Computer Graphics

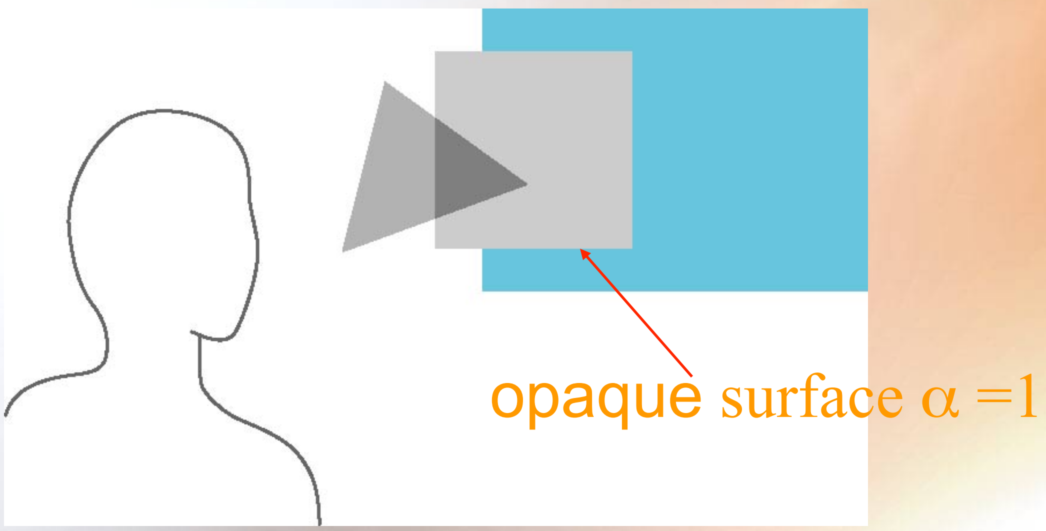
Transparency and Shadows in OpenGL

Based on slides by Dianna Xu, Bryn Mawr College

Opacity and Transparency

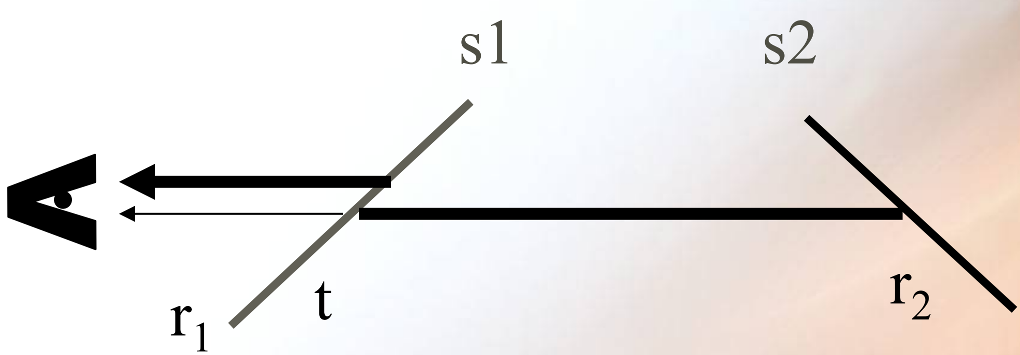
- Opaque surfaces permit no light to pass through
- Transparent surfaces permit all light to pass
- Translucent surfaces pass some light

  translucency = $1 - \alpha$



Translucency Model

- **Surface s1 is translucent and only allows a fraction t (transmittance) of the light reflected from surface s2 (behind it) to pass through:**



$$i = (1 - t)r_1 + t\, r_2$$

t = transmittance of s1
r_1 = reflected light from s1
r_2 = reflected light from s2

$t = 0 \Rightarrow\ i = r_1$ s1 is opaque
$t = 1 \Rightarrow\ i = r_2 \Rightarrow$ s1 is transparent

Blending Equation

- Source: the color of the polygon going to cover the pixel
- Destination: the color of original pixel in the frame buffer
- Blending factor is the same for all color components

$$c = B_d * C_s + B_s * C_d$$

OpenGL Blending and Compositing

- Must enable blending and pick source and destination factors

```
glEnable(GL_BLEND)
glBlendFunc(source_factor,
  destination_factor)
```

- Only certain factors supported
  - `GL_ZERO, GL_ONE`
  - `GL_SRC_ALPHA, GL_ONE_MINUS_SRC_ALPHA`
  - `GL_DST_ALPHA, GL_ONE_MINUS_DST_ALPHA`
  - See Redbook for complete list

Example

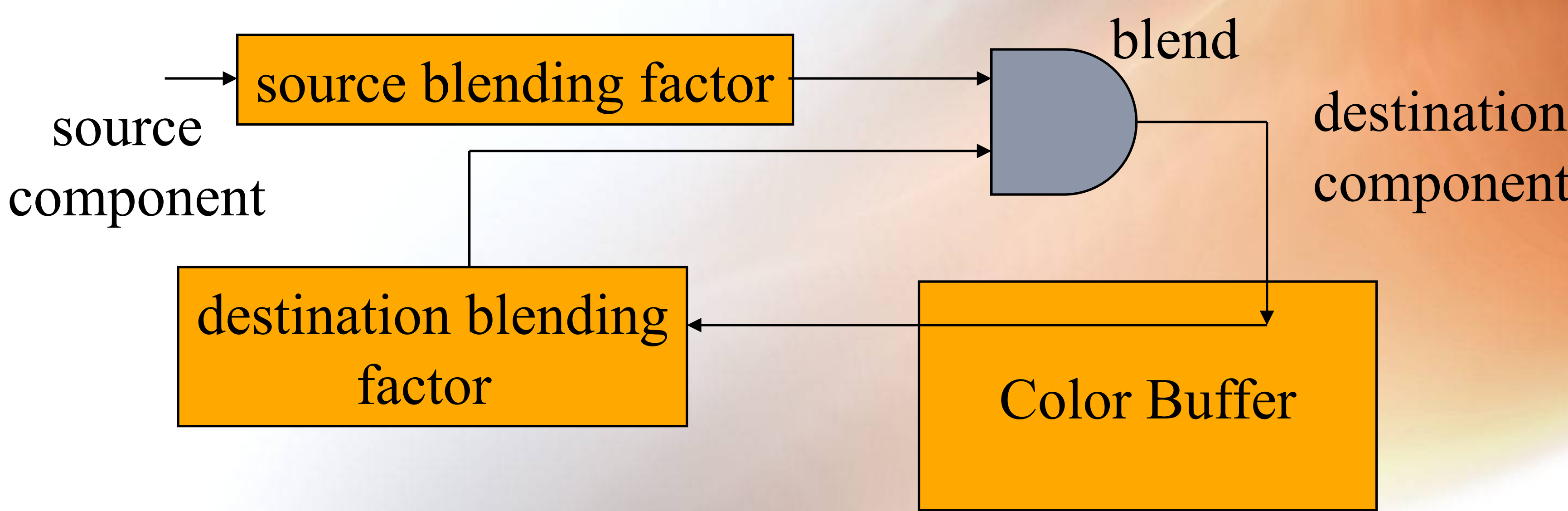
- Suppose that we start with the opaque background color $(R_0,G_0,B_0,1)$
  - This color becomes the initial destination color
- We now want to blend in a translucent polygon with color (R_1,G_1,B_1,α_1)
- Select `GL_SRC_ALPHA` and `GL_ONE_MINUS_SRC_ALPHA` as the source and destination blending factors

