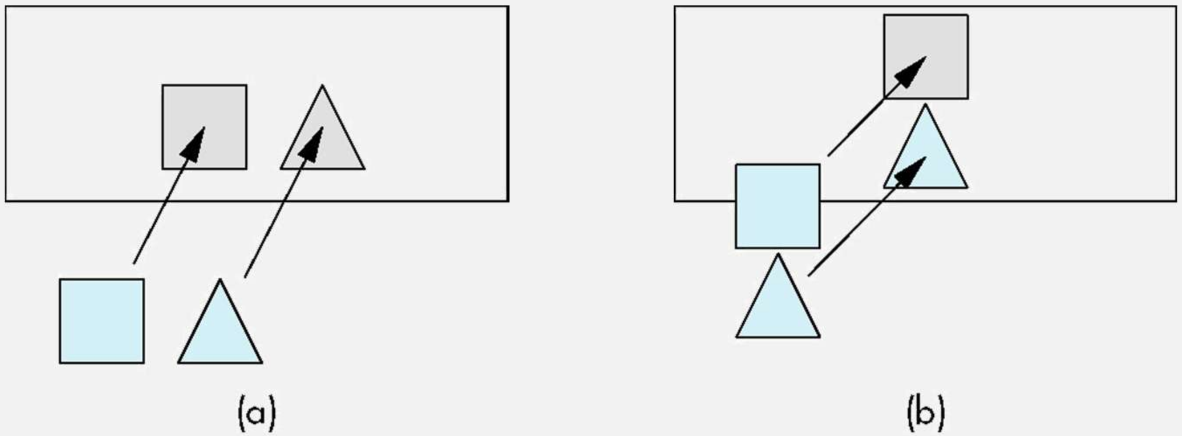
- Requires ordering of polygons first
  - O(n log n) calculation for ordering
  - Not every polygon is either in front or behind all other polygons
- Order polygons and deal with easy cases first, harder later



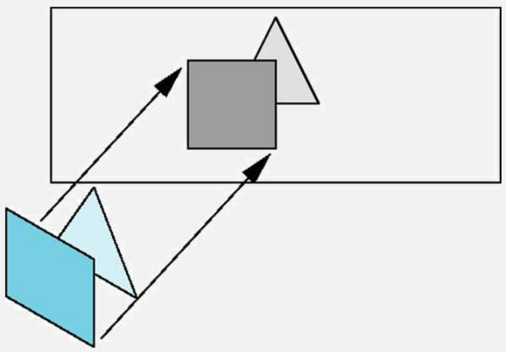
Easy Cases

- A polygon lies behind all other polygons
  - Can be rendered first (e.g. A)
- Polygons overlap in z but not in either x or y
  - Can be rendered independently

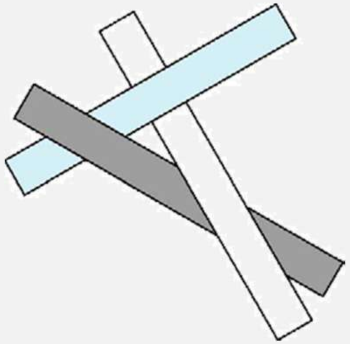




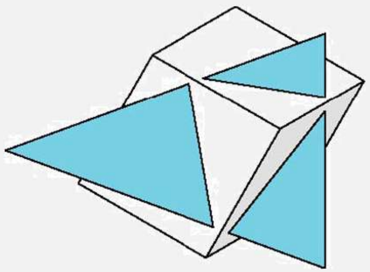
Difficult Cases



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



cyclic overlap



penetration

Image Space Approach

- Three surfaces overlapping pixel position (x, y) on the view plane. The visible surface, S_1, has the smallest depth value.

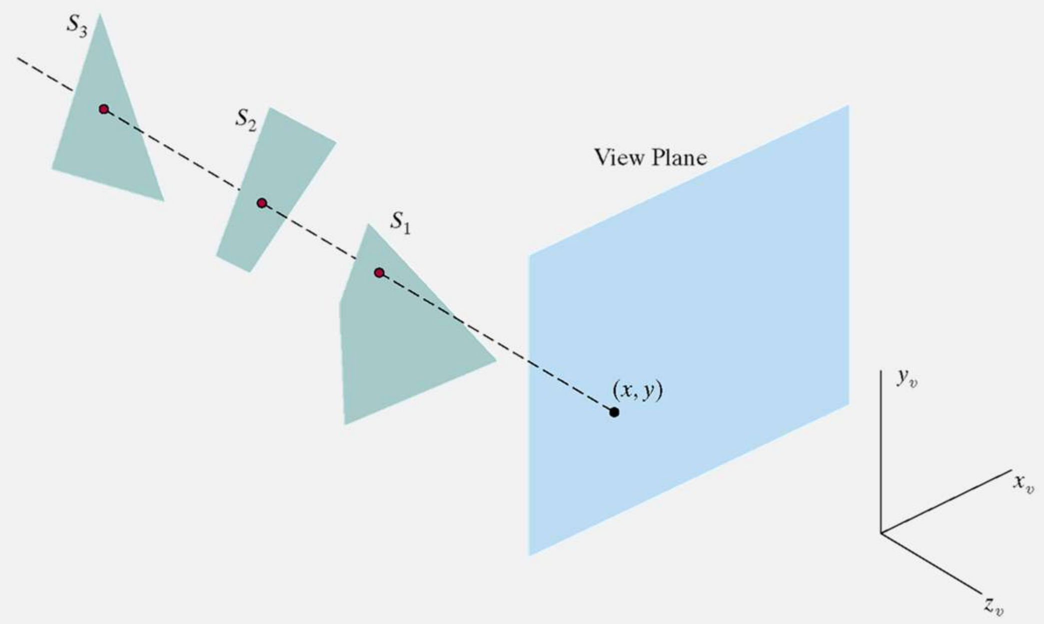
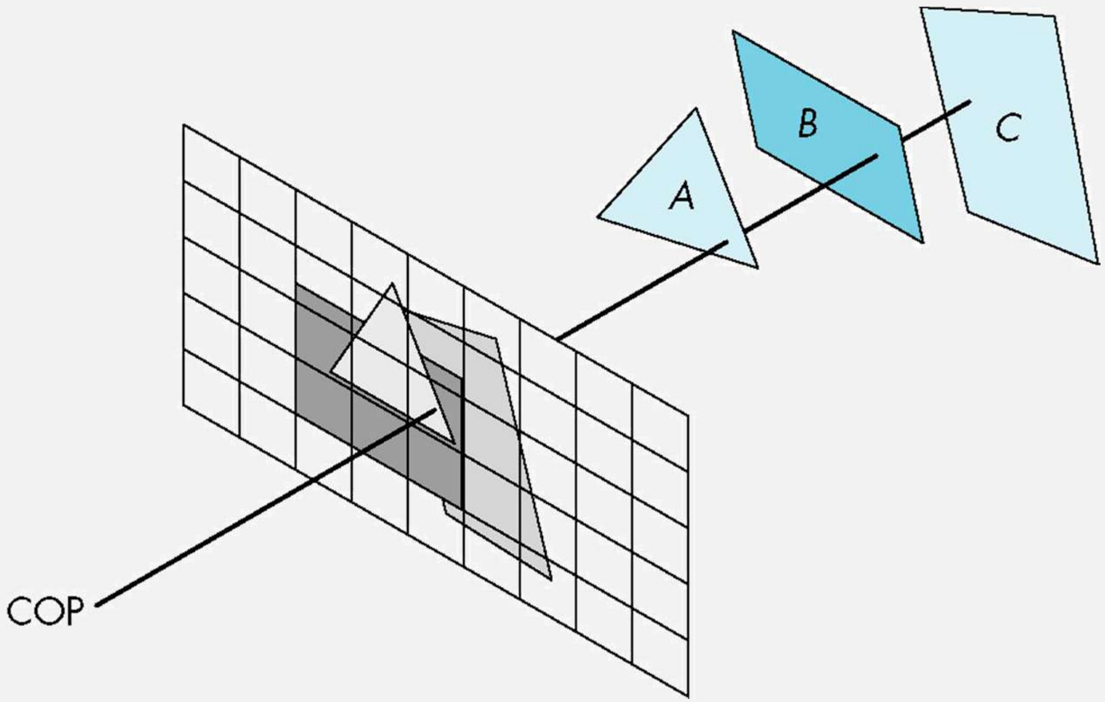


