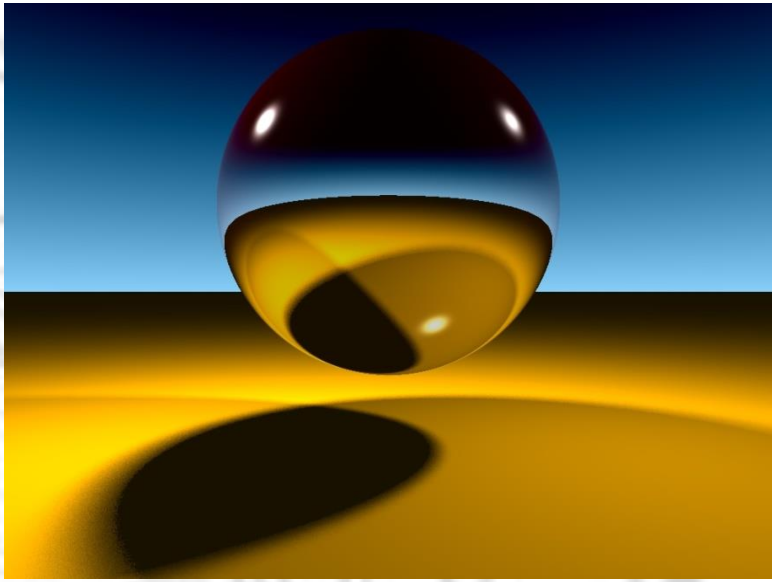
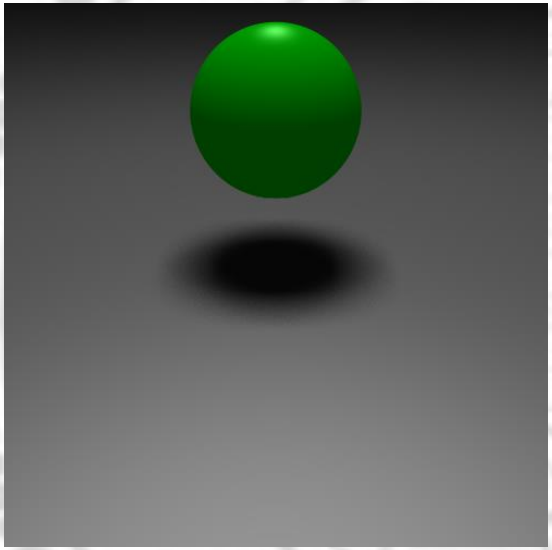
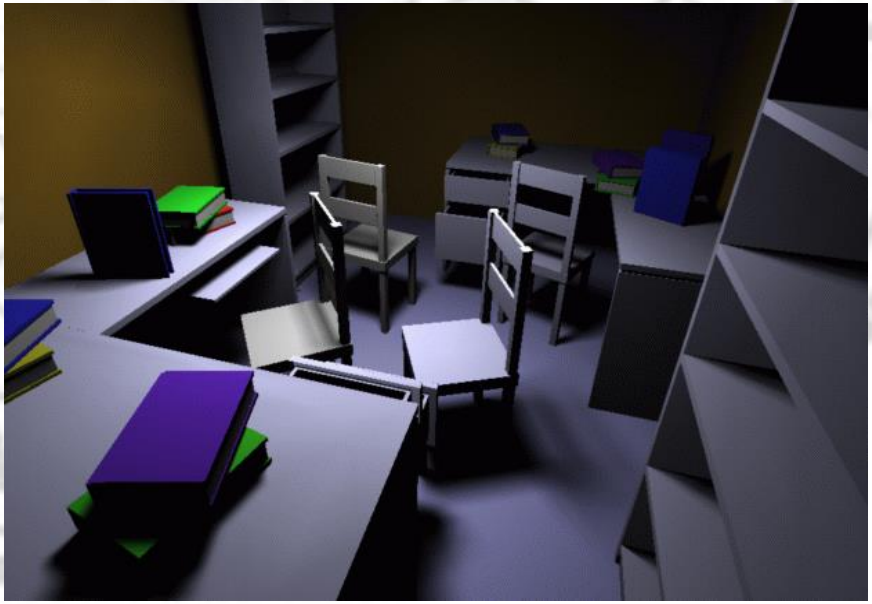
Shadows







One Slide Solution

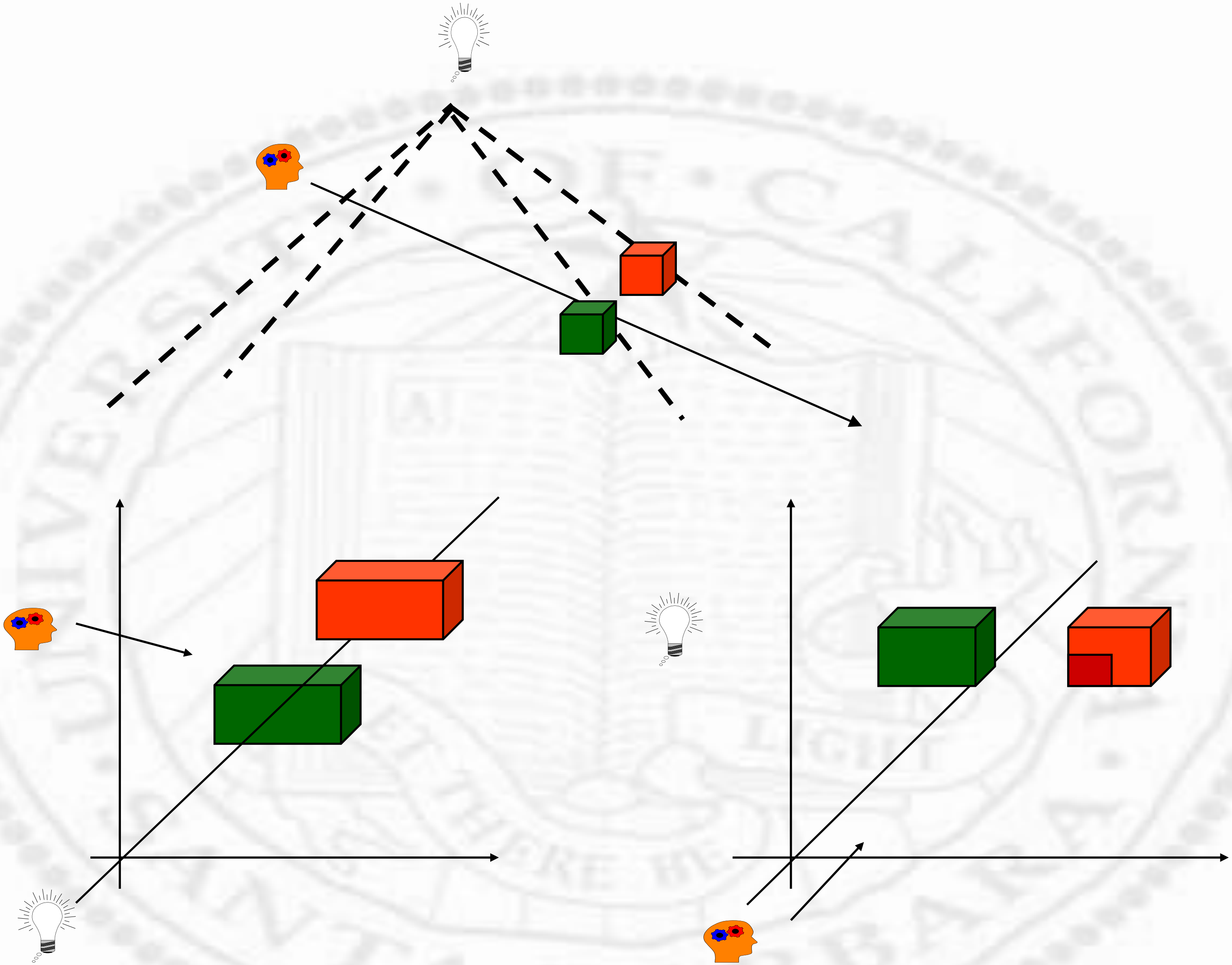
- It is really very simple
- Can you see something from the eye position? Yes, then visible. No, then not visible (occluded)
- Can you see something from a light source position? Yes, then not in shadow. No, then in shadow
- If you know HLHSR, then do that from the light instead of the eye location