$$\alpha_1 R_1 + (1- \alpha_1) R_{0,,} \alpha_1 G_1 + (1- \alpha_1) G_0 \; \alpha_1 B_1 + (1- \alpha_1) B_0$$

- Note this formula is also correct if polygon is either opaque or transparent

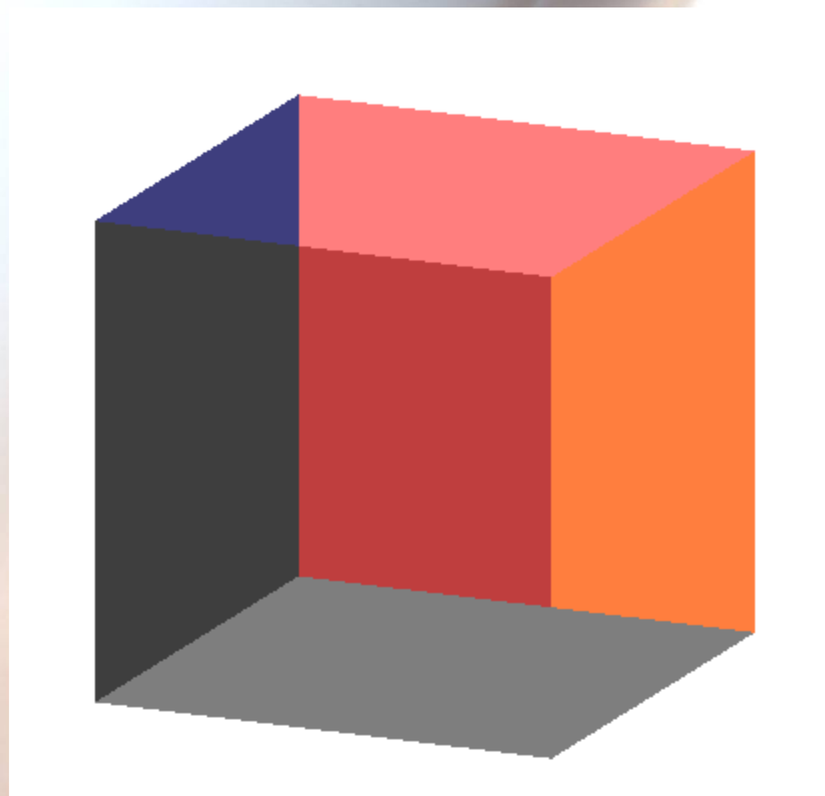
Writing Model

- Use α component of RGBA (or RGBα) color to store opacity
- During rendering we can expand our writing model to use RGBA values



Order Dependency

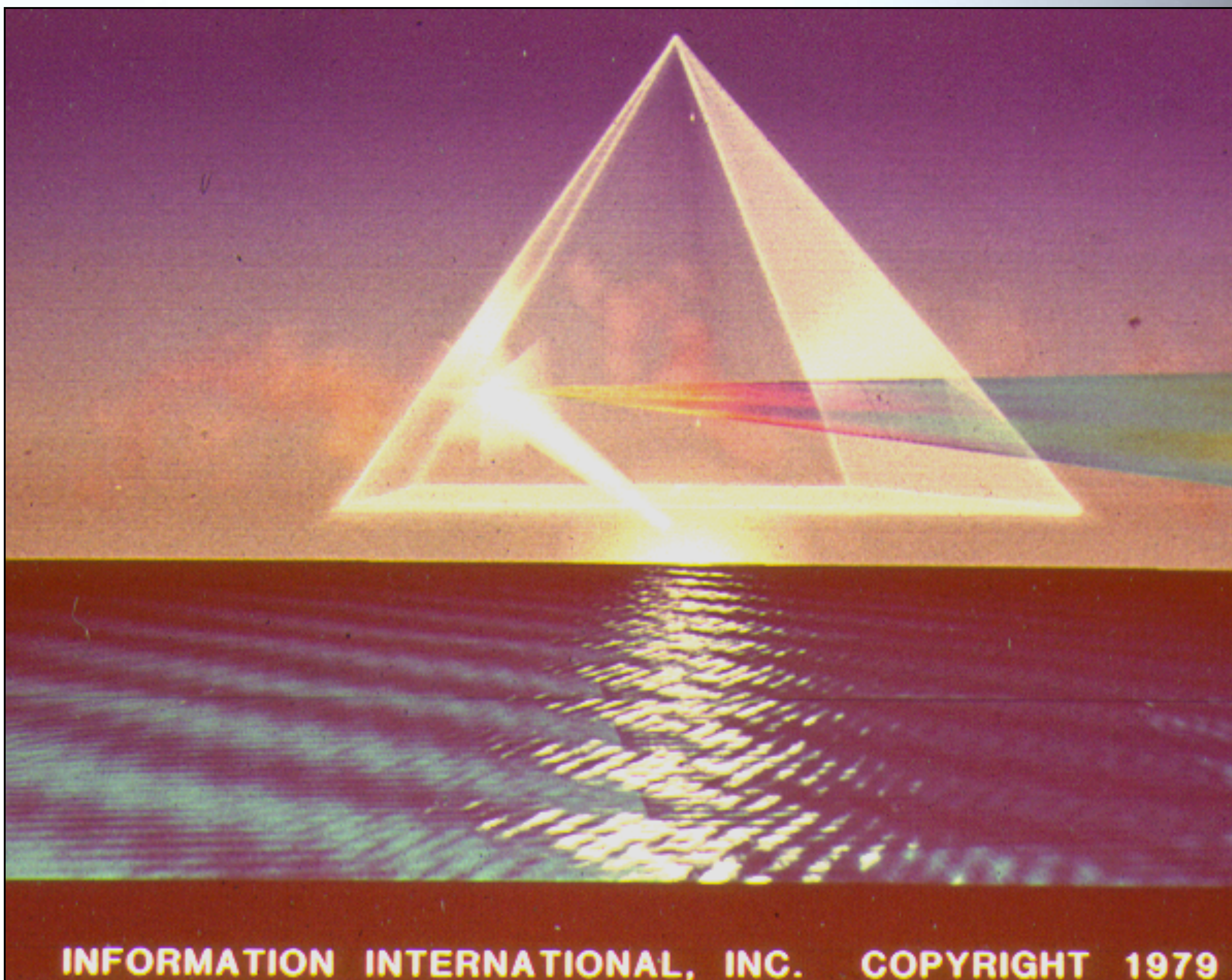
- Is this image correct?
  - Probably not
  - Polygons are rendered in the order they pass down the pipeline
  - Blending functions are order dependent



