

CMP205: Computer Graphics



Lecture 9: Graphics Pipeline

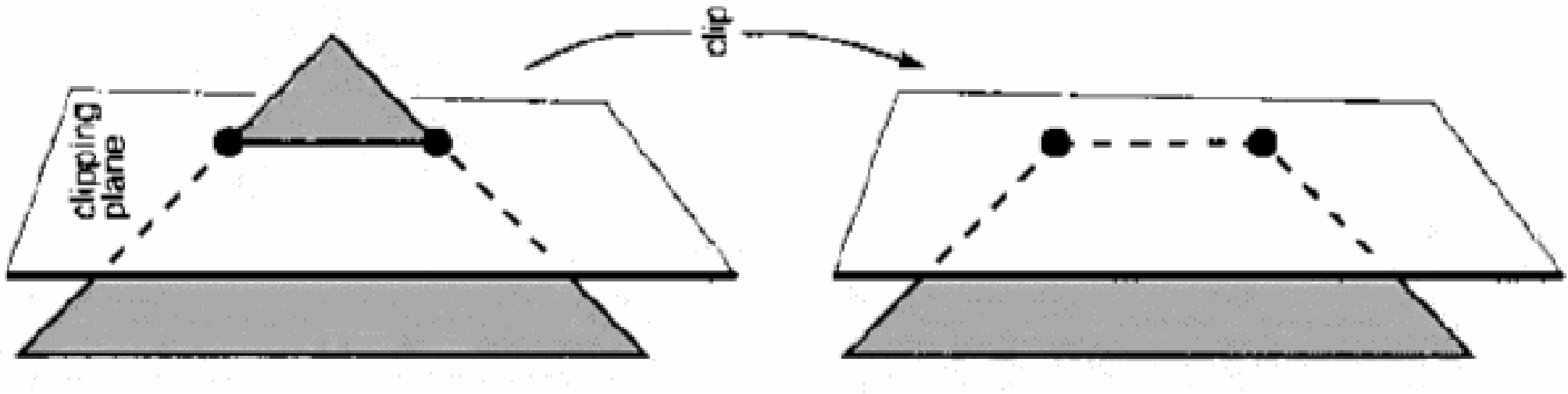
Mohamed Alaa El-Dien Aly
Computer Engineering Department
Cairo University
Fall 2013