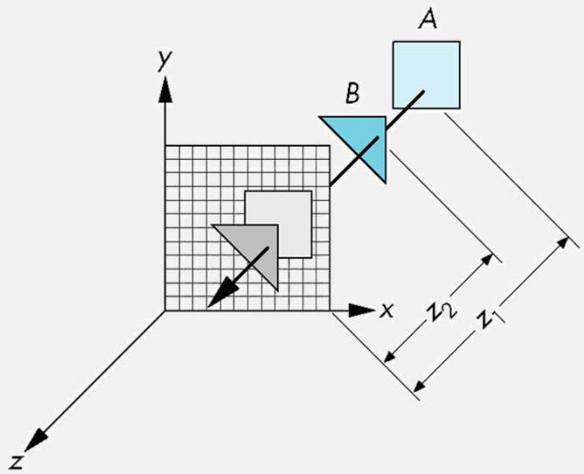
Image Space Approach (Cont.)

- Look at each projector (nm for an $n \times m$ frame buffer) and find the closest of the k polygons
- Complexity O(nmk)
- Ray casting
- z-buffer



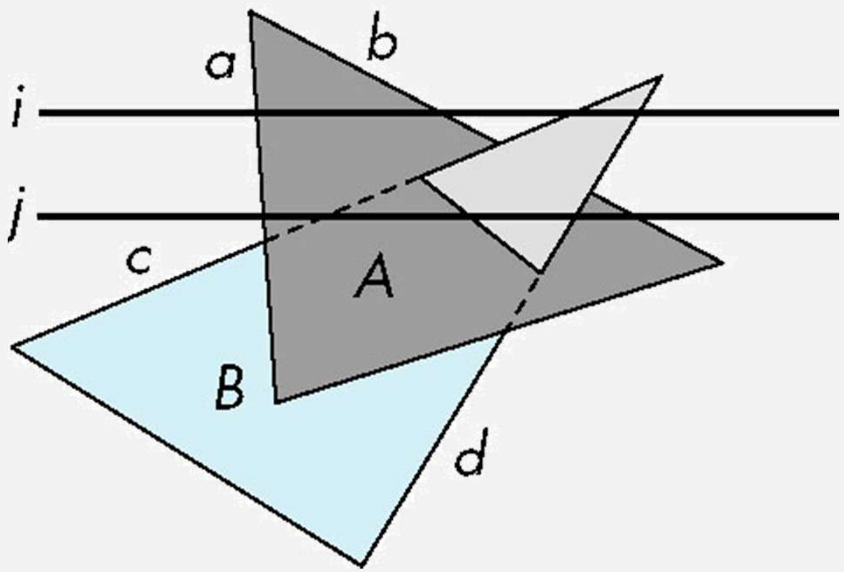
z-Buffer Algorithm

- The z or depth buffer
  - 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 the shade of pixel in the color buffer and update z buffer



Scan-Line Algorithm

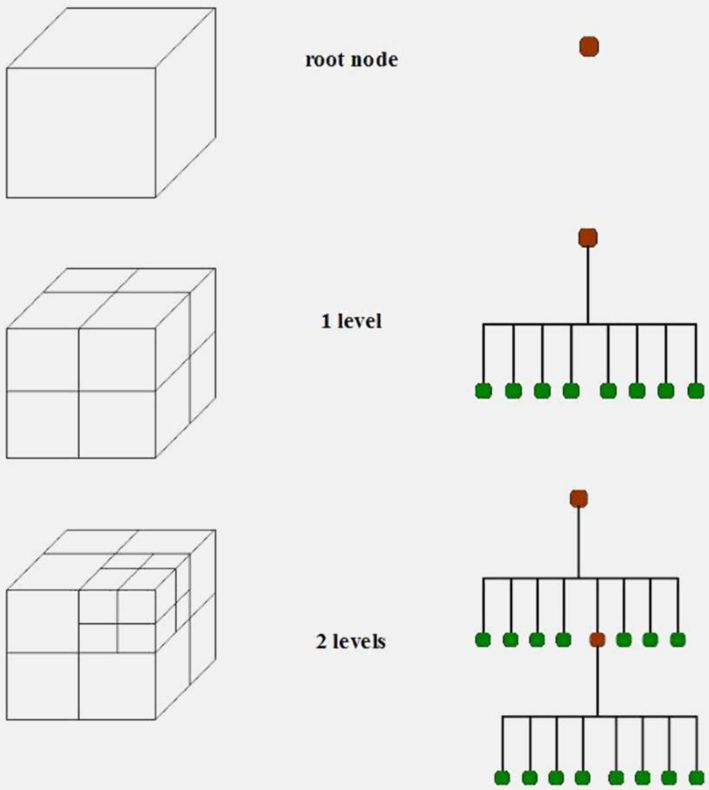
- Can combine shading and HSR through scan line algorithm

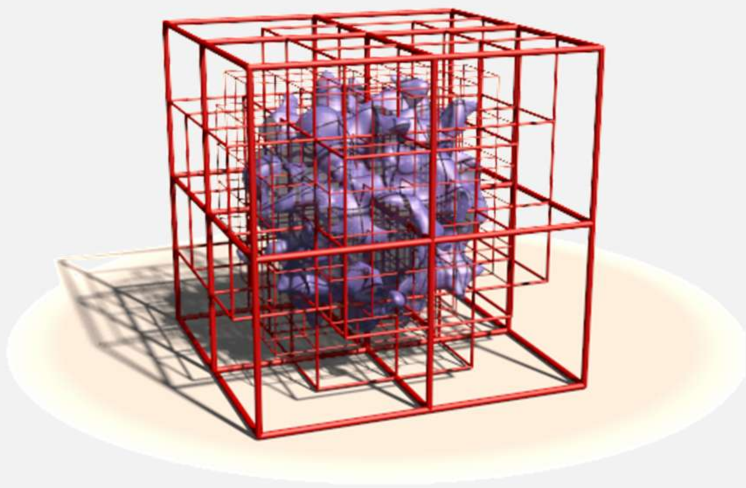


Space Partitioning

- Avoid rendering an object when it's unnecessary
  - In many real-time applications, we want to eliminate as many objects as possible within the application.
  - Reduce burden on pipeline
  - Reduce traffic on bus
- Octree
- BSP tree