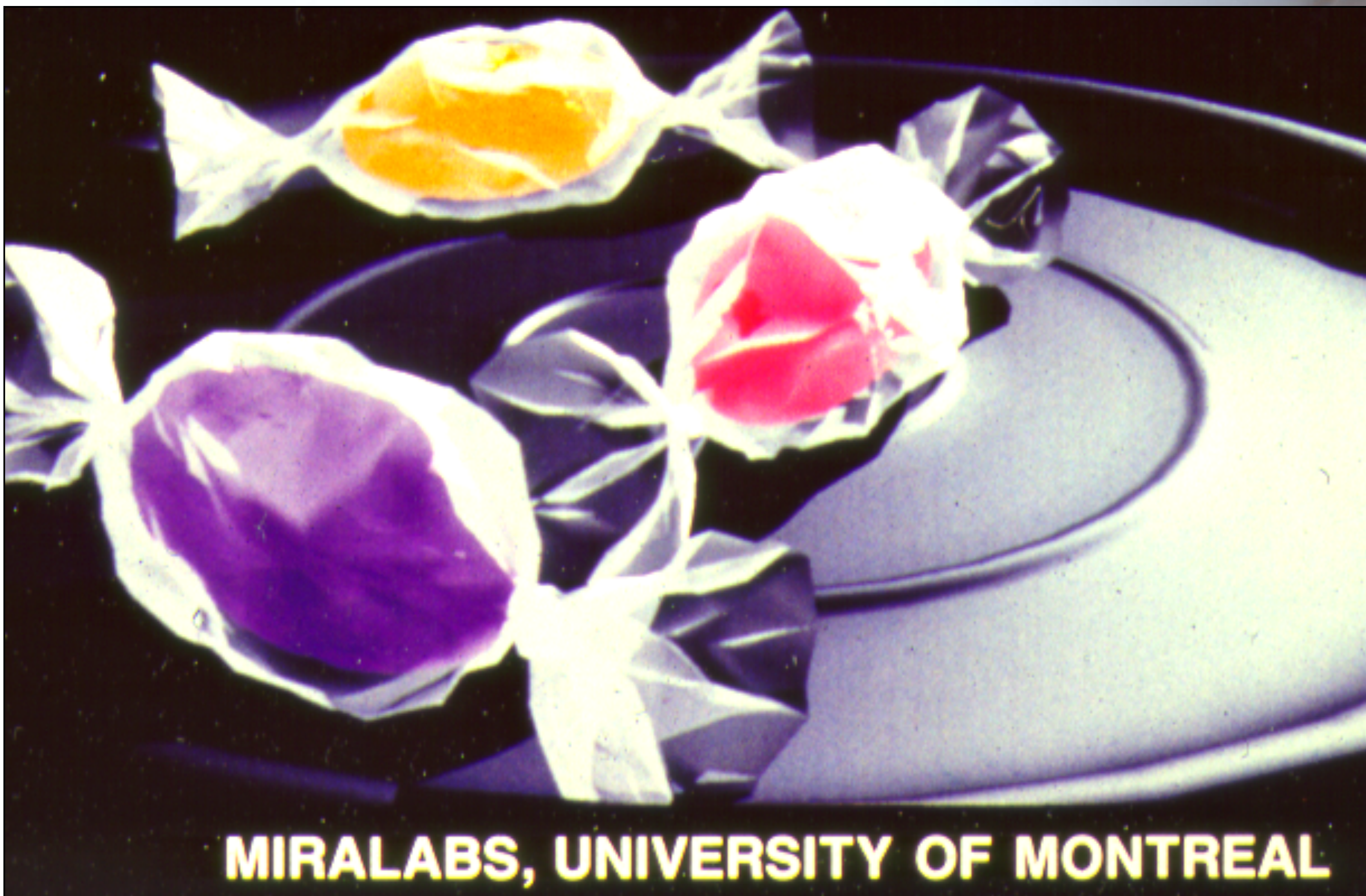
Translucency and HSR

- Suppose that we have a group of polygons some of which are opaque and some translucent
- How do we use hidden-surface removal?
- Opaque polygons block all polygons behind them and affect the depth buffer
- Translucent polygons should not affect depth buffer
  - Render with `glDepthMask(GL_FALSE)` which makes depth buffer read-only
- Sort polygons first to remove order dependency