Agenda

- Clipping
- Graphics Pipeline

Acknowledgment: Some slides adapted from Steve Marschner and Sayed Hemayed

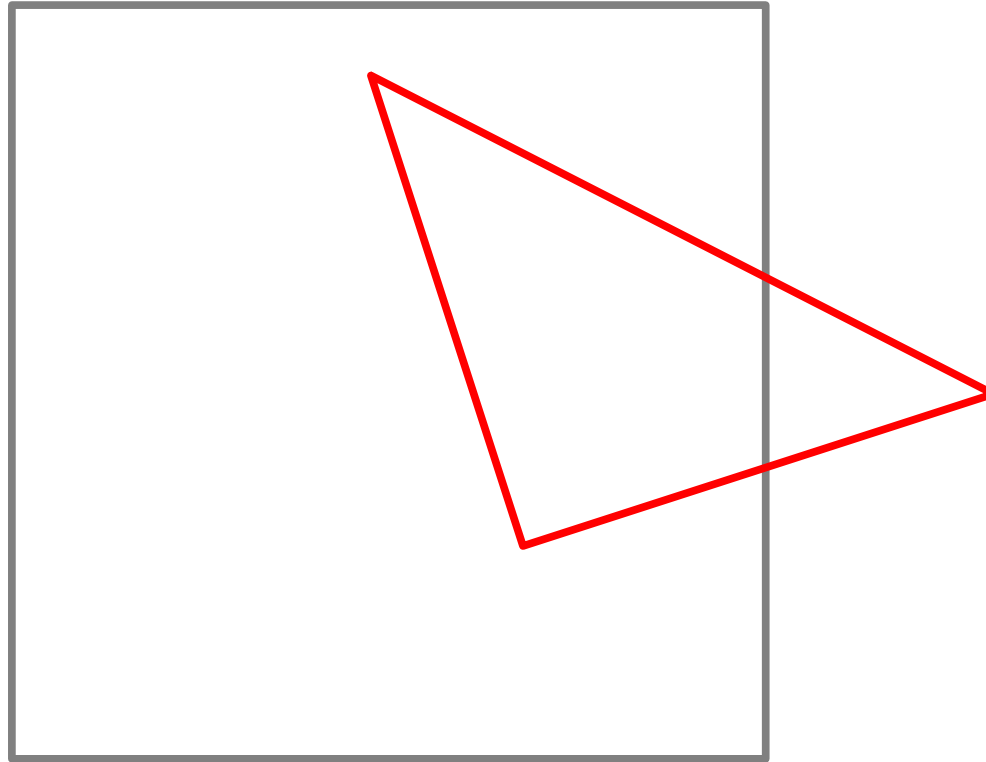
Clipping



A triangle is “clipped” if it cuts a plane

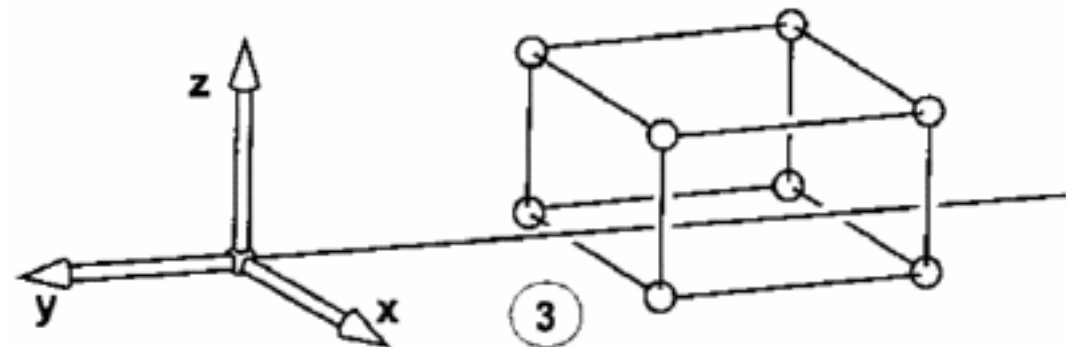
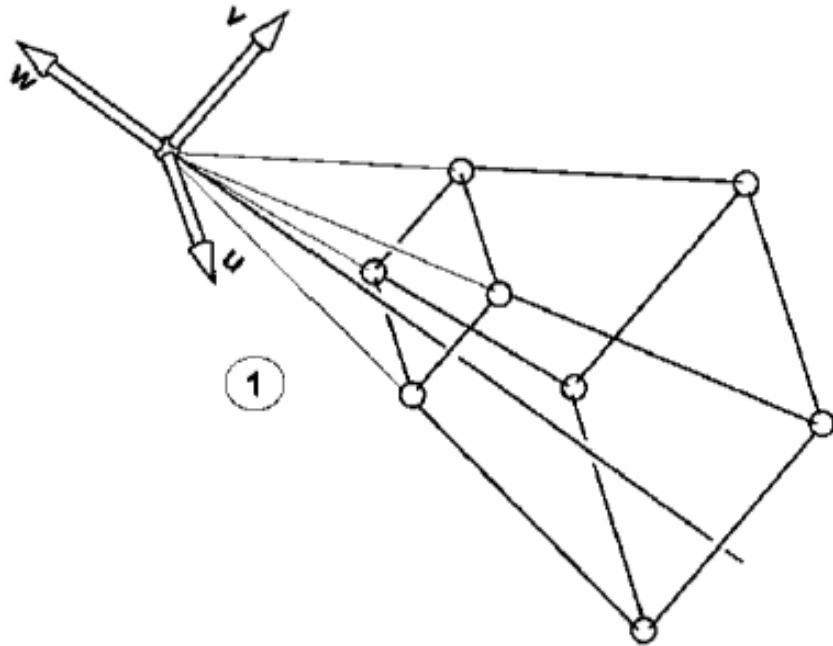
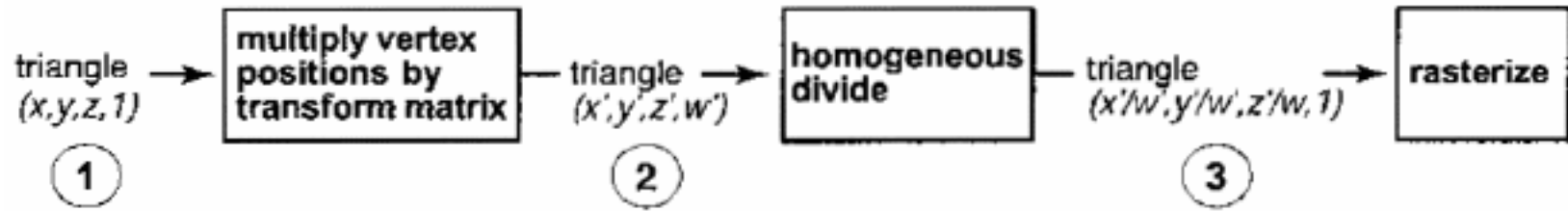
When is clipping required?

Clipping



Clipping required if a triangle cuts the view volume

Clipping



Clipping

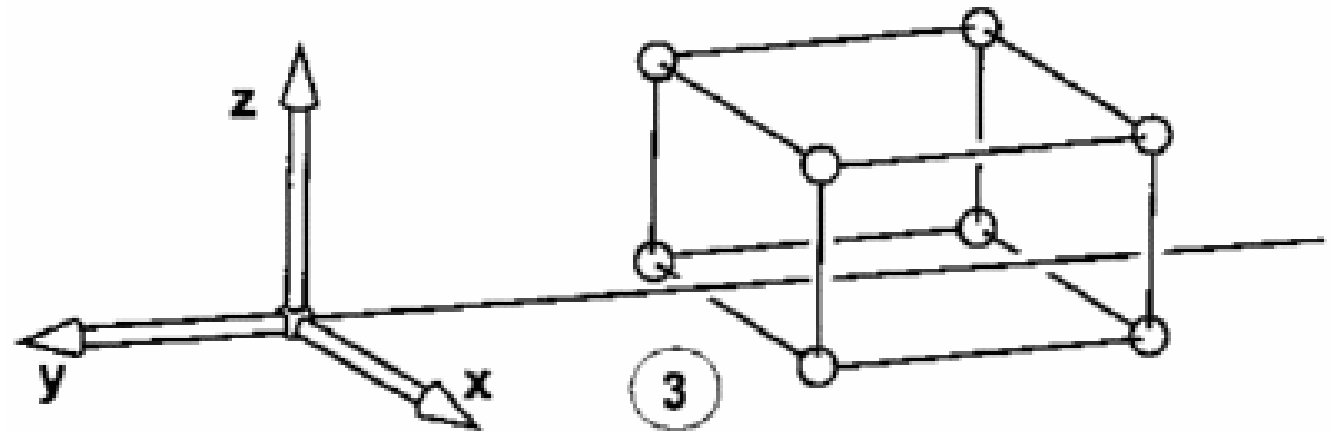
```
for each of the six planes
  if triangle entirely outside plane
    break // not visible
  else if triangle cuts plane
    clip triangle
    if quadrilateral left
      convert into two triangles
```

Where should clipping be done?

