Hidden Surface Algorithms

Clipping

Image space algorithms

- **Z-buffering**
- **Painter's algorithm**

Object space algorithms

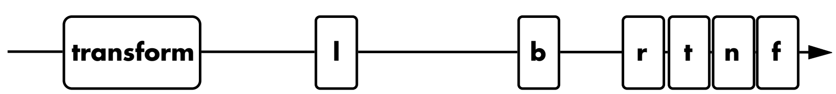
- **BSP trees**
- **Robert's algorithm**
- **Portals**

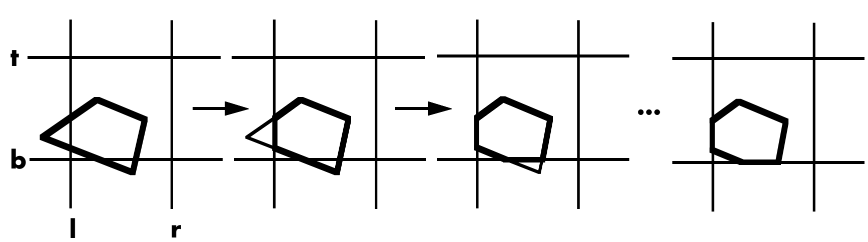
Rendering tricks

Quake game engine

Clipping Pipeline

Clip polygon to 6 planes of the frustum in a pipeline

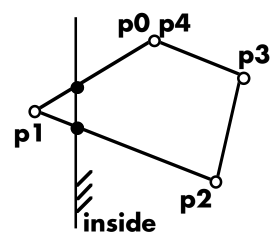




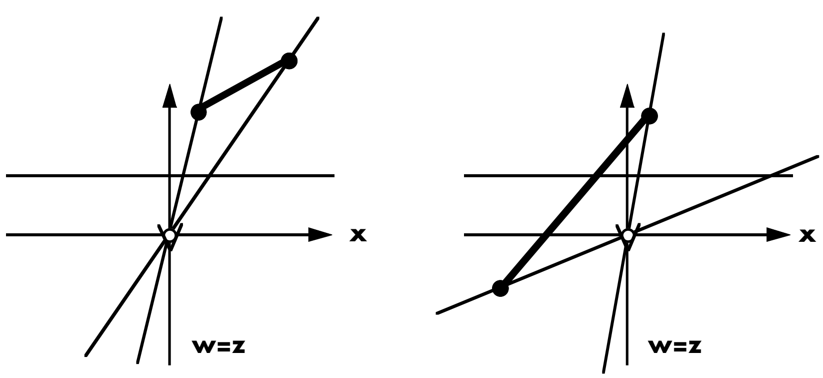
Clipping Stage

```
moveto()
  prevpt = input();
  prevside = sign(pl o pt);
```

```
drawto()
  if( inside(prevside) )
    output(prevpt);
  pt = input();
  side = sign(pl o pt);
  if( side != prevside ) {
    pt = intersect(prevpt,pt,pl);
    output(pt);
  }
  prevpt = pt; prevside = side;
```



Test & Clip *Before* Divide by w



Visibility Analysis

Hidden/Visible Surface/Line Elimination/Determination

Requirements

- **Handle diverse set of geometric primitives**
- **Handle large number of geometric primitives O(N)**

Classification: Sutherland, Sproull, Schumacher (1974):

- **Object Space**
  - Geometric calculations involving polygons
  - Floating point precision: Exact
  - Often process scene in object order
- **Image Space**
  - Visibility at pixel samples
  - Integer precision
  - Often process scene in image order

1. Z-buffering

1. Transform z at vertices
2. Modify scan conversion to interpolate z
3. Maintain depth or range image (16 or 24-bits common)
4. Depth comparison during drawing

```
...
if( p.z < i[p.x][p.y].z ) {
  i[p.x][p.y].z = p.z;
  i[p.x][p.y].c = p.c;
}
p.z += p.dz;
p.c += p.dc;
...
```

Why So Popular?