Octree

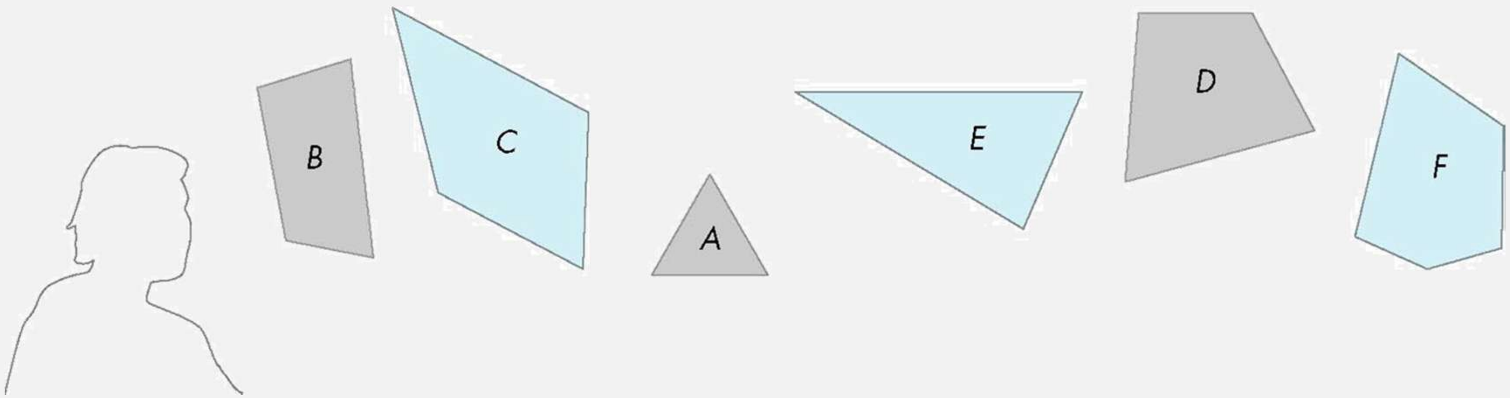




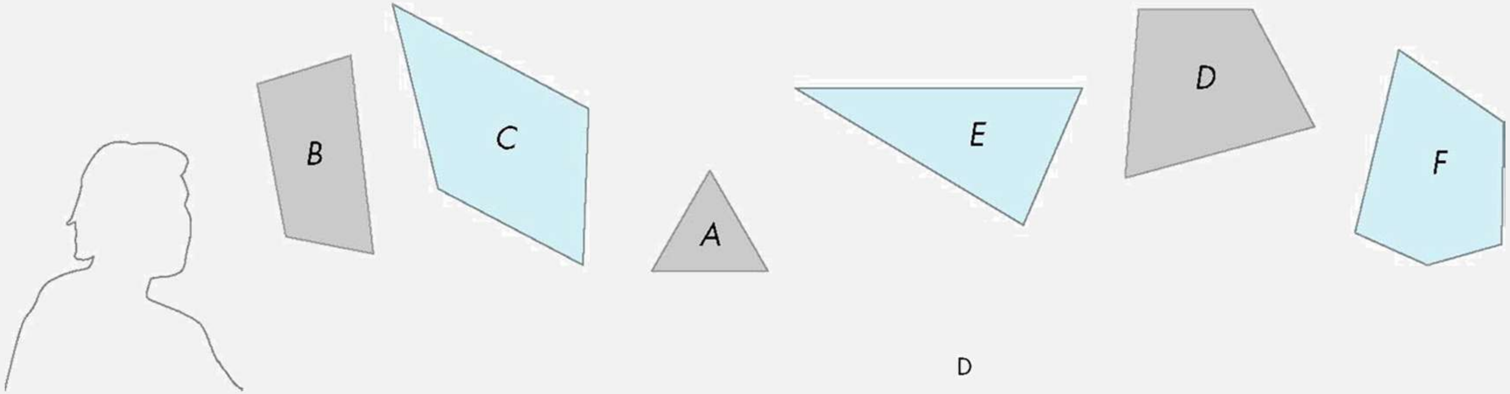
http://www.imagico.de/fast_iso/patch.html

Why do we use BSP trees?

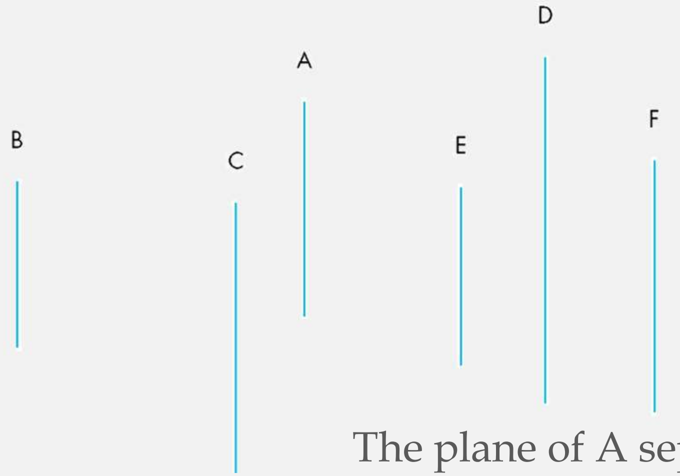
- Hidden surface removal
  - A back-to-front painter's algorithm
- Partition space with Binary Spatial Partition (BSP) Tree