Clipping

3. Clipping in the View Volume

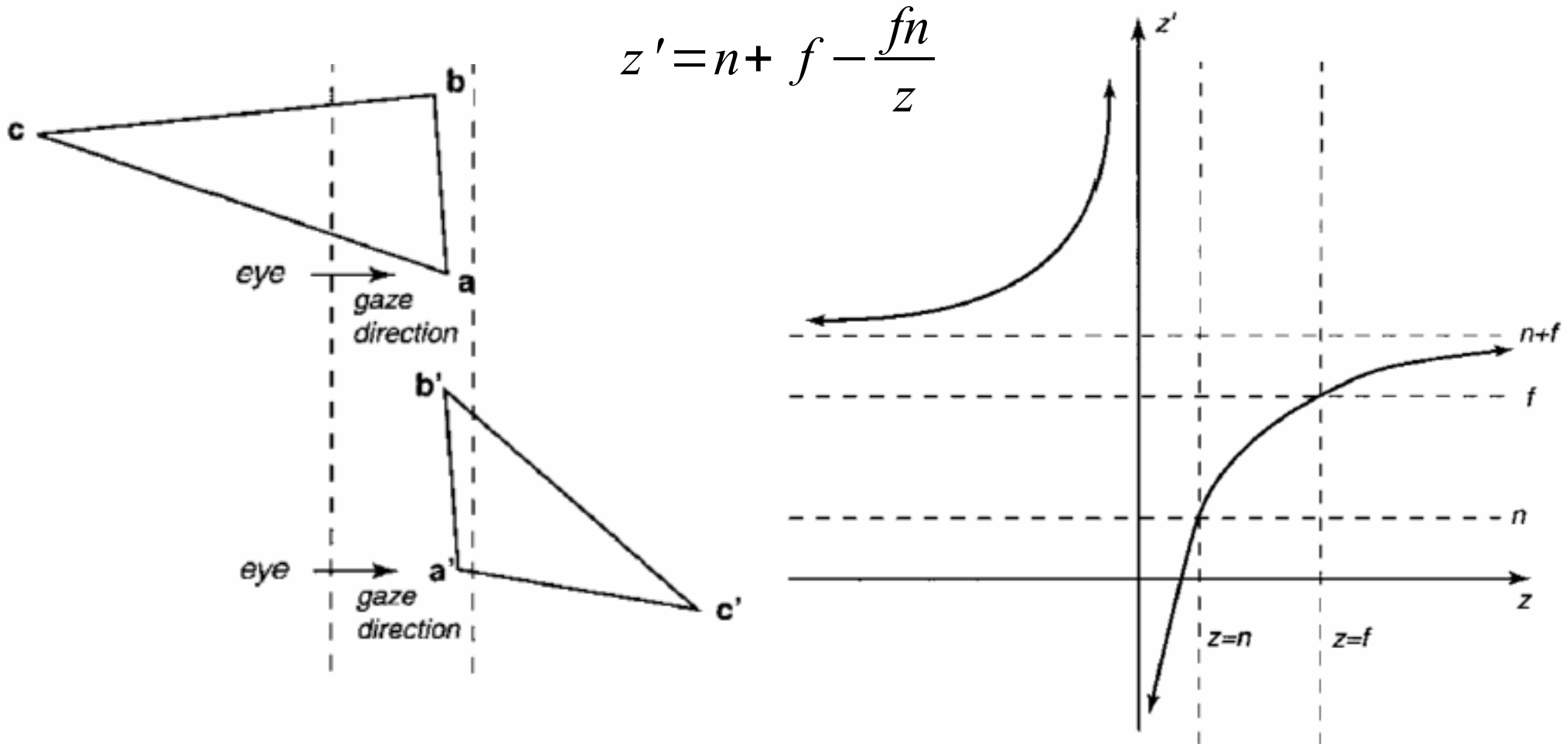
$$\begin{aligned} -x + l &= 0 \\ x - r &= 0 \\ -y + b &= 0 \\ y - t &= 0 \\ -z + n &= 0 \\ z - f &= 0 \end{aligned}$$



Problem?