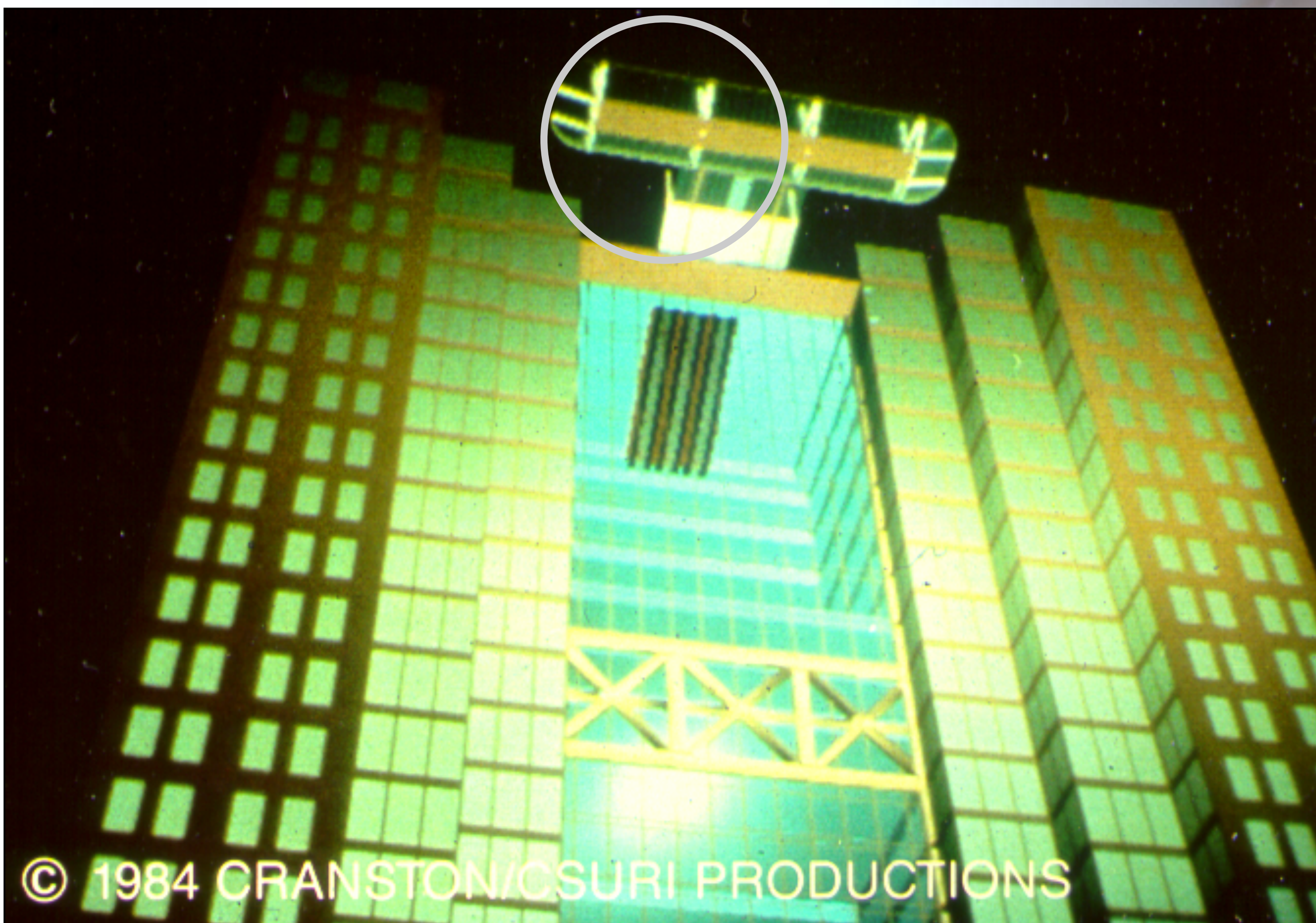
Changing Transmittance by Viewing Angle



Applied to Lots of Small Polygons



Specular Highlights Reduce Transmittance



Fog

- **Blend in distance-dependent color as each polygon is processed.**
- **Add a fog factor which is used much like alpha, but is dependent on depth, and blends between fog color and polygon color.**