A Simple Example



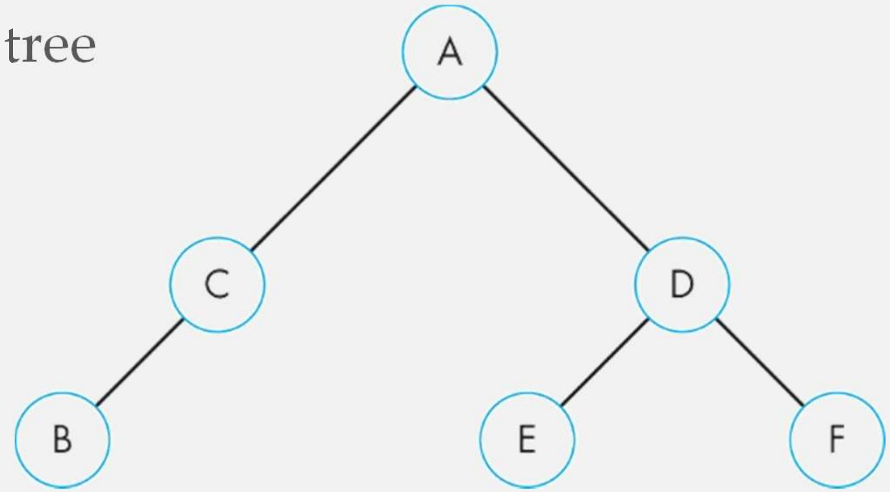
top view



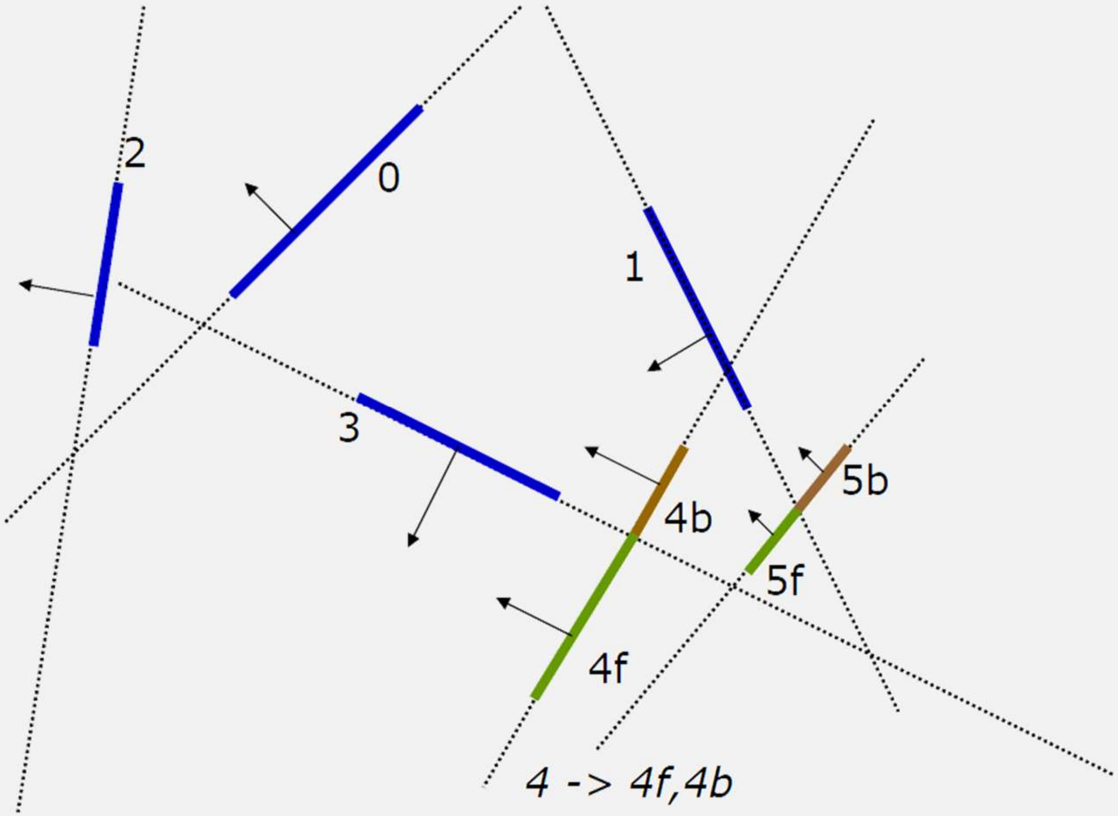
The plane of A separates B and C from D, E and F

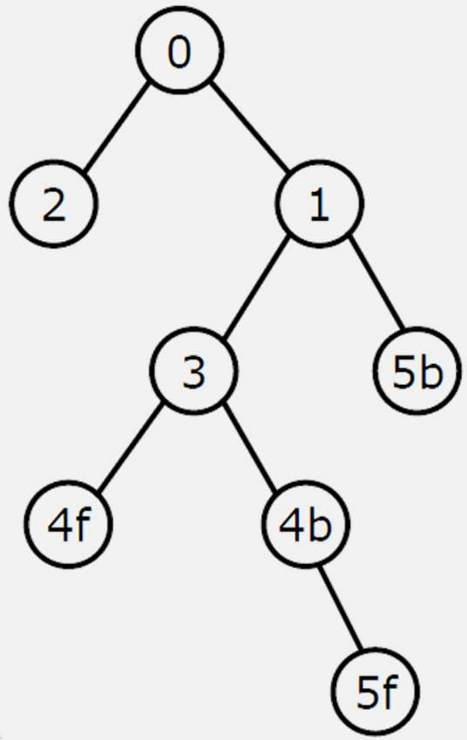
Binary Space Partitioning Tree

- Can continue recursively
  - Plane of C separates B from A
  - Plane of D separates E and F
- Can put this information in a BSP tree
  - Use for visibility and occlusion testing



Creating a BSP tree

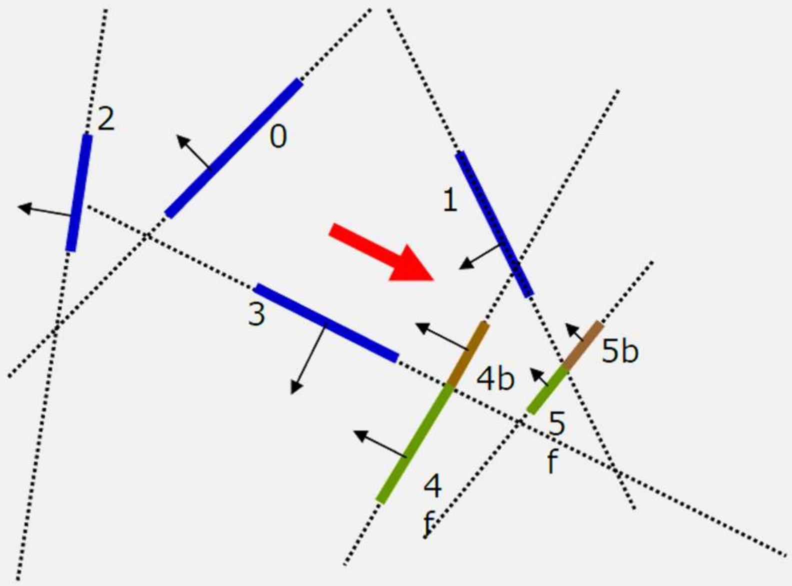


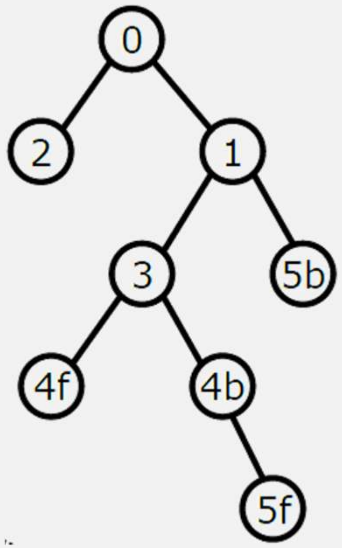


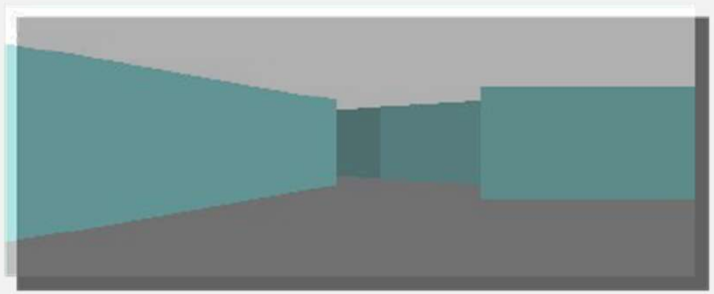
Back-to-Front Render

```
Render(node, view){
        if node is a leaf
                { draw this node to the screen }
        else
                if the viewpoint is in back of the dividing line
                {
                        render(front subnode)
                        draw node to screen
                        render(back subnode)
                }
                else the viewpoint is in front of the dividing line
                {
                        render (back subnode)
                        draw node to screen
                        render (front subnode)
                }
```