Advantage

- **+ Simple to implement in hardware**
  - **Add additional z interpolator**
  - **Memory for z-buffer**
- **+ Diversity of primitives**
- **+ Unlimited complexity**

Disadvantage

- **- Memory still too expensive for personal computers**
- **- Waste time drawing hidden objects**
- **- Z-precision errors / Must use point sampling**

Rendering Tricks: Decals

Graphics packages

- **May draw directly in the z-buffer**
- **May mask bits to be written to framebuffers**

Decal

1. **Draw base polygon using z-buffer compare,**
   but, *don't update z-buffer*
2. **Draw decal polygon using z-buffer compare,**
   but, *don't update z-buffer*
3. **Draw base polygon using z-buffer compare,**
   and, *update z-buffer*, but, don't *update color buffer*

Rendering Tricks: Hidden Lines

Z-buffering modes

- **Partition 24 bits: msb mask, 23 lsb's depths**
- **Mapping: near -> 2^{23}-1, far -> 0**
- **Z comparison: Write if Z-GE**

Hidden lines

1. Draw polygon into z-buffer,
but only setting msb-bit in the z-buffer
2. Draw outline into z-buffer,
clearing msb-bit in the z-buffer
msb-bit is now set in the interior of the polygon
3. Draw polygon into color-buffer using outline color
only perimeter values are near, thus outline is drawn
4. Draw polygon into the z-buffer clearing the msb

2. Painter's Algorithm

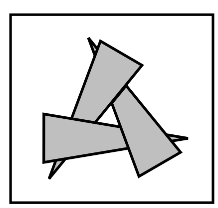
1. Draw surfaces in back-to-front order

Front surfaces are drawn over back surfaces, hiding them

2. Draw surfaces in front to back order with under operator

Previously drawn surfaces mask drawing of those behind

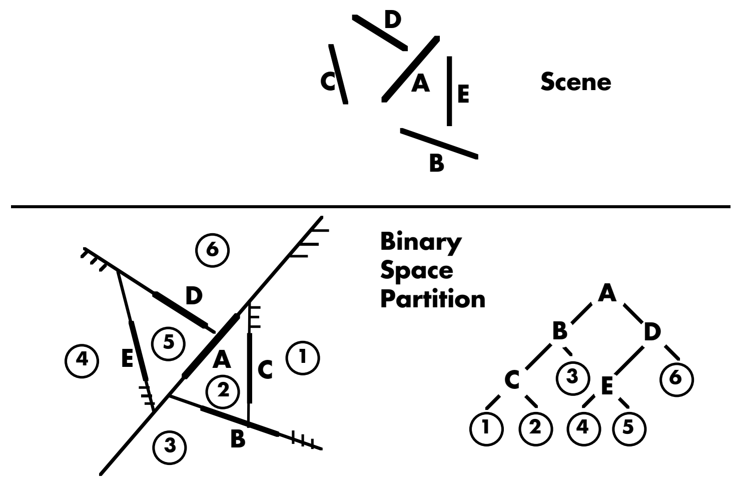
Supports transparency!



Key problem is priority determination

- **Manually**
- **Exploit spatial properties of the model**
- **BSP (Binary Space Partition) Tree**

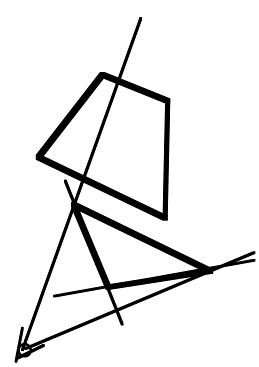
BSP Tree



3. Object-Space Algorithm

Robert's Algorithm
Input: Set of convex polyhedra
Output: Set of visible line segments

```
for each polyhedron
  form shadow volume
    discard back-facing faces
    keep front-facing faces
    create silhouette planes
for each edge
  for each shadow volume
    clip edge to shadow volume
  draw visible edge
```



Portals

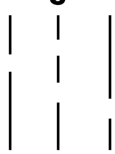
Model scene as a graph

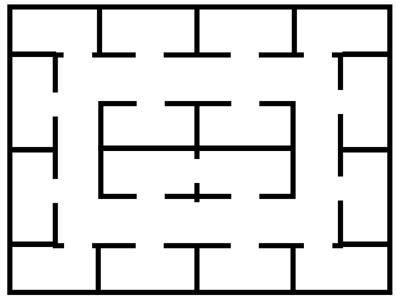
- Nodes: Rooms
- Edges: Portals

Potentially visible set

- Superset of visible polys
- Room to room visibiity

Stabbing line test





Quake Game Engine

Neat combination of all of the above!!

- Environment
  - Use portals to determine potentially visible set
  - Use bsp-tree to order polygons from front-to-back
  - Maintain front-to-back ordering of the spans on the active edge list
  - Maintain scanline visibility mask when drawing spans
  - Output only visible pixels (color and depths)
- Objects
  - Draw using the environment z-buffer