Clipping

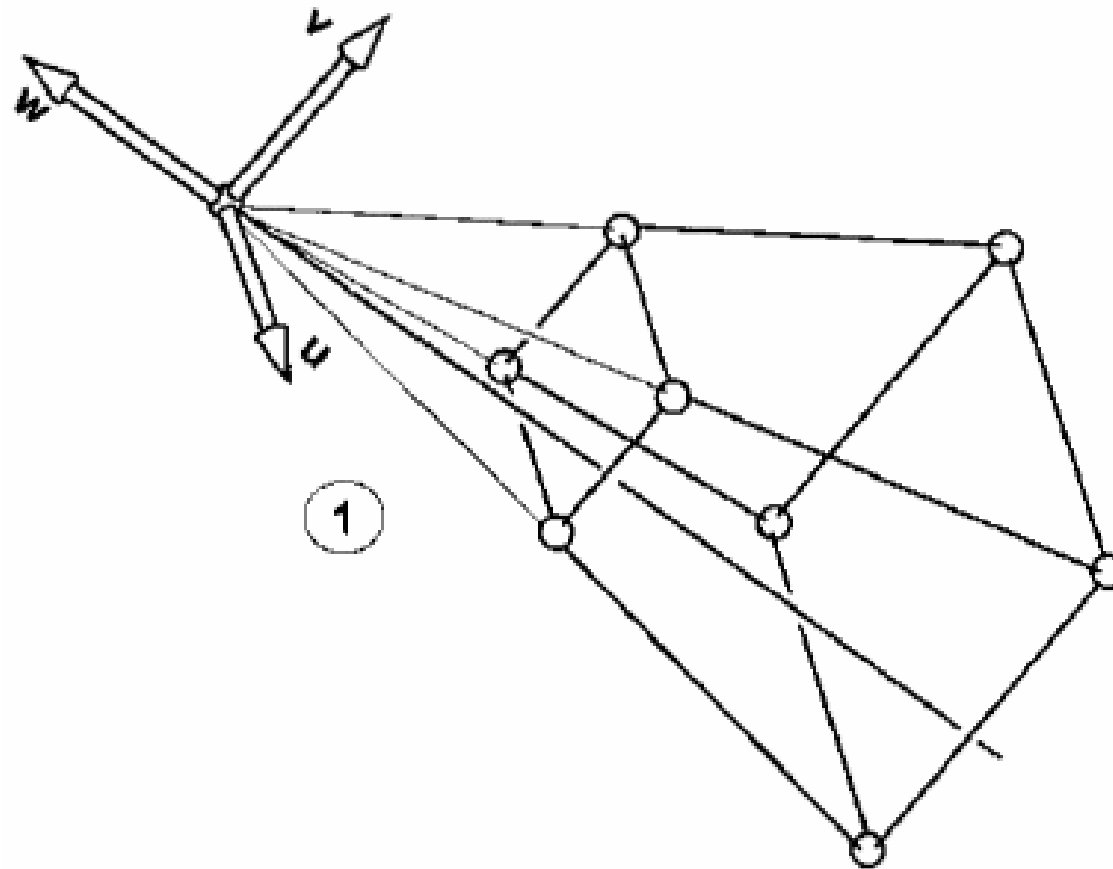
3. Clipping in the View Volume



Discontinuity at $z = 0$

Clipping

1. Clipping in the View Frustum



Compute plane equations for the view frustum

Problem? Planes equations more complicated than (3).

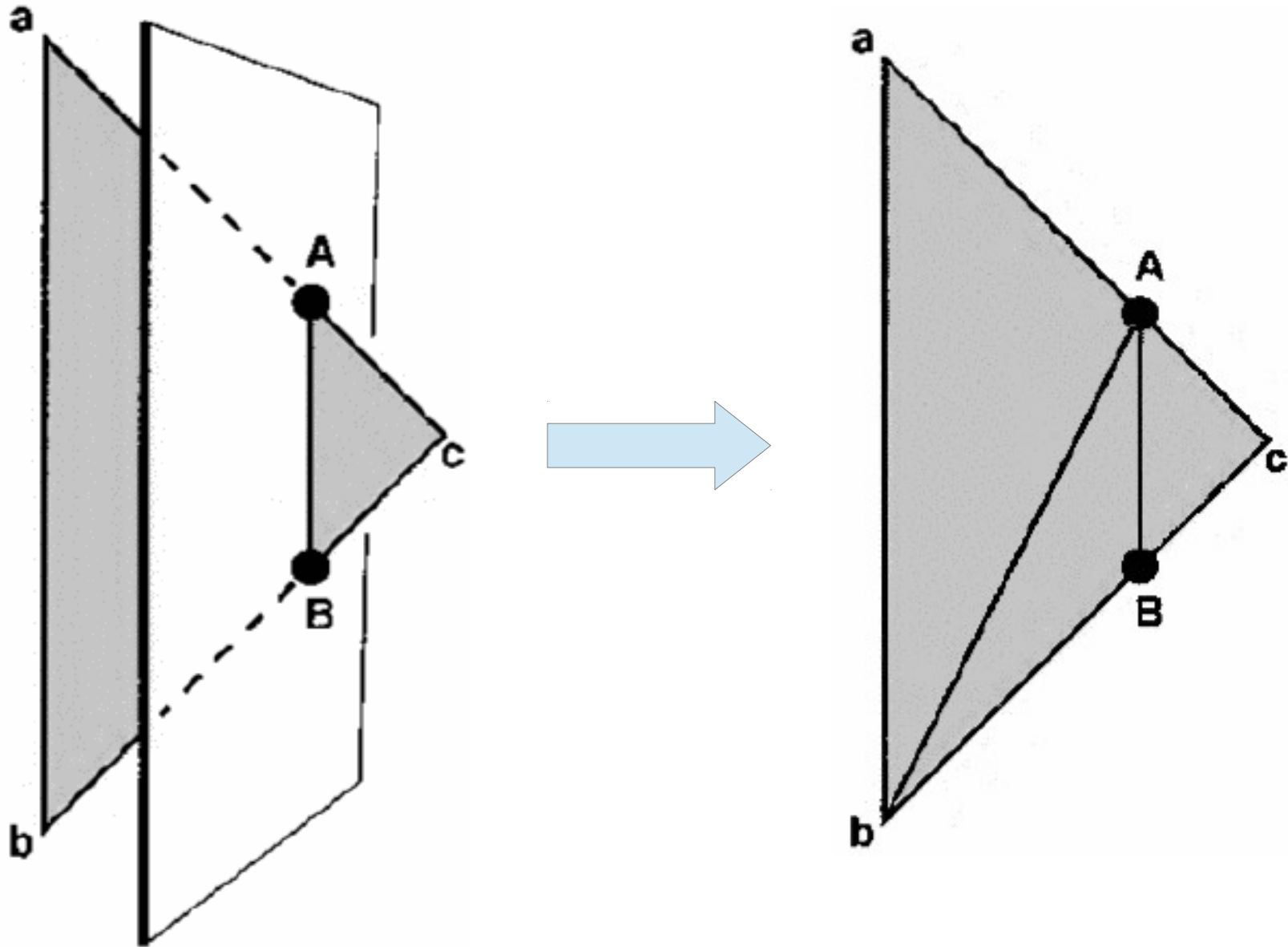
Clipping

2. Clipping in Homogeneous Coordinates

$$\text{Homogeneous Point in 4D: } \begin{bmatrix} x \\ y \\ z \\ w \end{bmatrix} \quad \text{Planes: } \begin{array}{l} -x + lw = 0 \\ x - rw = 0 \\ -y + bw = 0 \\ y - tw = 0 \\ -z + nw = 0 \\ z - fw = 0 \end{array}$$