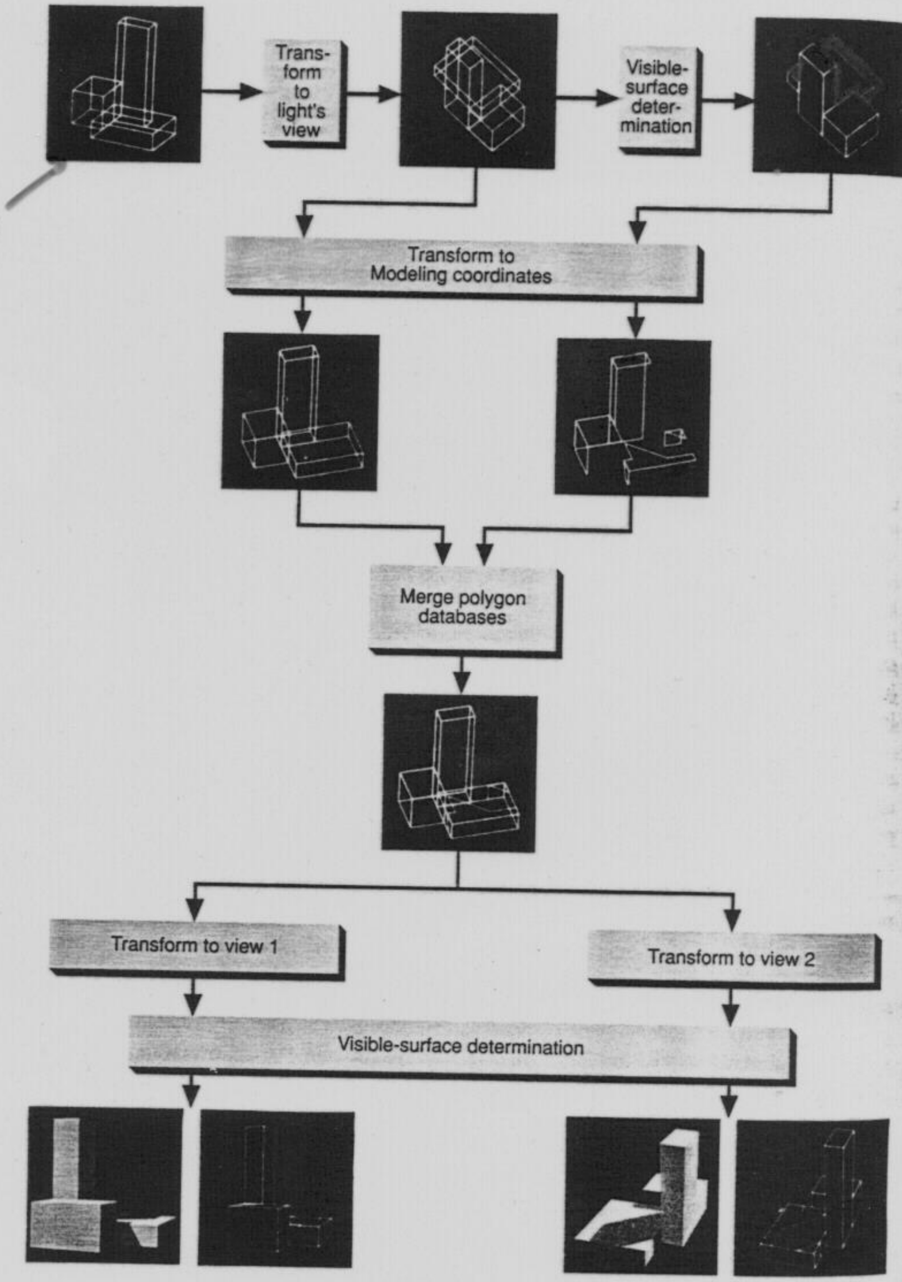
Multiple Slides Solution

- But there can be multiple light sources
- The light source might not be a single point or a single direction (e.g., extended sources)
- Want to determine both visibility and lighting without multiple transforms

Two-Pass Object Precision

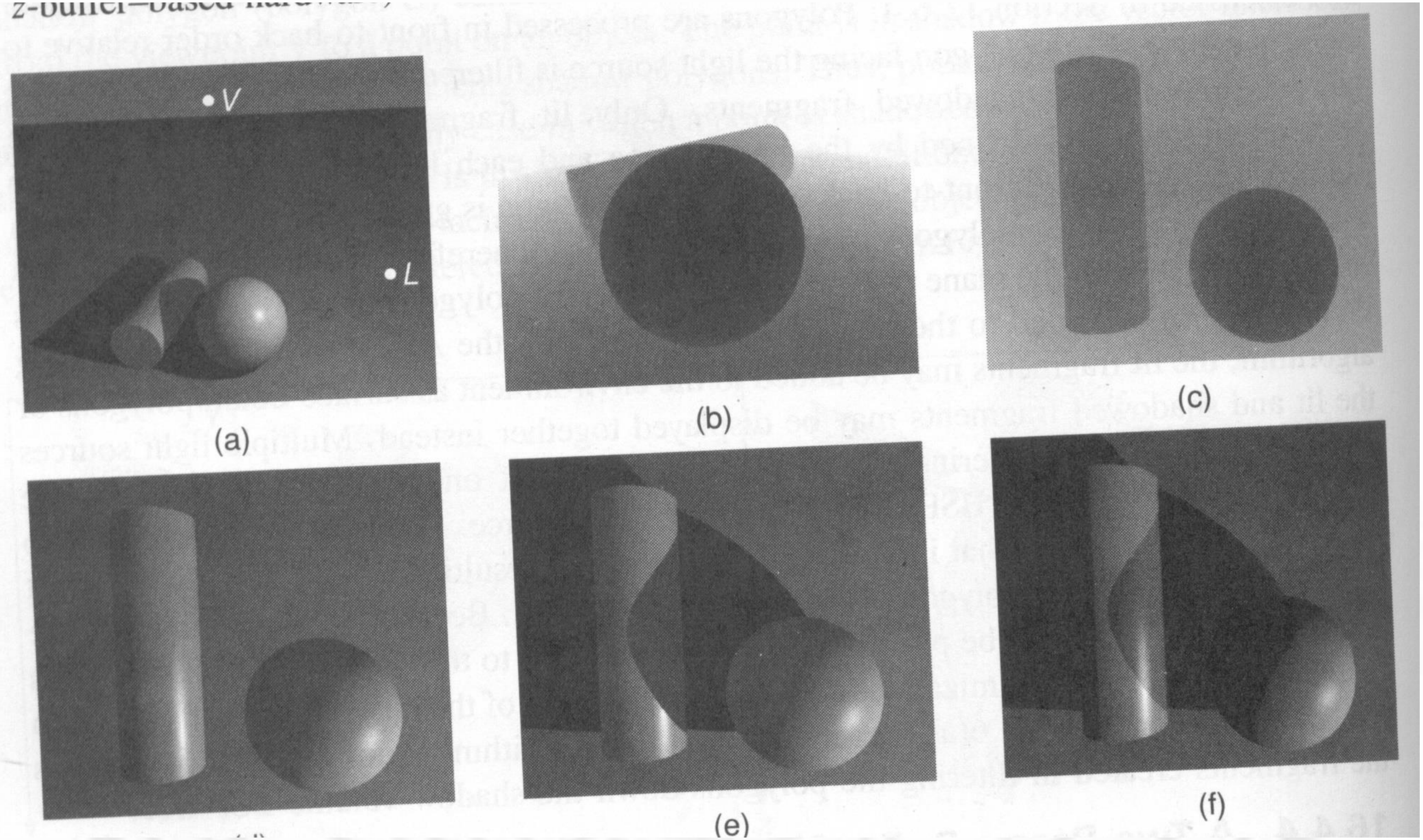
- 1st pass: transform to light position
  - hidden surface determination (polygons which are not in shadow)
- 2nd pass: transform to original world coordinate sys
  - polygons not in shadow are merged to become *surface detail* polygons (*which algorithm*?)
- Postprocessing: transform to eye coordinate
  - visible surface determination + surface details