$$c = f * C_s + (1 - f) * C_f$$

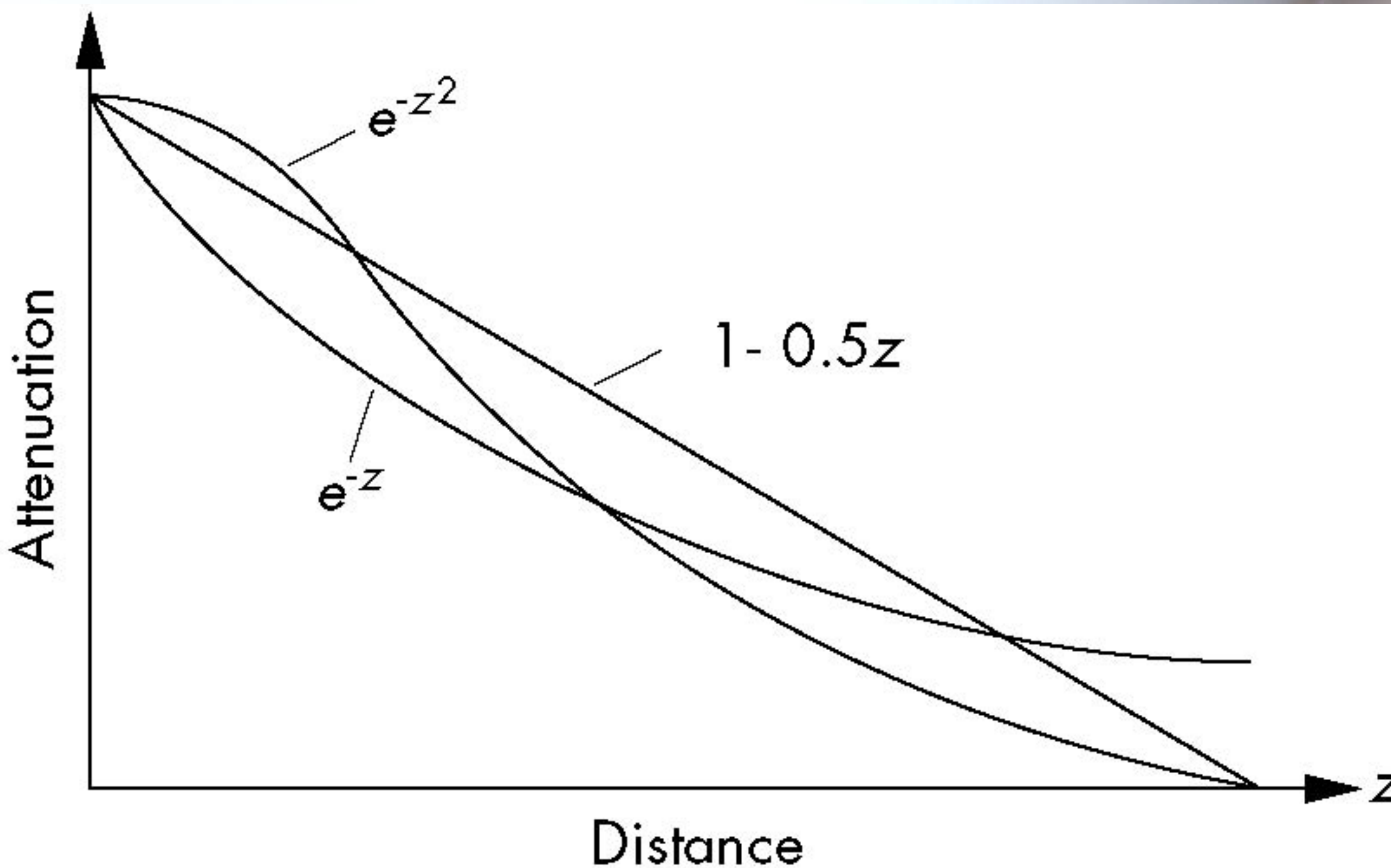
- **f is the *fog factor*, and is calculated by a function on depth**
  - **Exponential**
  - **Gaussian**
  - **Linear (depth cueing)**

OpenGL Fog

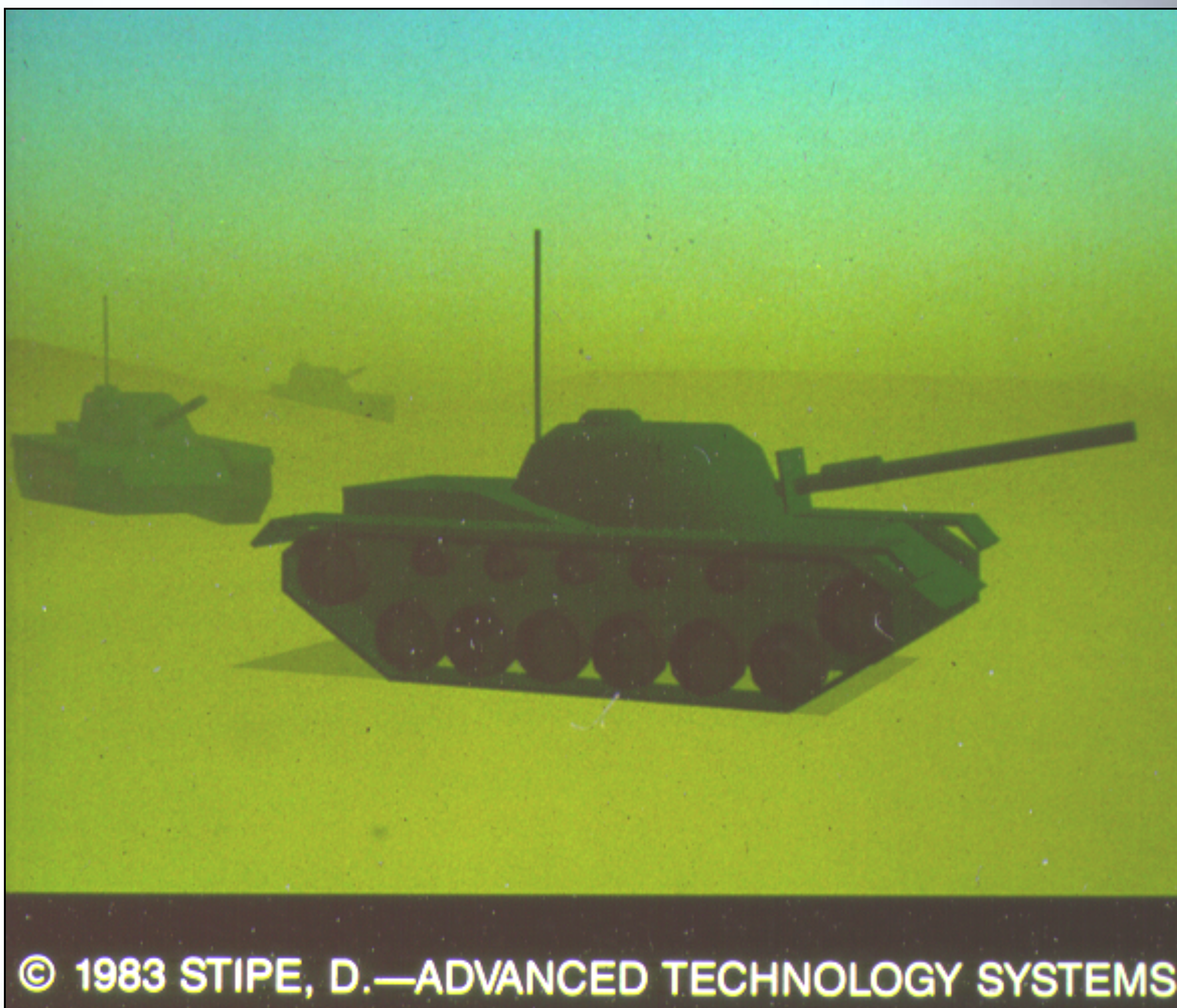
```
GLfloat fogc[4] = {…};
glEnable(GL_FOG);
glFogfv(GL_FOG_COLOR, fogc);
glFogf(GL_FOG_MODE, GL_EXP);
glFogf(GL_FOG_DENSITY, 0.5); //
```