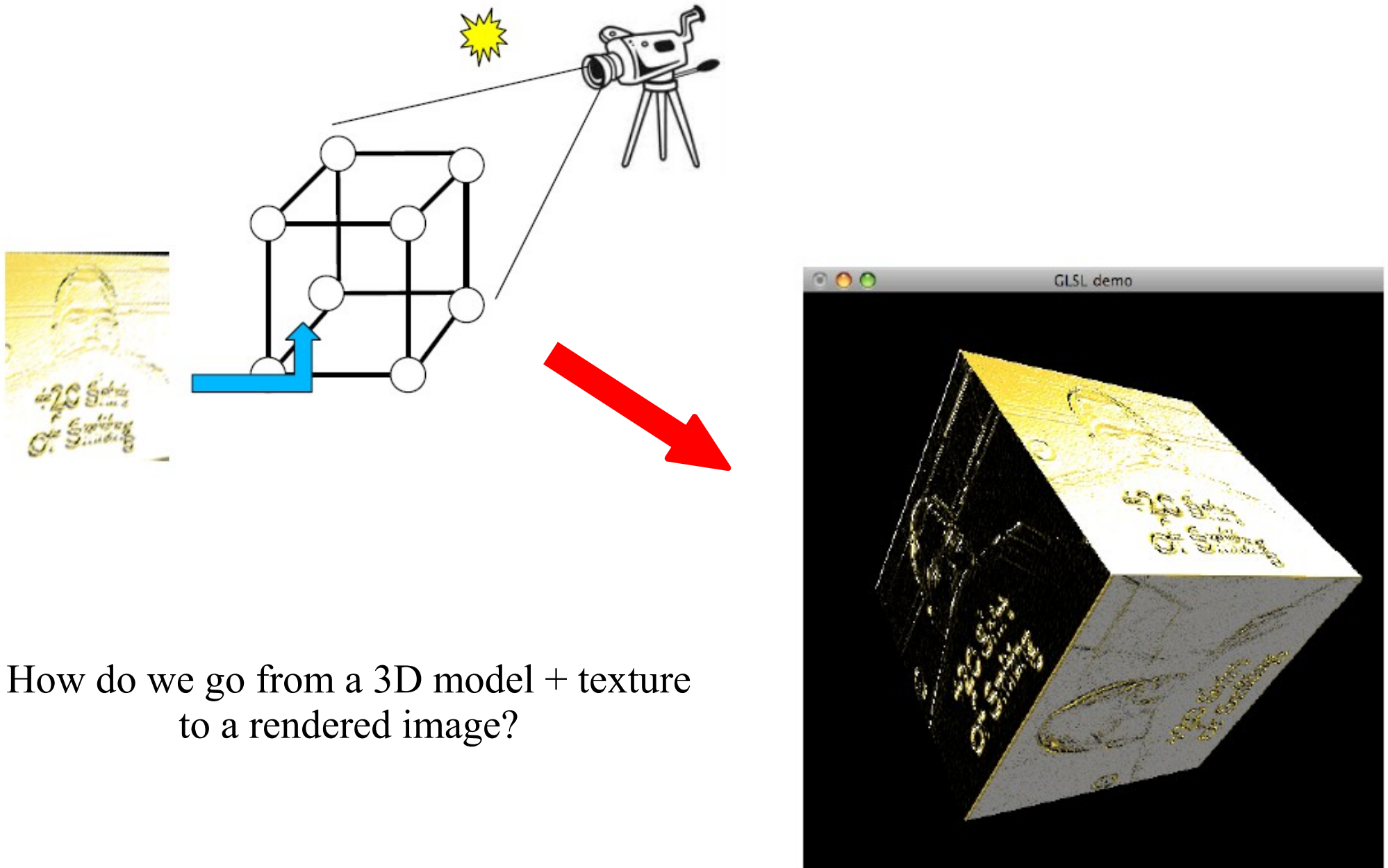
Easy equations and no discontinuities !

Clipping



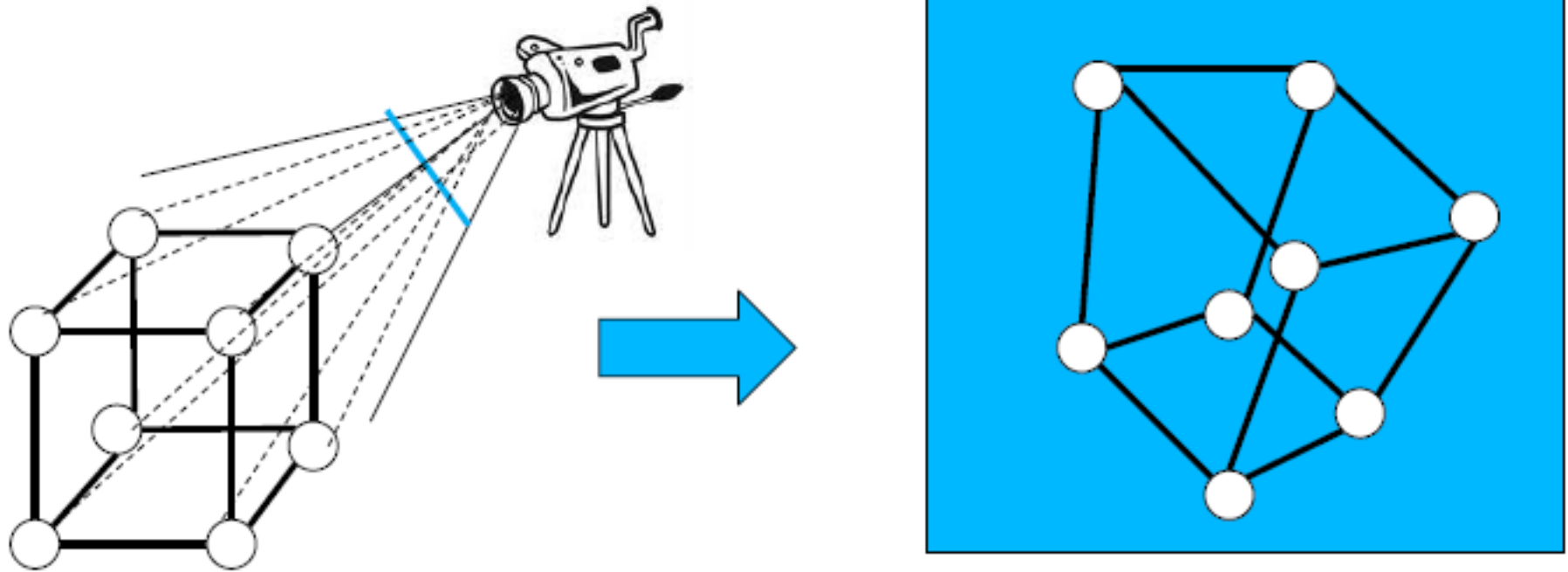
Find intersection points and clip triangle