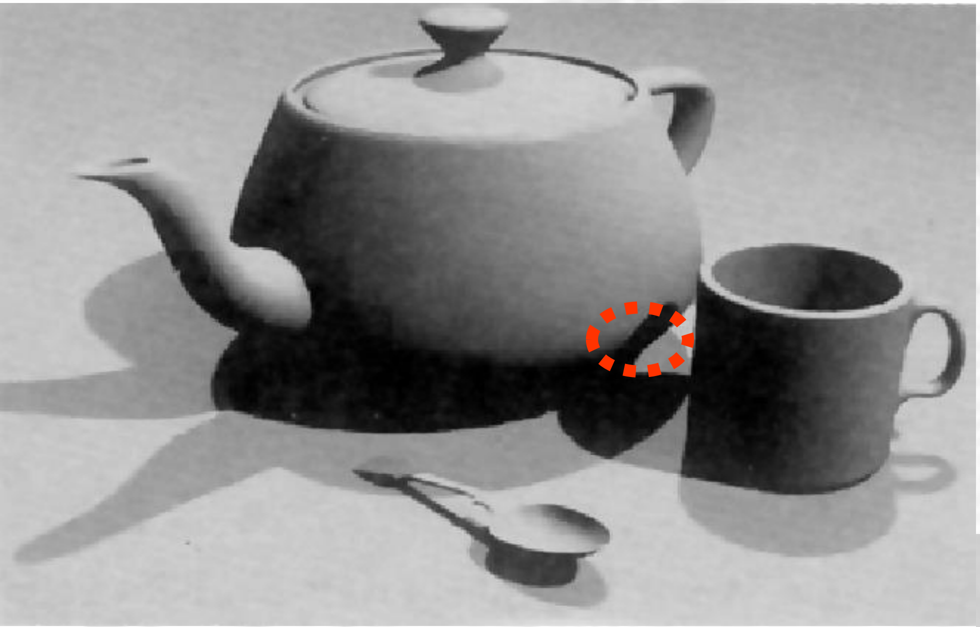


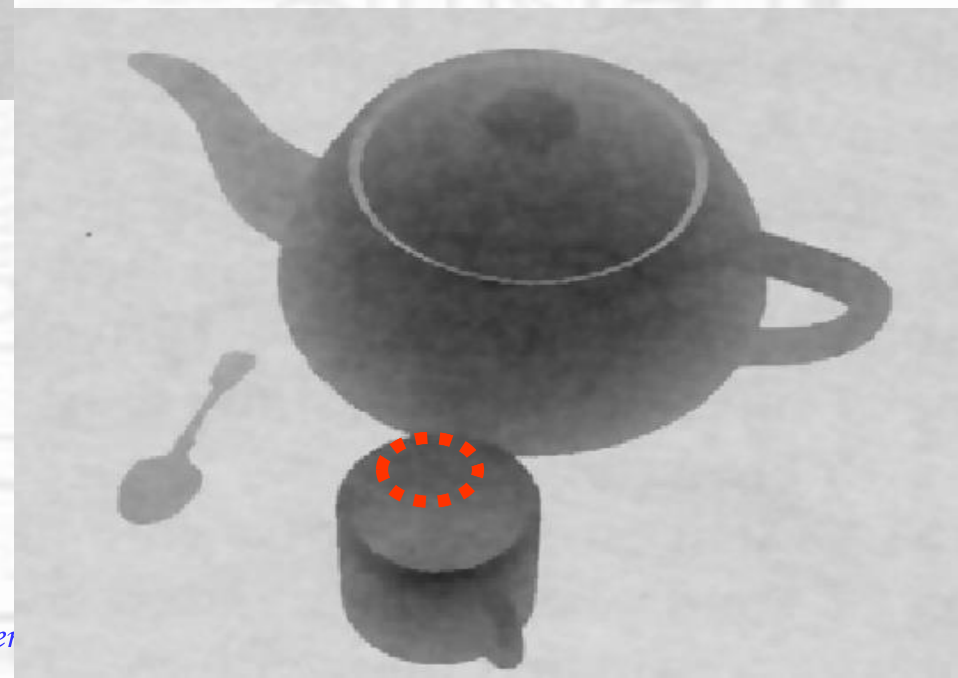

Trans-
form
to
light's
view
Visible-
surface
deter-
mination
Transform to
Modeling coordinates
Merge polygon
databases
Transform to view 1
Transform to view 2
Visible-surface determination