$f = e^{-0.5z^2}$

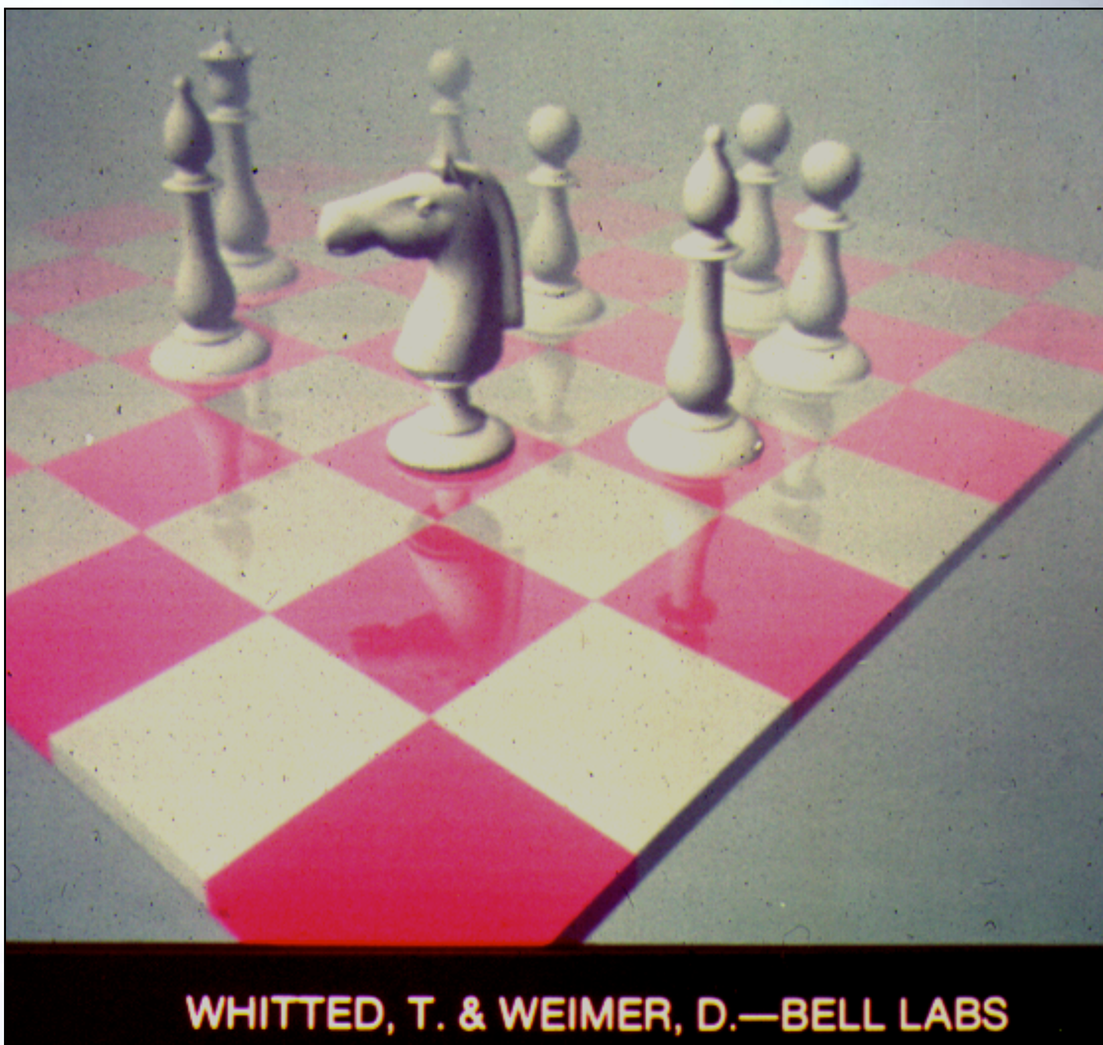
Fog Functions



Fog or Haze

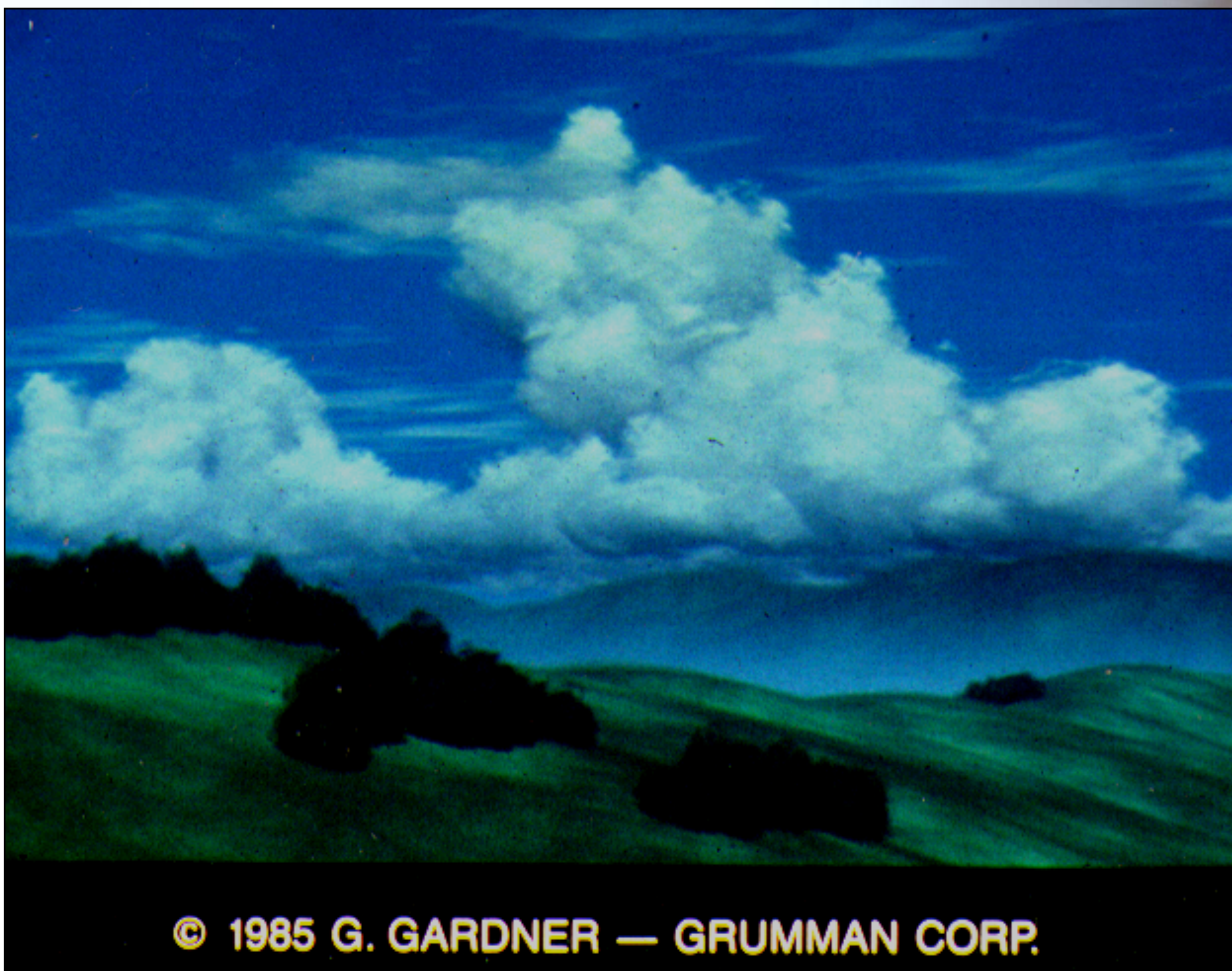


Foggy Chessmen



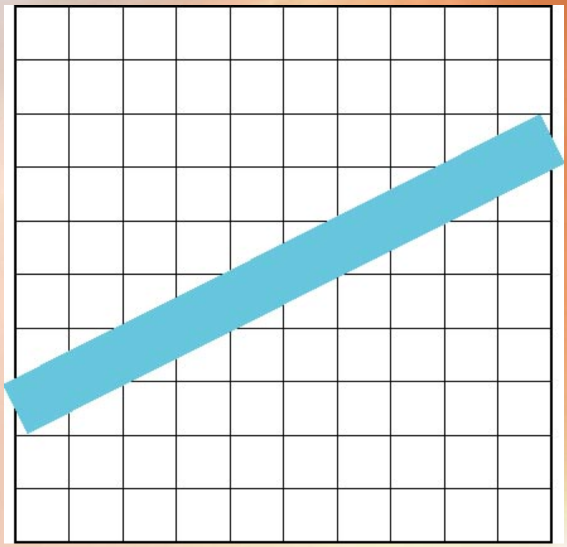
Transmittance Function: Varies over Interior of Ellipsoid Shapes

Using a Denser Transmittance Function (or 1)



Line Aliasing

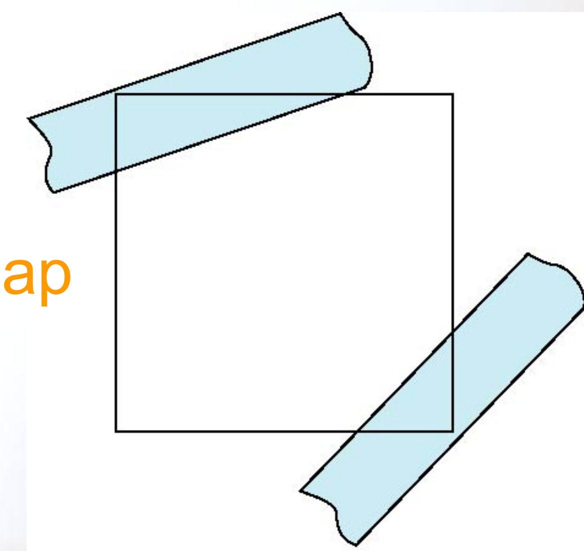
- Ideal raster line is one pixel wide
- All line segments, other than vertical and horizontal segments, partially cover pixels
- Simple algorithms color only whole pixels
- Lead to the “jaggies” or aliasing
- Similar issue for polygons

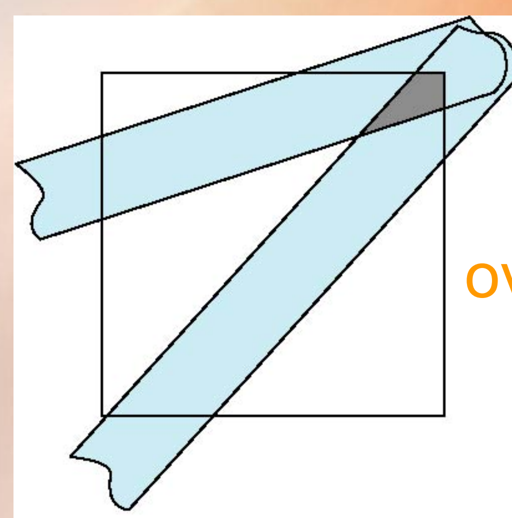


Antialiasing

- Can try to color a pixel by adding a fraction of its color to the frame buffer
  - Fraction depends on percentage of pixel covered by fragment
  - Fraction depends on whether there is overlap