Graphics Pipeline



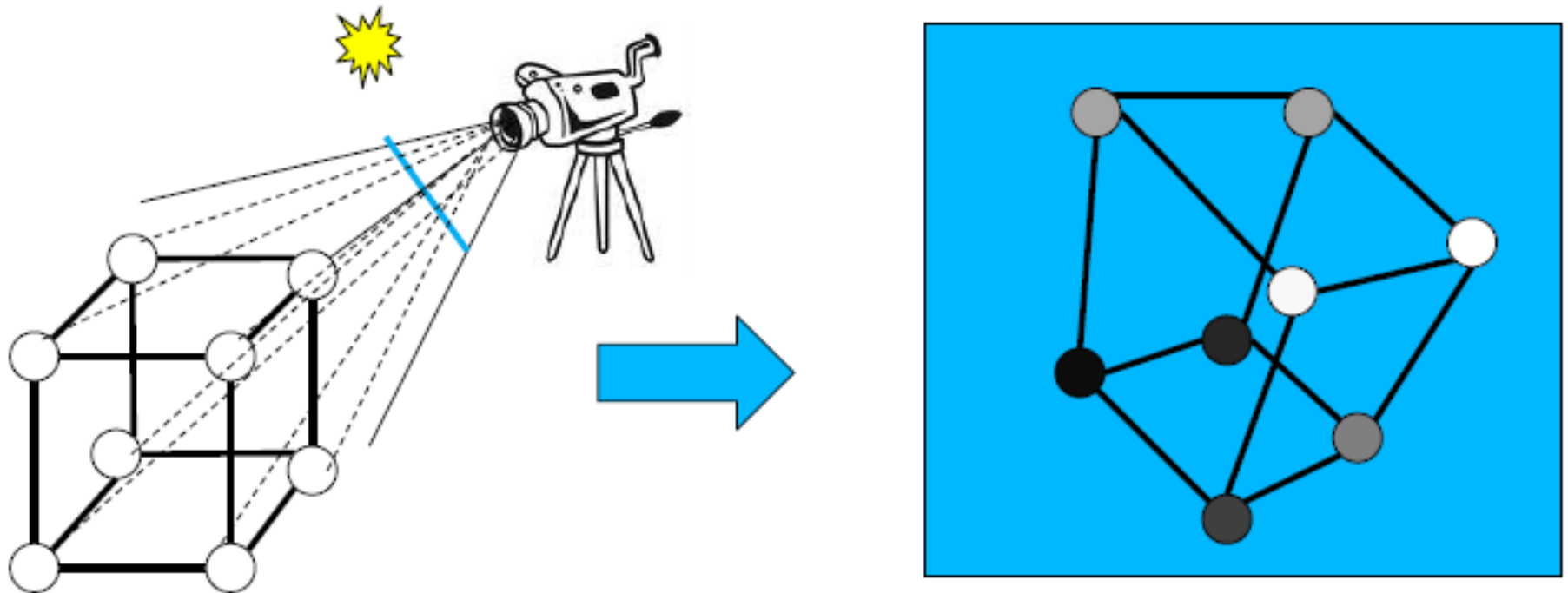
How do we go from a 3D model + texture to a rendered image?