Two-pass Image Precision

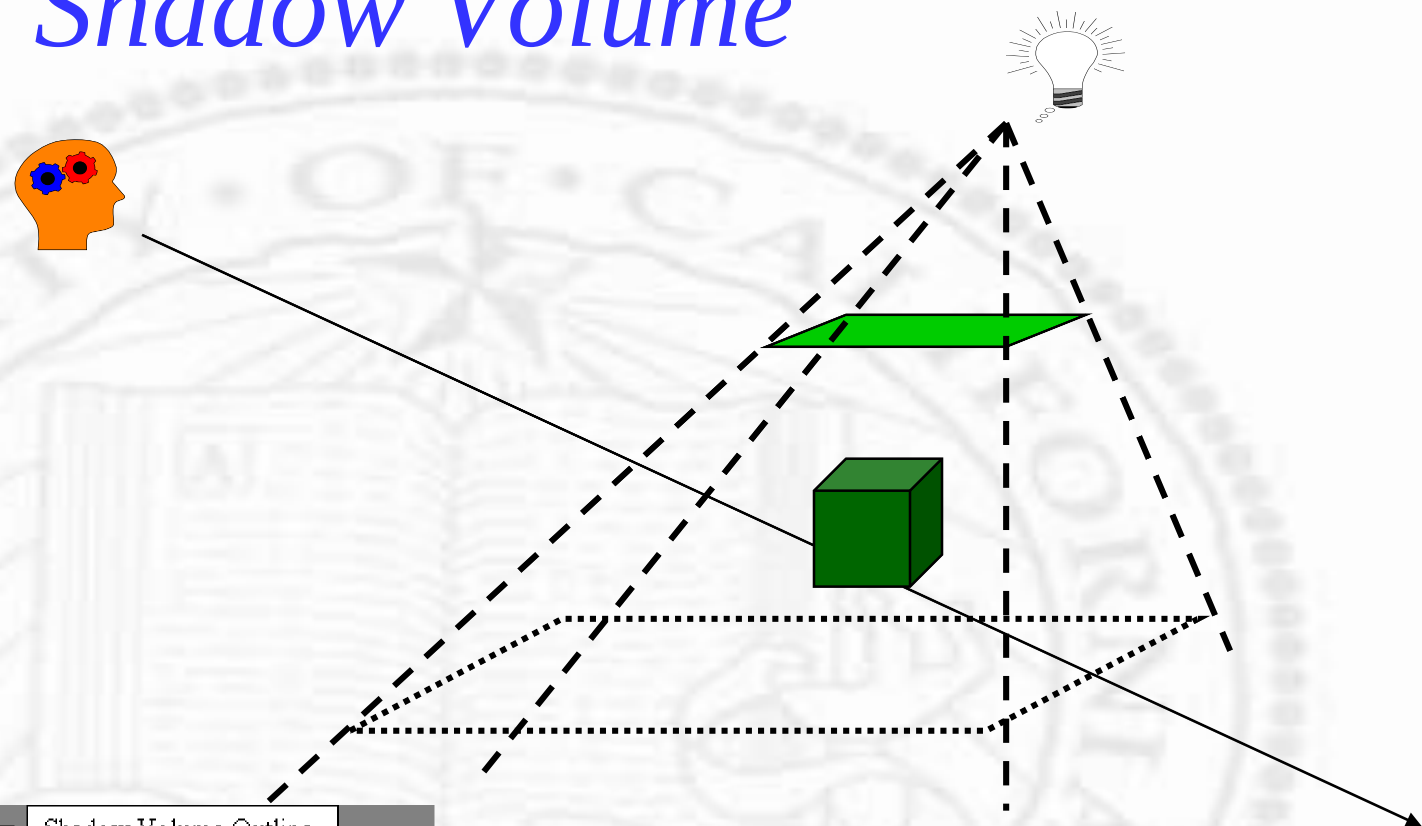
- Z buffer from eye (e): what the viewer can see
- Z buffer from light (l): what the light source can see
- for each (xe,ye,ze)
  - transform to (xl,yl,zl)
  - is zl more distant than z(xl,yl)
    - yes, (xe,ye) is in shadow
    - no, (xe,ye) is not in shadow

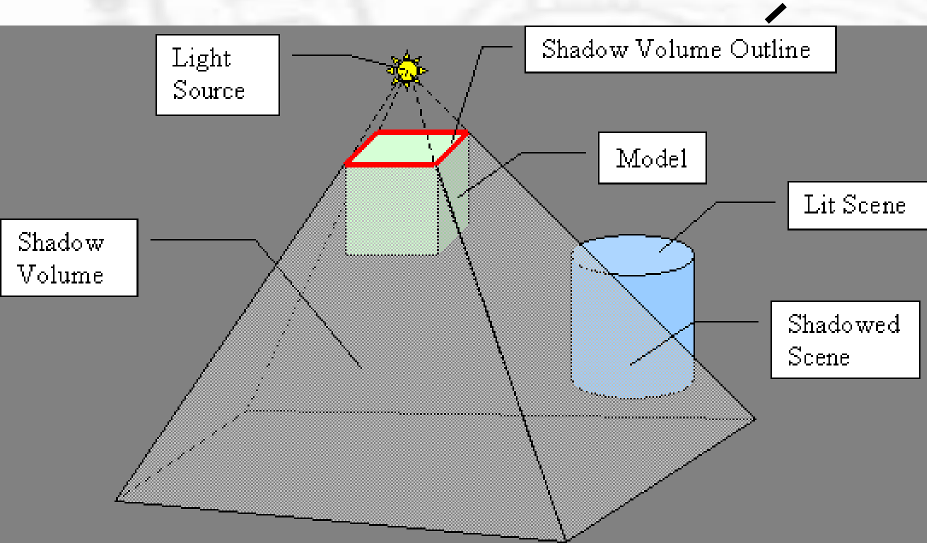

V
L
(a)
(b)
(c)
(e)
(f)





Shadow Volume





Shadow Volume

- Enclosed by
  - (side) *shadow* polygons
  - scene polygon
  - back *shadow* polygon (scaled version of the original scene polygon)
- Shadow polygons are invisible and not rendered (used to determine whether an object is in shadow)
- SV polygons = scene polygon + all shadow polygons

Shadow Volume

- From the viewer
  - each front-facing (normal pointing to the viewer) SV polygon causes object to be in shadow
  - each back-facing (normal pointing away from the viewer) SV polygon causes object to be out of shadow
  - #FF intersections >= #BF intersections to be in shadow

Shadow Volume

- How do you do this?
- A modified depth-sort type algorithm
  - include SV polygons in the depth-sort list but process them front-to-back (instead of back-to-front)
  - determine whether the eye is in any SV
  - then count how many times the projection ray intersects FF and BF SV polygons
  - easier said than done