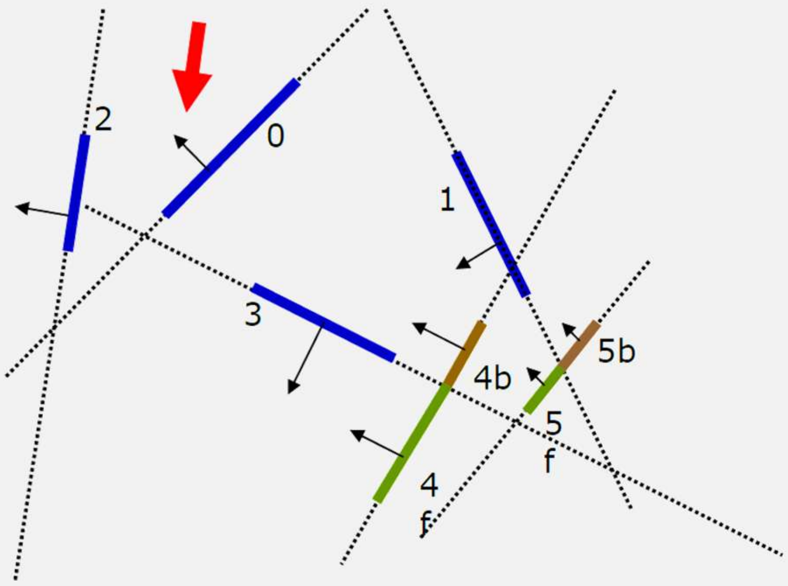
Back-to-Front Render (Cont.)

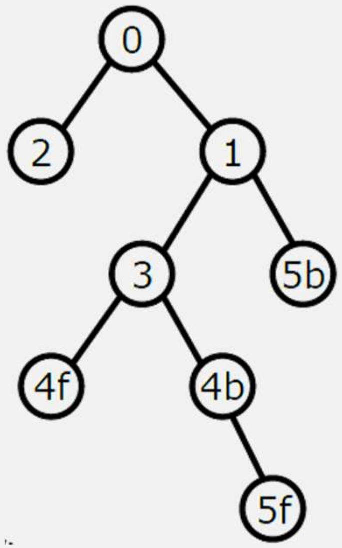


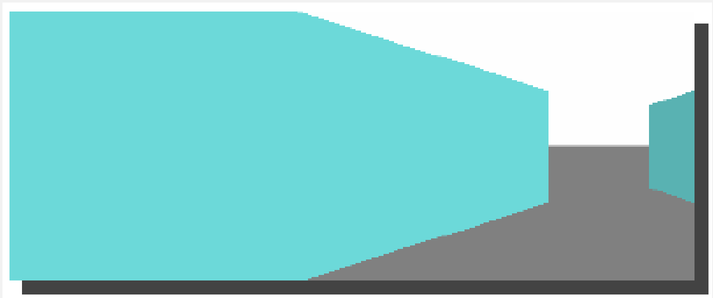




Back-to-Front Render (Cont.)







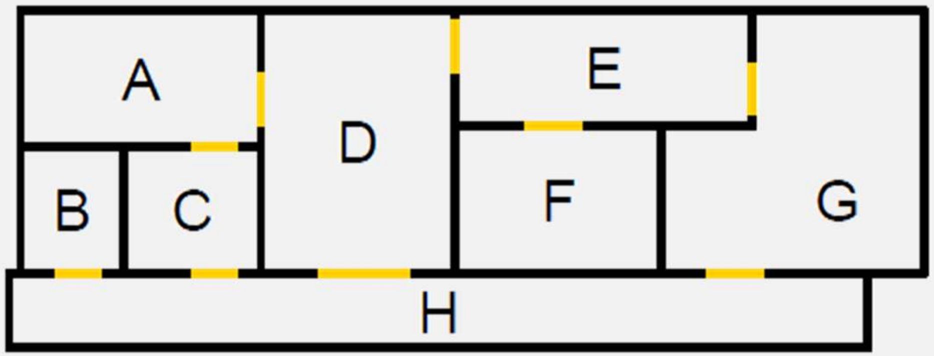
BSP-based Culling

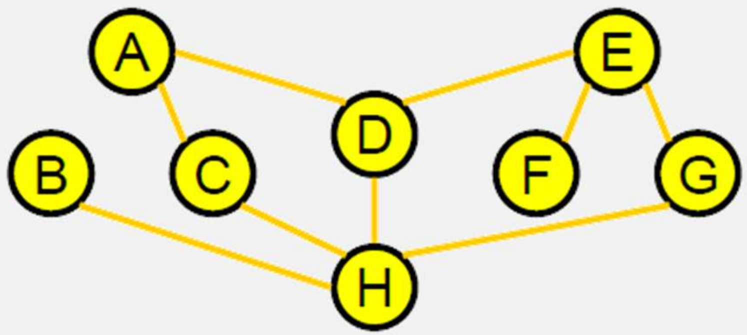
- Pervasively used in first person shooting games.
  - Doom, quake….etc.
- Visibility test
- Skip objects that are "occluded".

a screen shot from Doom

Other Culling Tech.