Graphics Pipeline



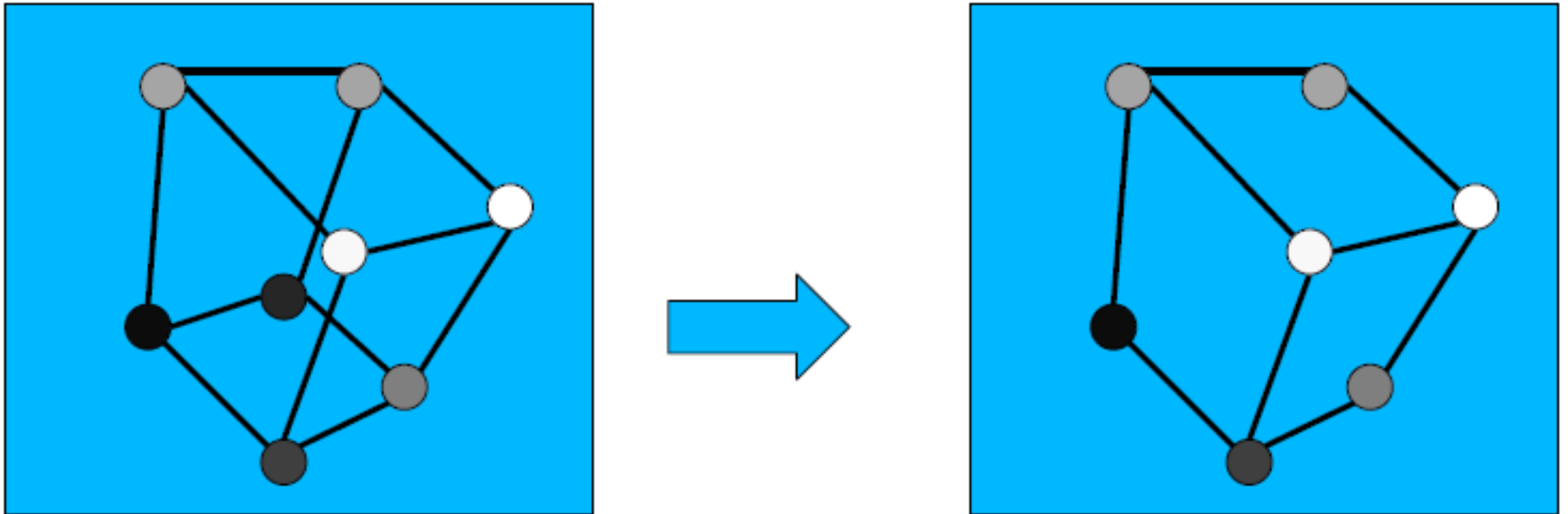
Viewing transformations on vertices

Graphics Pipeline



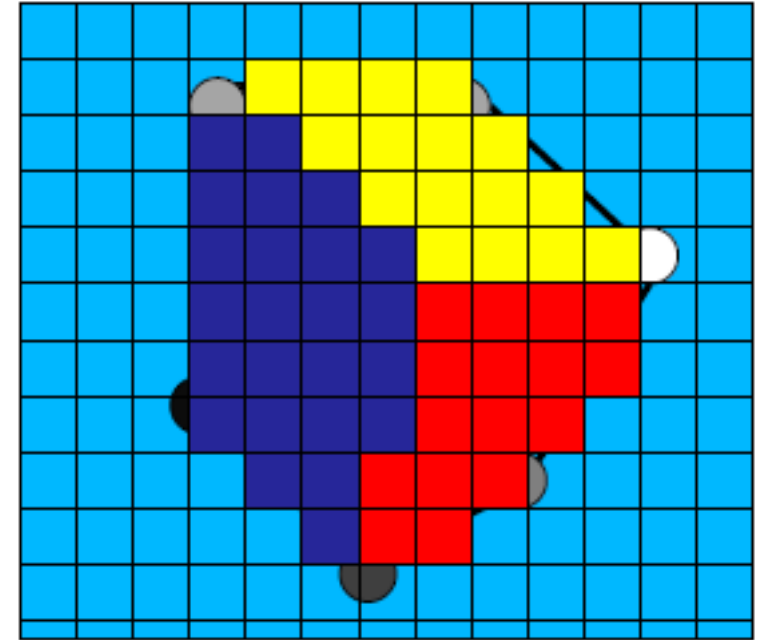
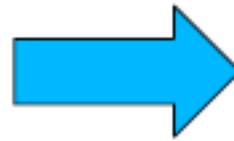
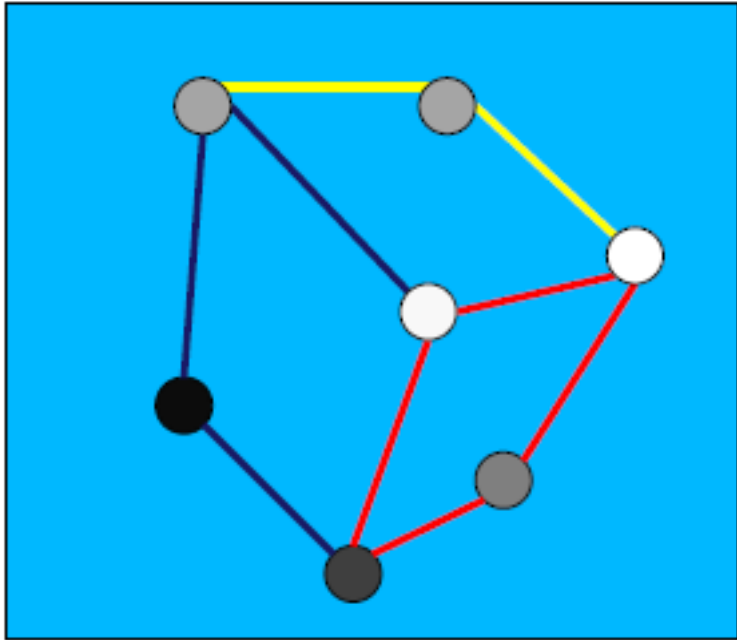
Lighting/Shading for vertices

Graphics Pipeline



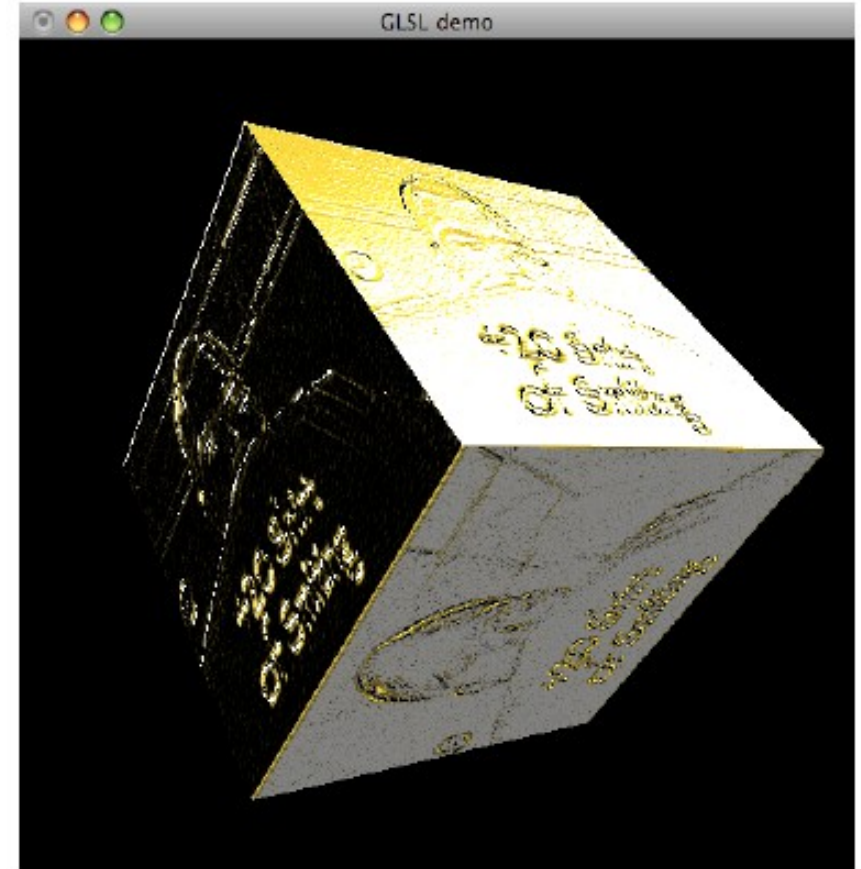
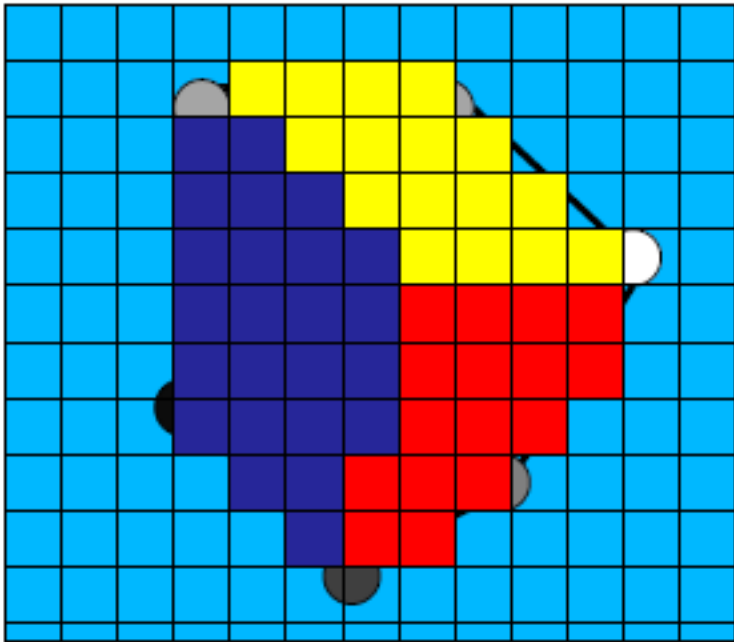
Clipping and Hidden Surface Removal