Soft Shadow

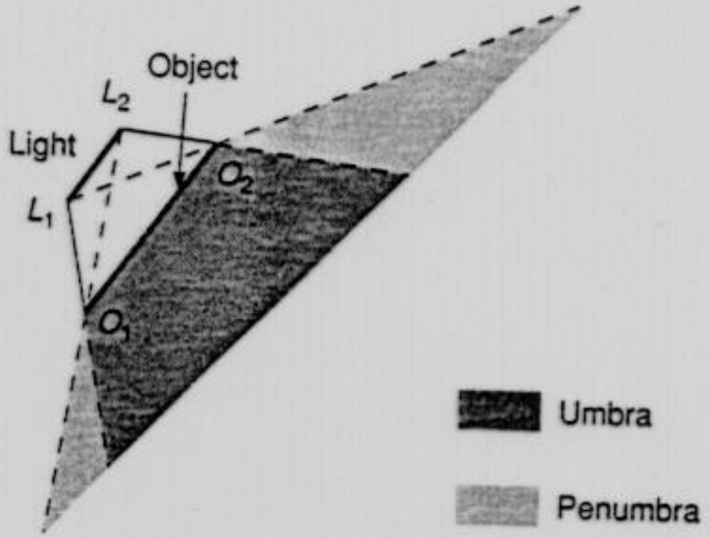
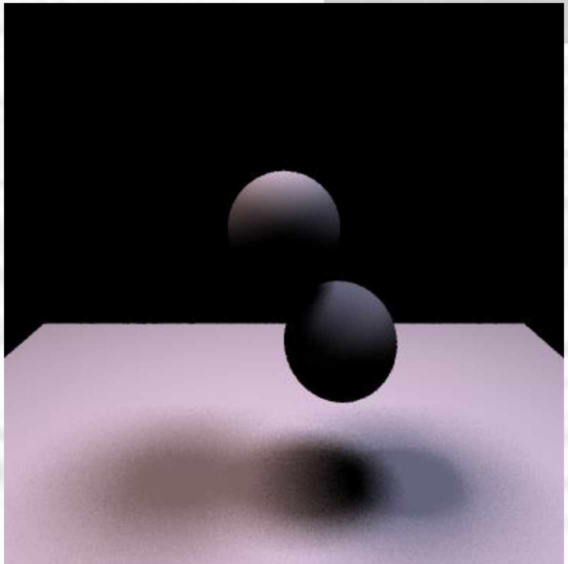
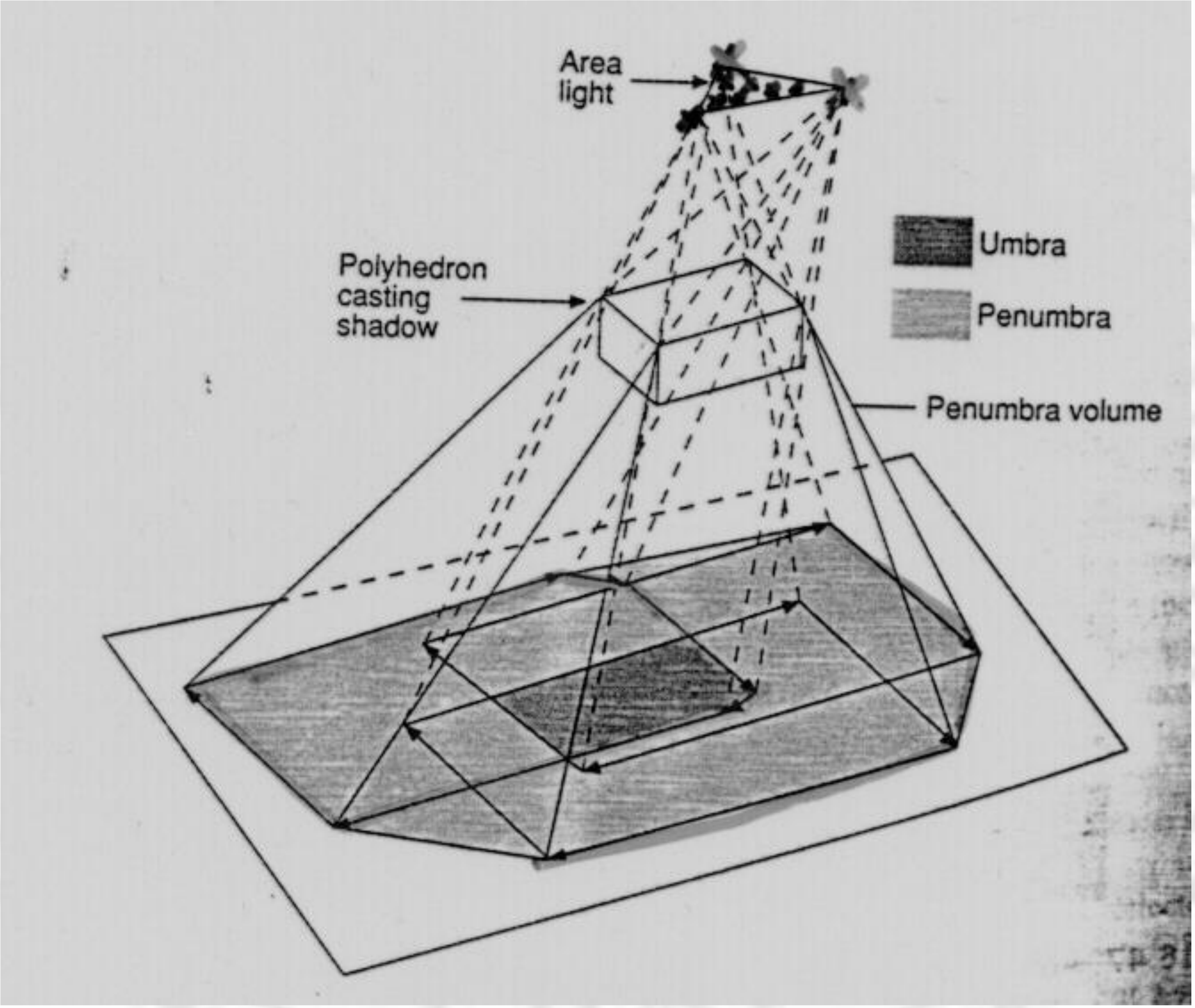


Fig. 16.48 Umbra and penumbra.



Soft Shadow


Area
light
Polyhedron
casting
shadow
Umbra
Penumbra
Penumbra volume

Using BSP Tree

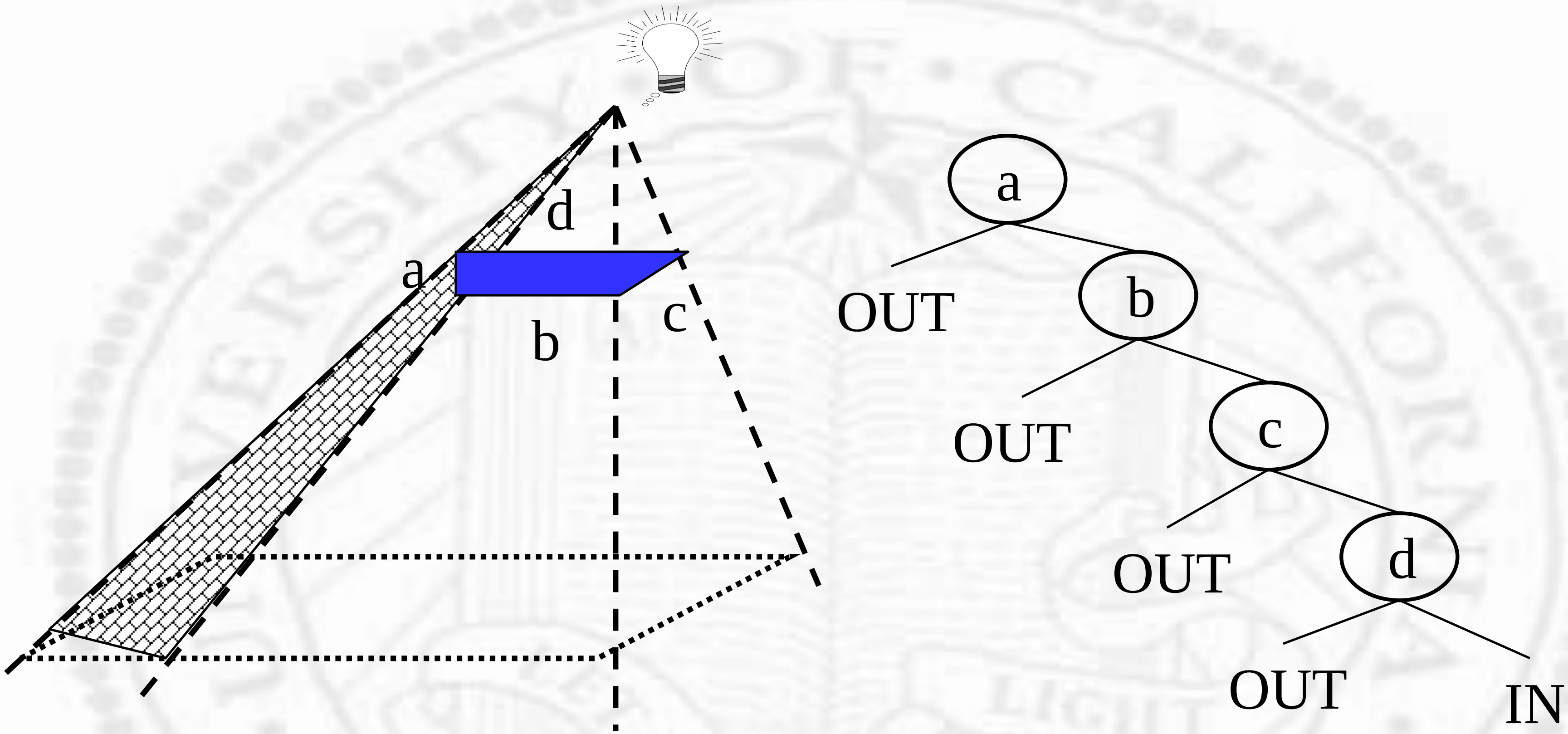
- Stationary light source
- Stationary scene
- Moving camera
- Basic BSP tree algorithm
  - Construct a tree based on *scene* polygons
  - Determine *rendering* order
- Enhancement
  - Polygons need *surface details* for right order and appearance
  - Order is taken care of by basic BSP
  - How about *surface details*?