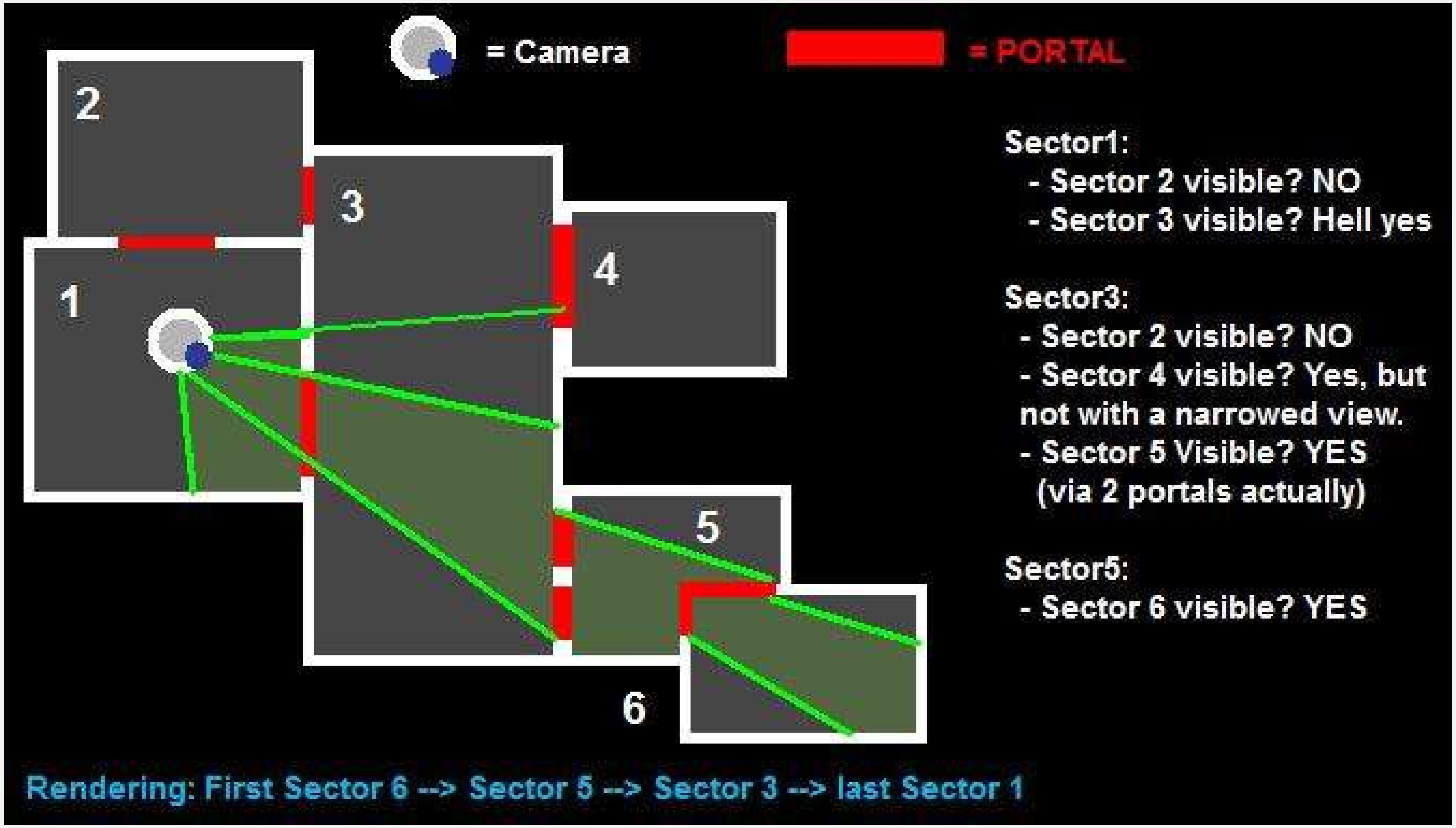
- Portal Culling
  - Walking through architectures
  - Dividing space into cells
  - Cells only see other cells through portals





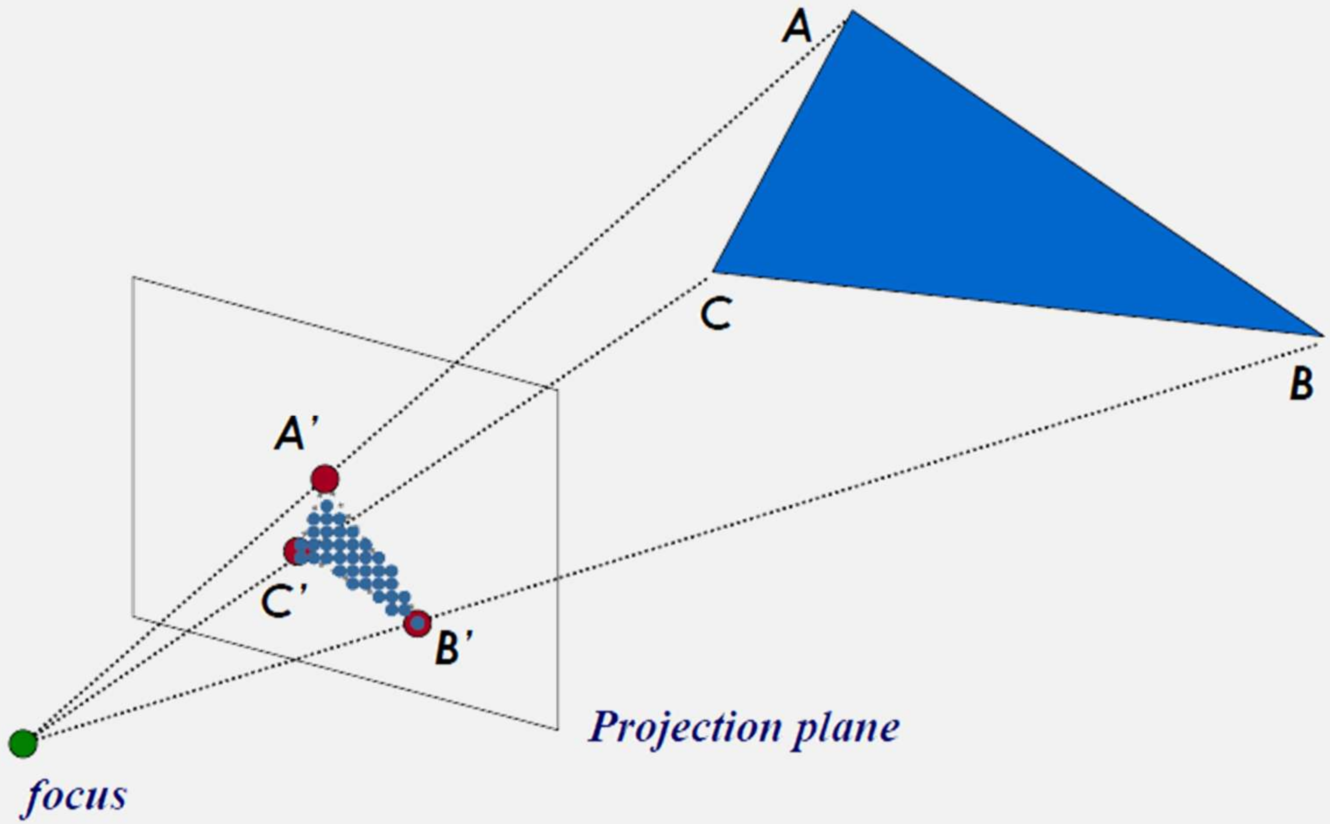
Ref: www.cse.ohio-state.edu/~hwshen

Other Culling Tech.



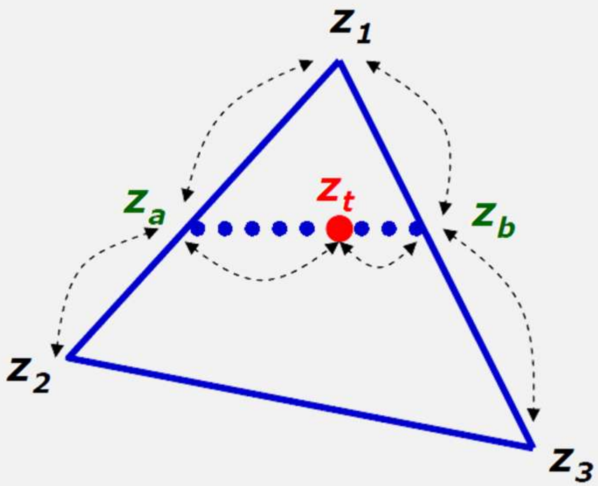
Ref: http://tower22.blogspot.tw/2011_07_01_archive.html

Interpolation of Z values



Interpolation of Z values (Cont.)