Graphics Pipeline



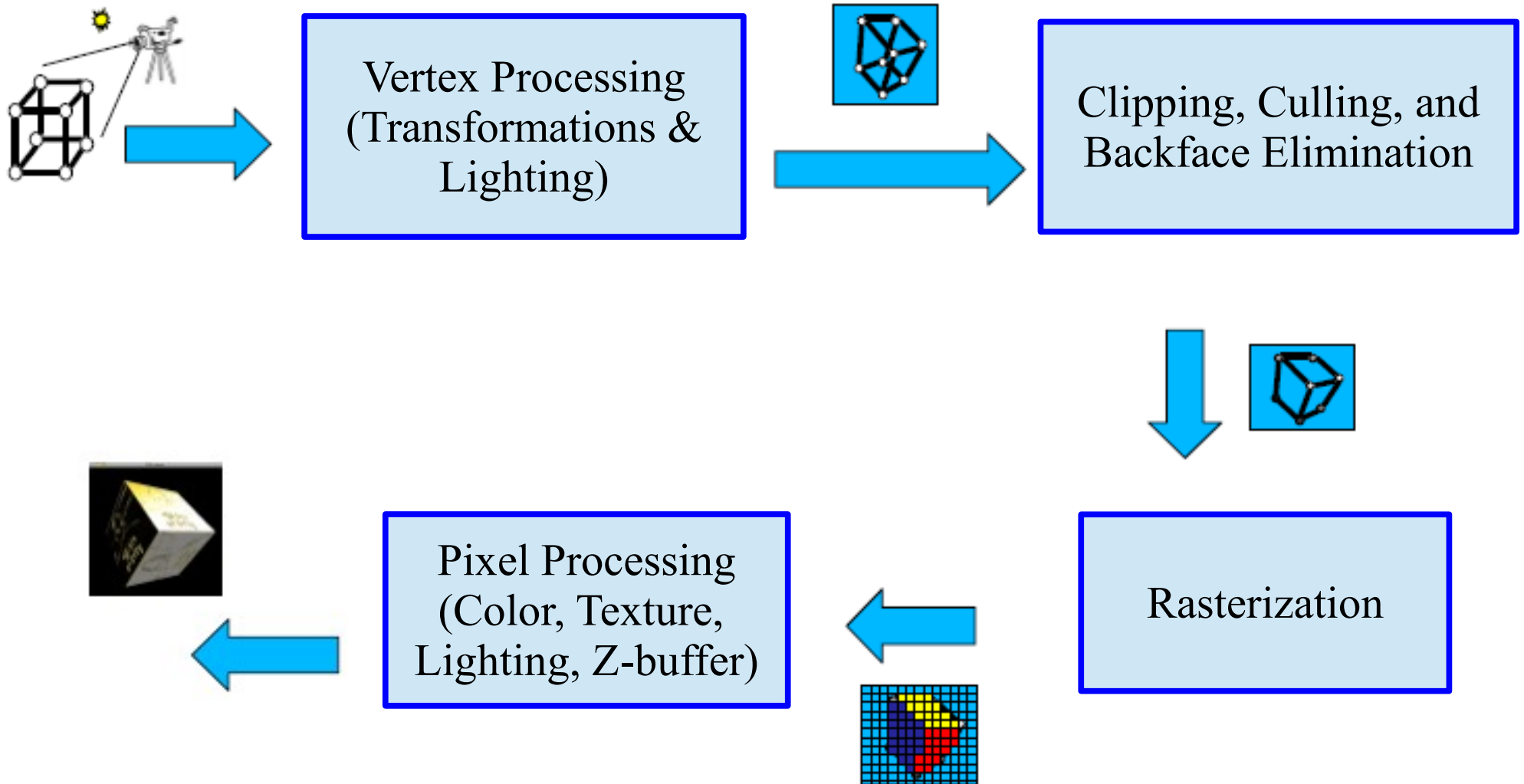
Rasterization

Graphics Pipeline



Pixel Processing & Texture Mapping

Graphics Pipeline



Graphics Pipeline

```
for each triangle in the model
  if triangle is facing away
    break

// Vertex Processing
Transform the vertices
Clip the triangle and homogenize
Compute lighting/shading for vertices

// Rasterization
for each pixel in the bounding box
  Compute barycentric coordinates
  if pixel inside triangle

    // Pixel Processing
    Compute color/shading
    Compute texture coordinates
    Compute z-value (depth)
    if depth < z-buffer
      Write pixel color and update Z-buffer
```

Recap

- Clipping
- Graphics Pipeline