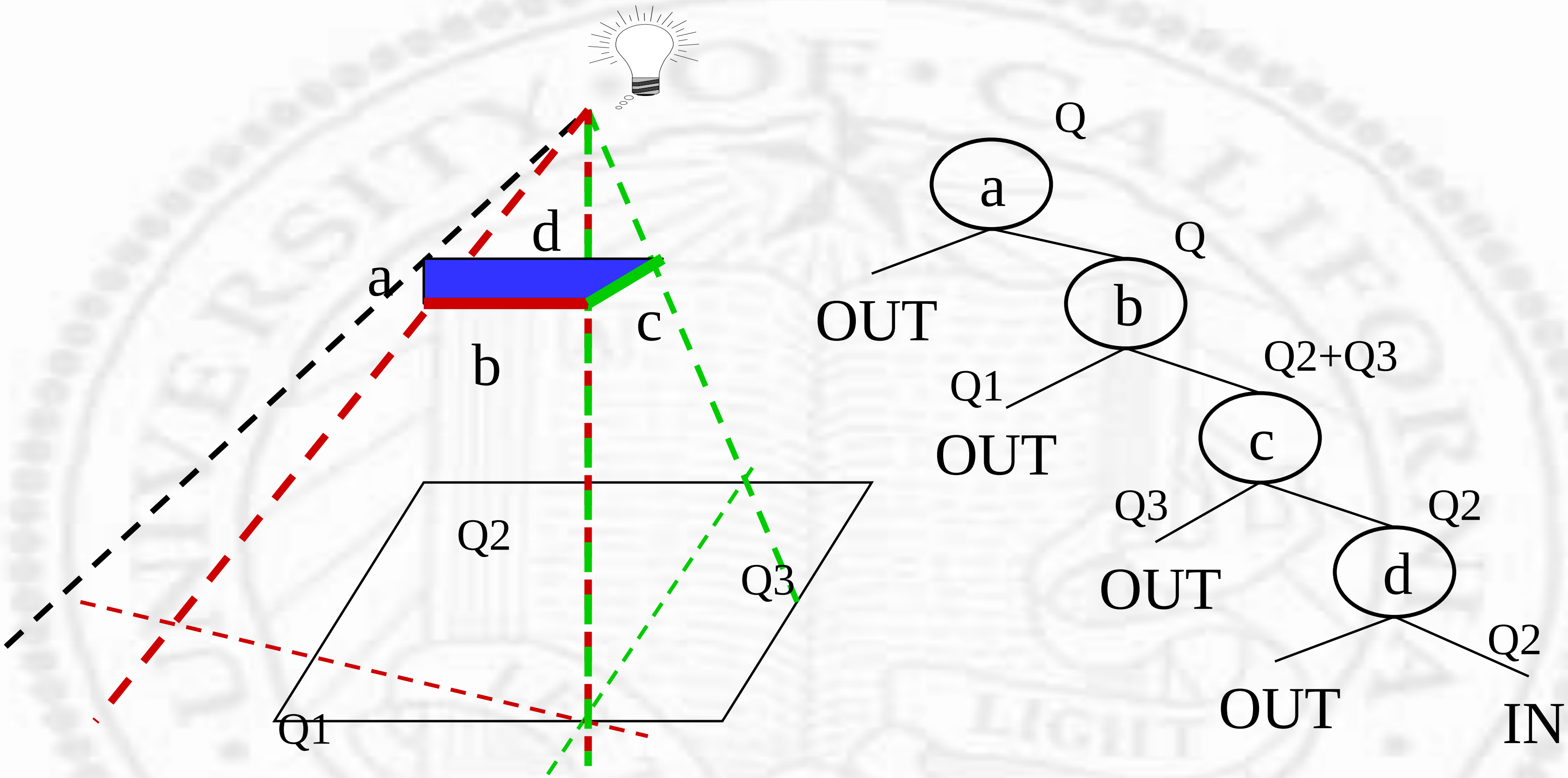
Intuition

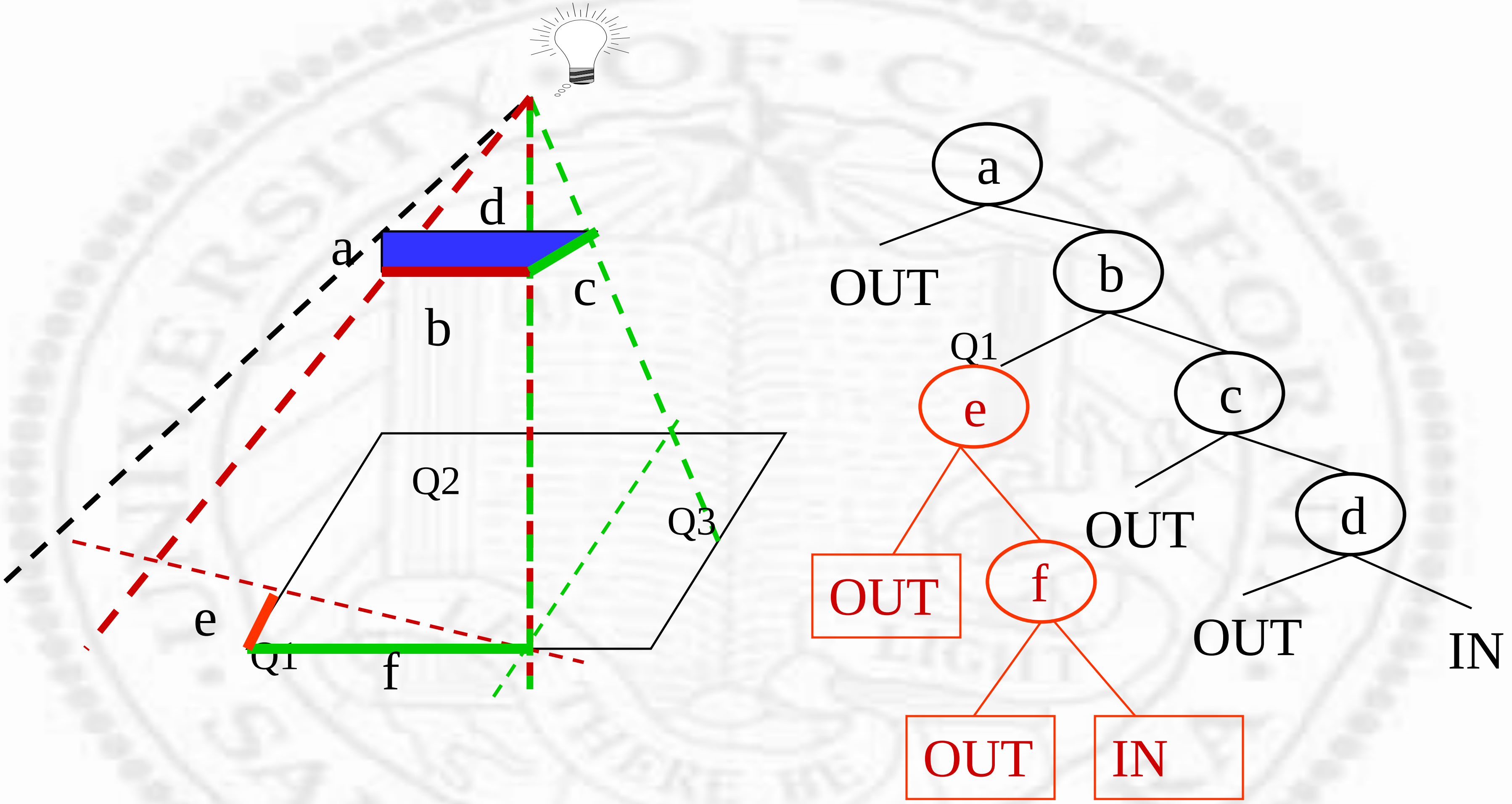
- Surface details (in shadow or not) are *stationary* regardless of camera position
  - Find once
    - if a polygon is in shadow or not, and
    - Which part is in shadow (surface detail polygons)
- Which polygon is *NOT* in shadow
  - The one that is closet to the light source
- The polygon 2nd closest to the light source can only have shadow from the closet polygons
- The polygon 3rd closest to the light source can only have shadow from the 1st and 2nd closet polygons, etc.

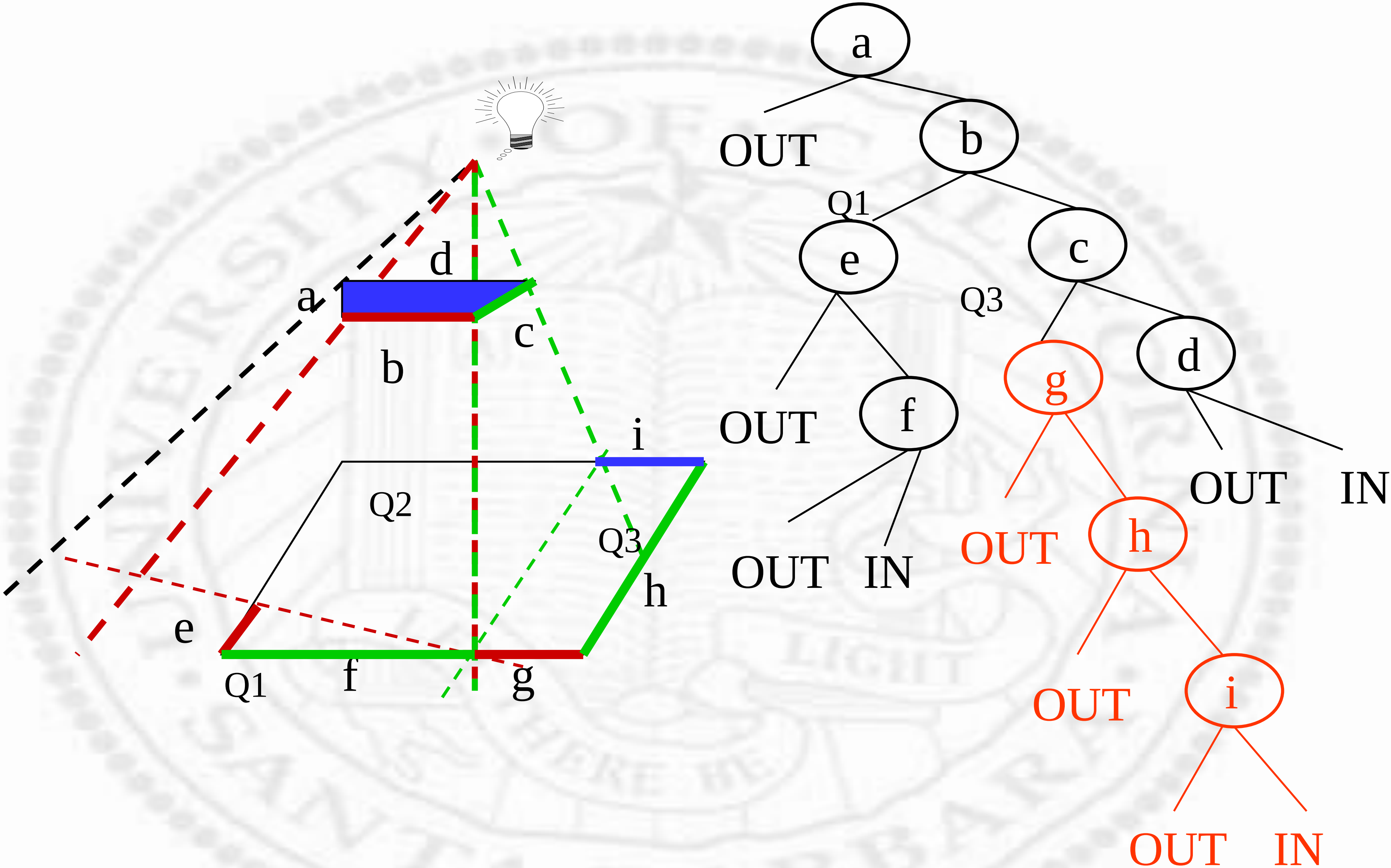
SVBSP Tree

- A binary tree
- Each node is a *SV* polygon (instead of a *scene* polygon)
- Space is divided into IN/OUT by a node (a SV polygon, normal pointing out)
- Leaf nodes are labeled IN/OUT


d
a
b
c
a
OUT
b
OUT
c
OUT
d
OUT
IN


a
d
b
c
Q2
Q3
Q1
Q
a
Q
b
OUT
Q1
Q2+Q3
OUT
c
Q3
Q2
OUT
d
Q2
OUT
IN


d
a
c
b
Q2
Q3
e
Q1
f
a
OUT
b
Q1
e
c
OUT
f
OUT
d
OUT
OUT
IN
OUT
IN


d
a
c
b
i
Q2
Q3
h
e
f
g
Q1
a
OUT
b
Q1
e
c
Q3
d
g
OUT
f
OUT
IN
OUT
IN
OUT
h
OUT
i
OUT
IN

SVBSP Tree Construction

- Ordering is important
  - the polygon which is closest to the light source must be used first
  - the polygon which is 2nd closest to the light source then filtered down the SVBSP tree to generate surface details polygons
  - add the 2nd closest polygons to SVBSP tree
  - the polygon which is 3rd closest to the light source then filtered down the SVBSP tree to generate surface details polygons
  - add the 3rd closest polygons to SVBSP tree
  - ...