- To fill the polygon on the screen, we only fill the color and estimate the z value "pixel by pixel".
- How to estimate z of in-between pixels ?

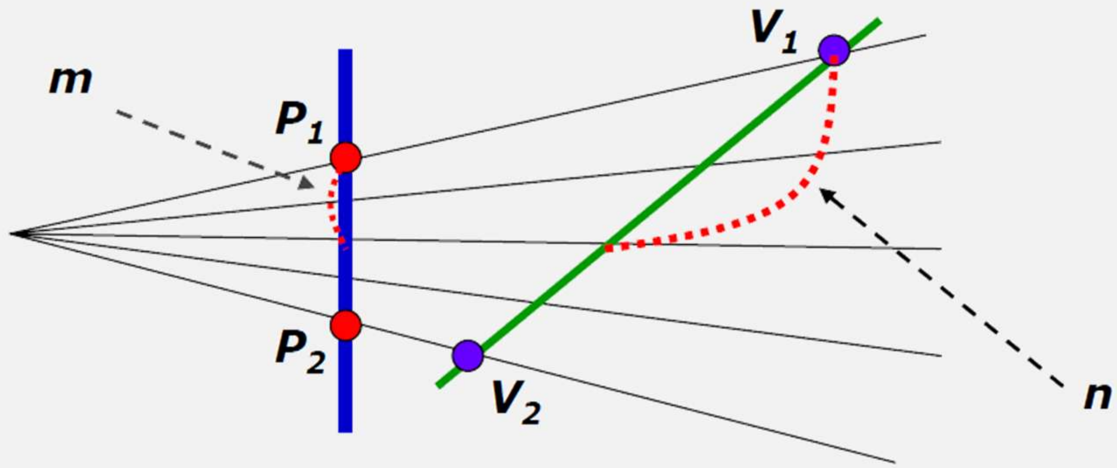


Screen Space vs. 3D Space

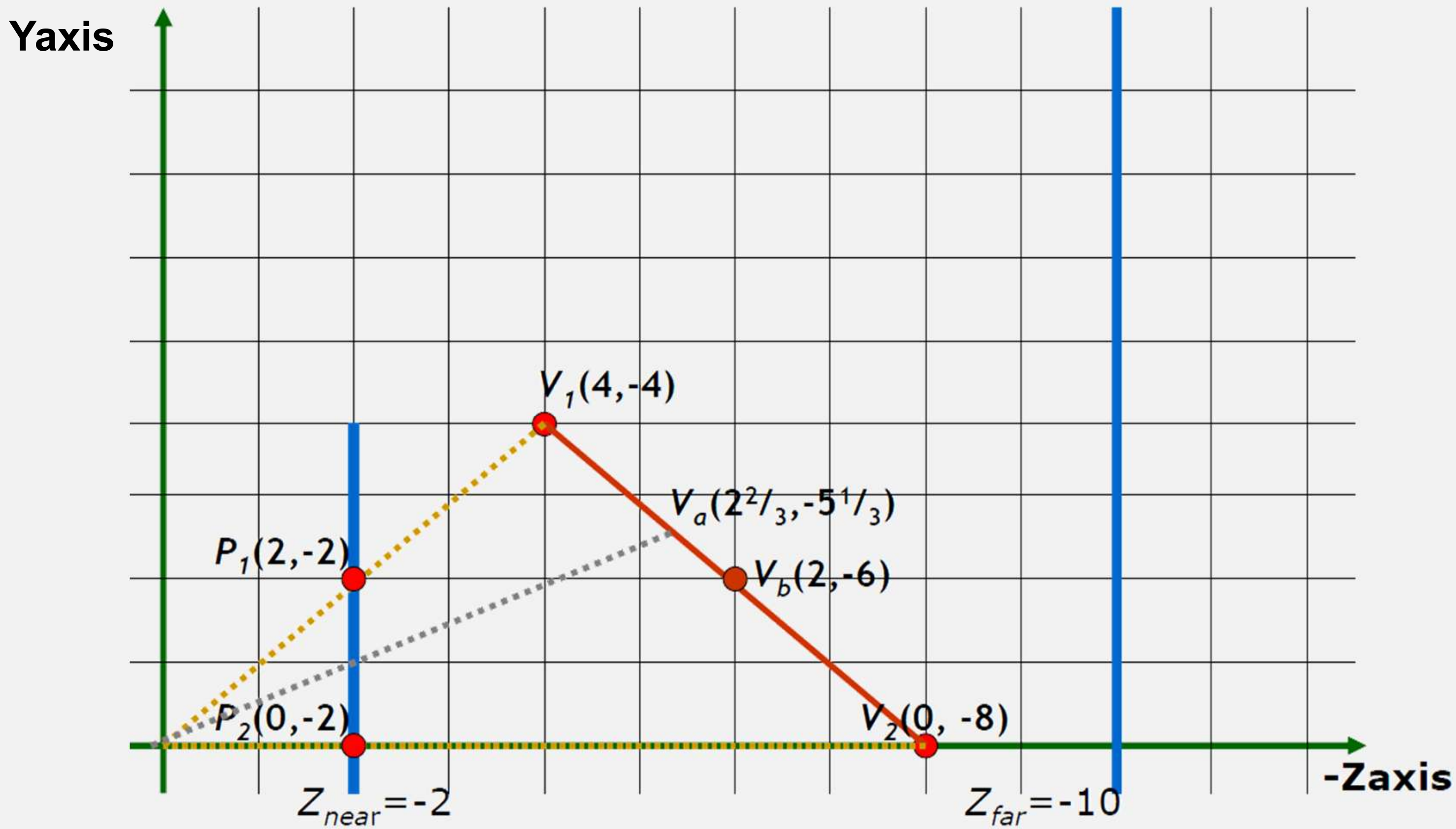
- Interpolation in screen space
  - $P(m) = P_1 + m(P_2 - P_1)$
- Interpolation in 3D space
  - $V(n) = V_1 + n(V_2 - V_1)$
  - $\boxed{P_y(n) = V_y(n)\ /\ V_z(n)}$