- How to know which polygon is closest (2nd, 3rd closest ….) to the light source?
- Use the regular BSP Tree
  - traverse according to the light source position
    - first the half containing light
    - then the partition plane
    - then the half not containing light
- First pass (SVBSP): surface details
- Second pass (BSP): eye locations for rendering

Other Possibilities

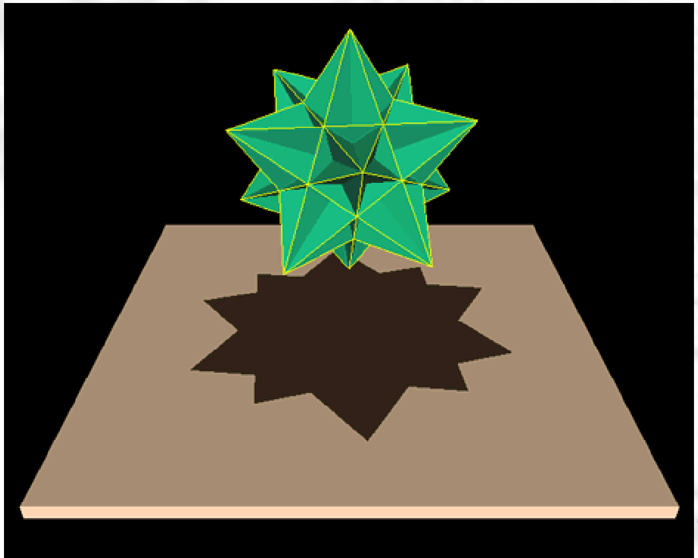
- Ray Tracing
  - with shadow rays to the sources
- Radiosity
  - with form factor computation
- Later

Fake Shadow

- Shadow generation is not trivial
  - OpenGL does not do it
- Reason
  - Shading calculation can be based entirely on "local" information, while shadow calculation cannot (need to know the relative position of many objects)
- In reality
  - Shadow does not to be entirely correct, it just has to be realistic

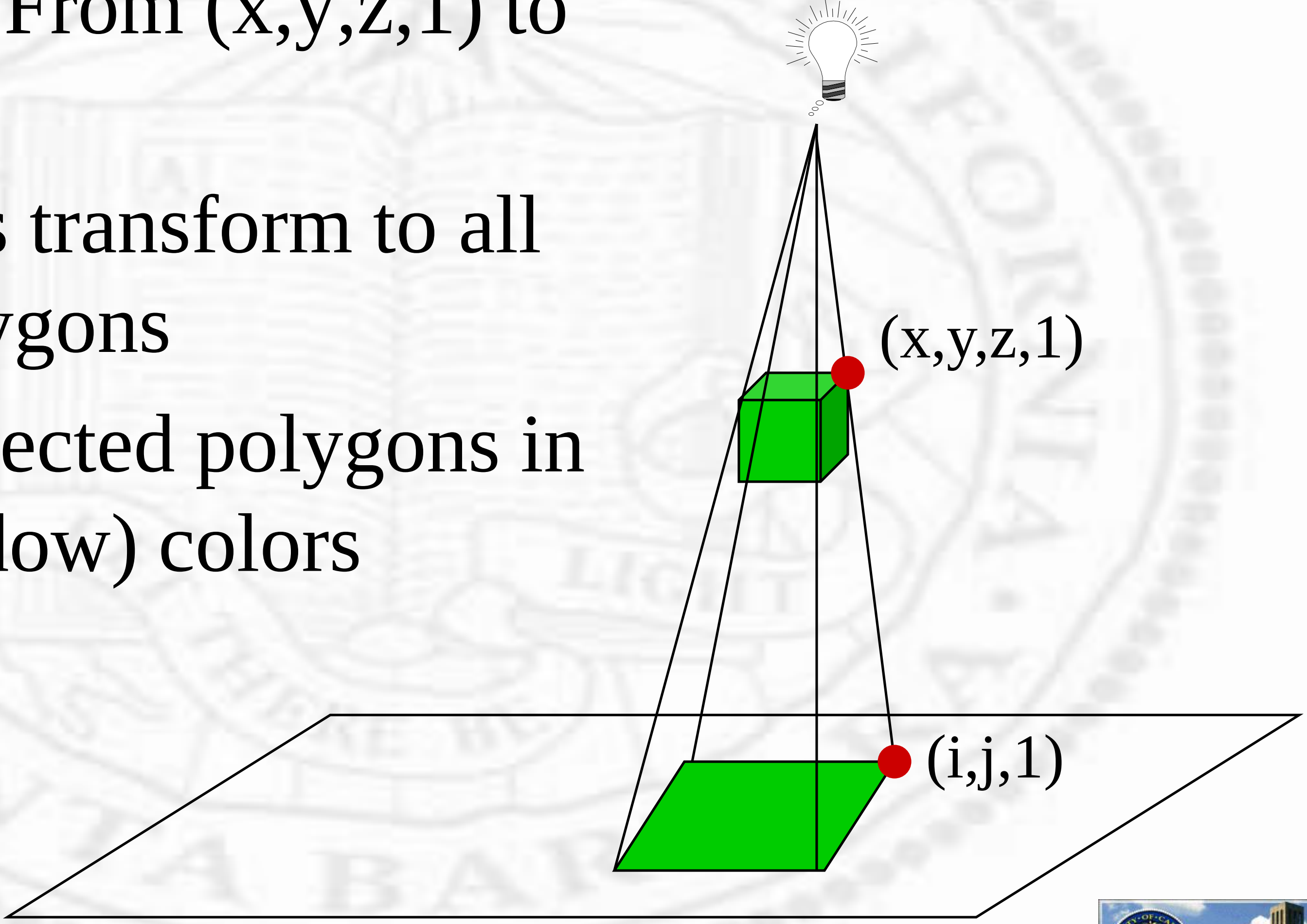
Fake Shadow (cont.)

- Usually, in an indoor environment
  - Light is on the ceiling
  - Walls and floor enclose the scene (and they are planar)
  - Cast shadows on those enclosing surfaces by projecting objects onto them



Example

- Figure out the projection transform From (x,y,z,1) to (i,j,1)
- Apply this transform to all scene polygons
- Draw projected polygons in dark (shadow) colors



Math

$$\textit{line} \quad \begin{cases} x = l_x + t(p_x - l_x) \\ y = l_y + t(p_y - l_y) \\ z = l_z + t(p_z - l_z) \end{cases}$$

$$\textit{plane} \qquad z = 0$$

$$\Rightarrow l_z + t(p_z - l_z) = 0$$

$$\Rightarrow t = -\frac{l_z}{(p_z - l_z)}$$

$$\Rightarrow x = \frac{l_z p_x - l_x p_z}{(p_z - l_z)}, y = \frac{l_z p_y - l_y p_z}{(p_z - l_z)}$$

$$\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} l_z & 0 & -l_x & 0 \\ 0 & l_z & -l_y & 0 \\ 0 & 0 & 1 & -l_z \end{bmatrix} \begin{bmatrix} p_x \\ p_y \\ p_z \\ 1 \end{bmatrix}$$