$n \neq m$

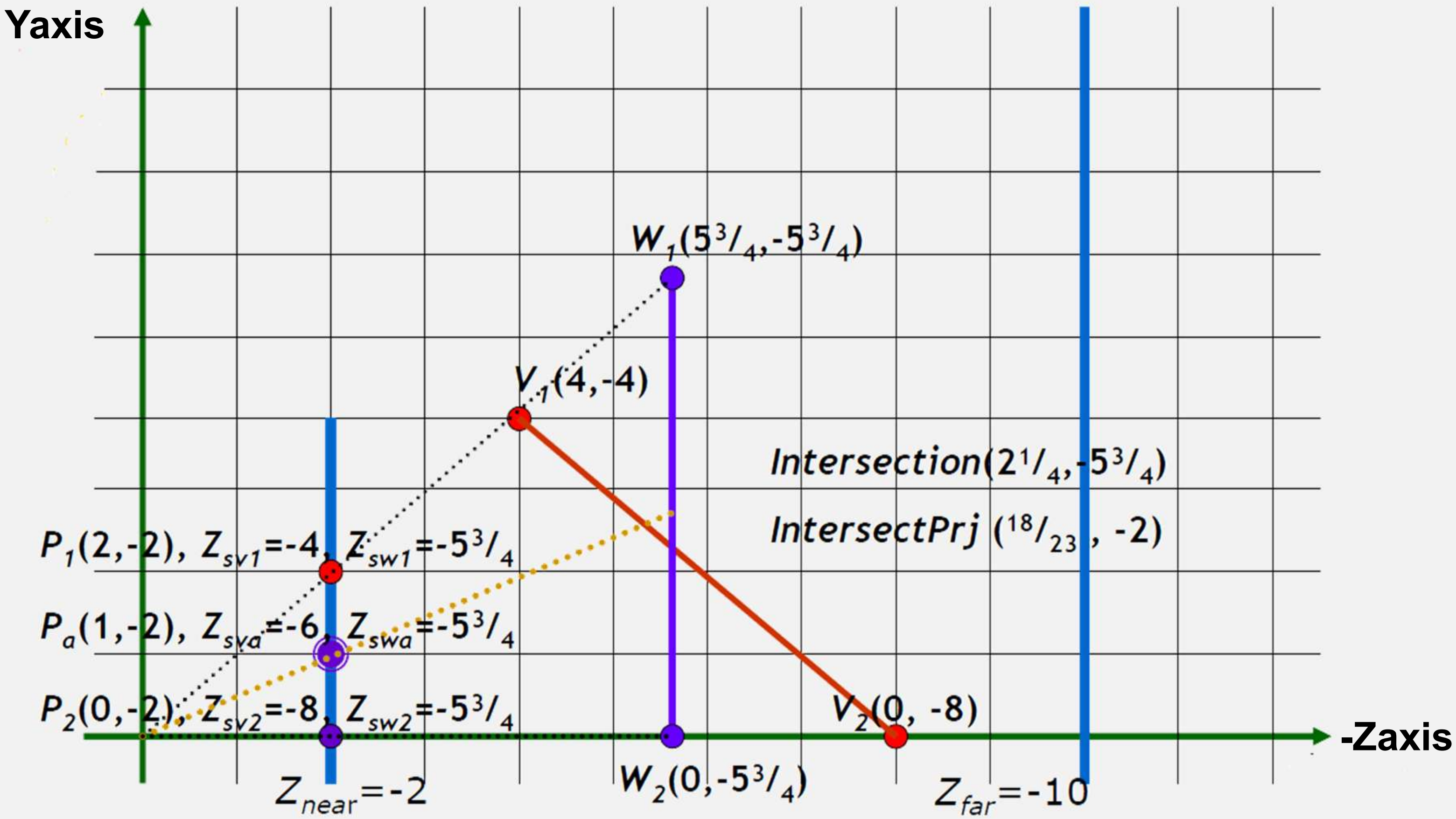
$$n = \frac{mz_1}{z_2 + m(z_1 - z_2)}$$



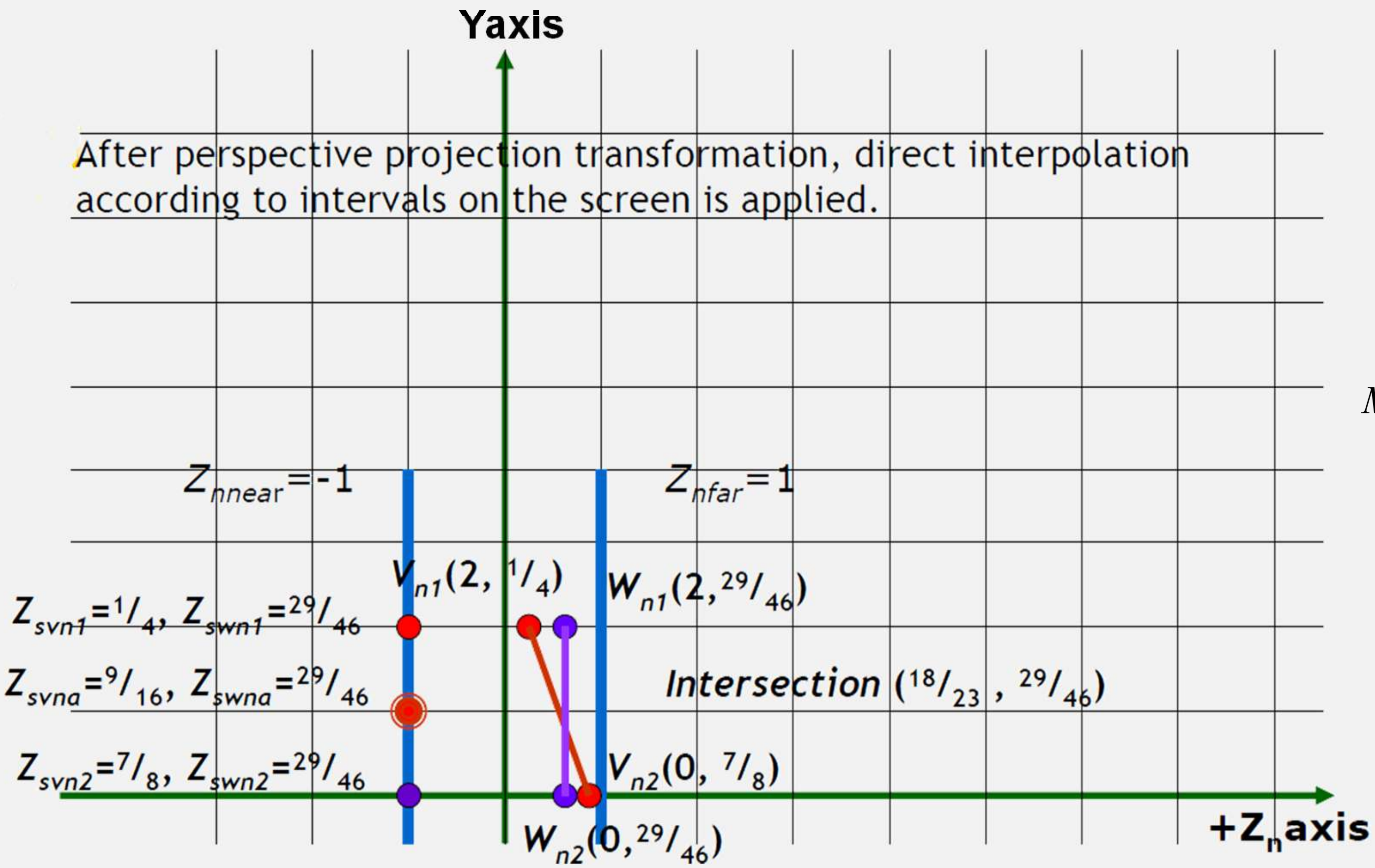
Screen Space vs. 3D Space (Cont.)



Simple Screen Interpolation



Perspective Projection Space



$$M_{pers} = \begin{bmatrix} -z_{near} & 0 & 0 & 0 \\ 0 & -z_{near} & 0 & 0 \\ 0 & 0 & \dfrac{z_{near}+z_{far}}{z_{near}-z_{far}} & \dfrac{-2z_{near}z_{far}}{z_{near}-z_{far}} \\ 0 & 0 & -1 & 0 \end{bmatrix}$$