no overlap

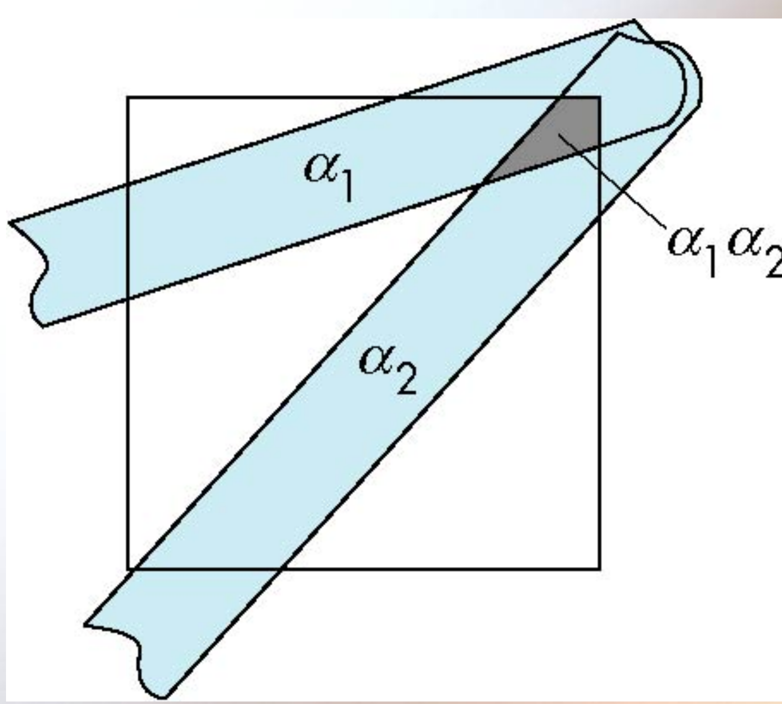




overlap

Area Averaging

- **Use average area $\alpha_1+\alpha_2-\alpha_1\alpha_2$ as blending factor**



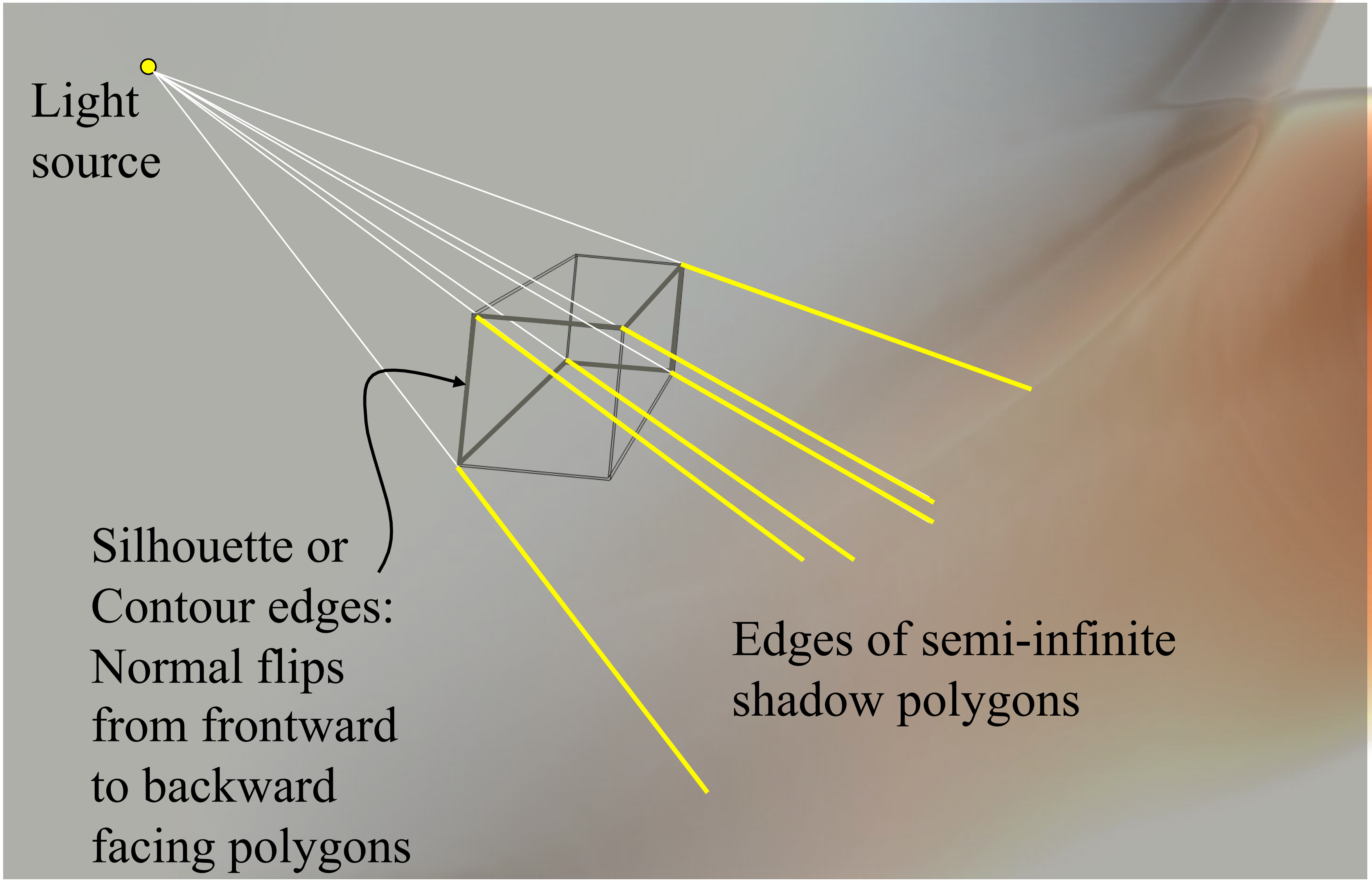
OpenGL Antialiasing

```
glEnable(GL_POINT_SMOOTH);
glEnable(GL_LINE_SMOOTH);
glEnable(GL_POLYGON_SMOOTH);
glEnable(GL_BLEND);
glBlendFunc(GL_SRC_ALPHA,
  GL_ONE_MINUS_SRC_ALPHA);
```

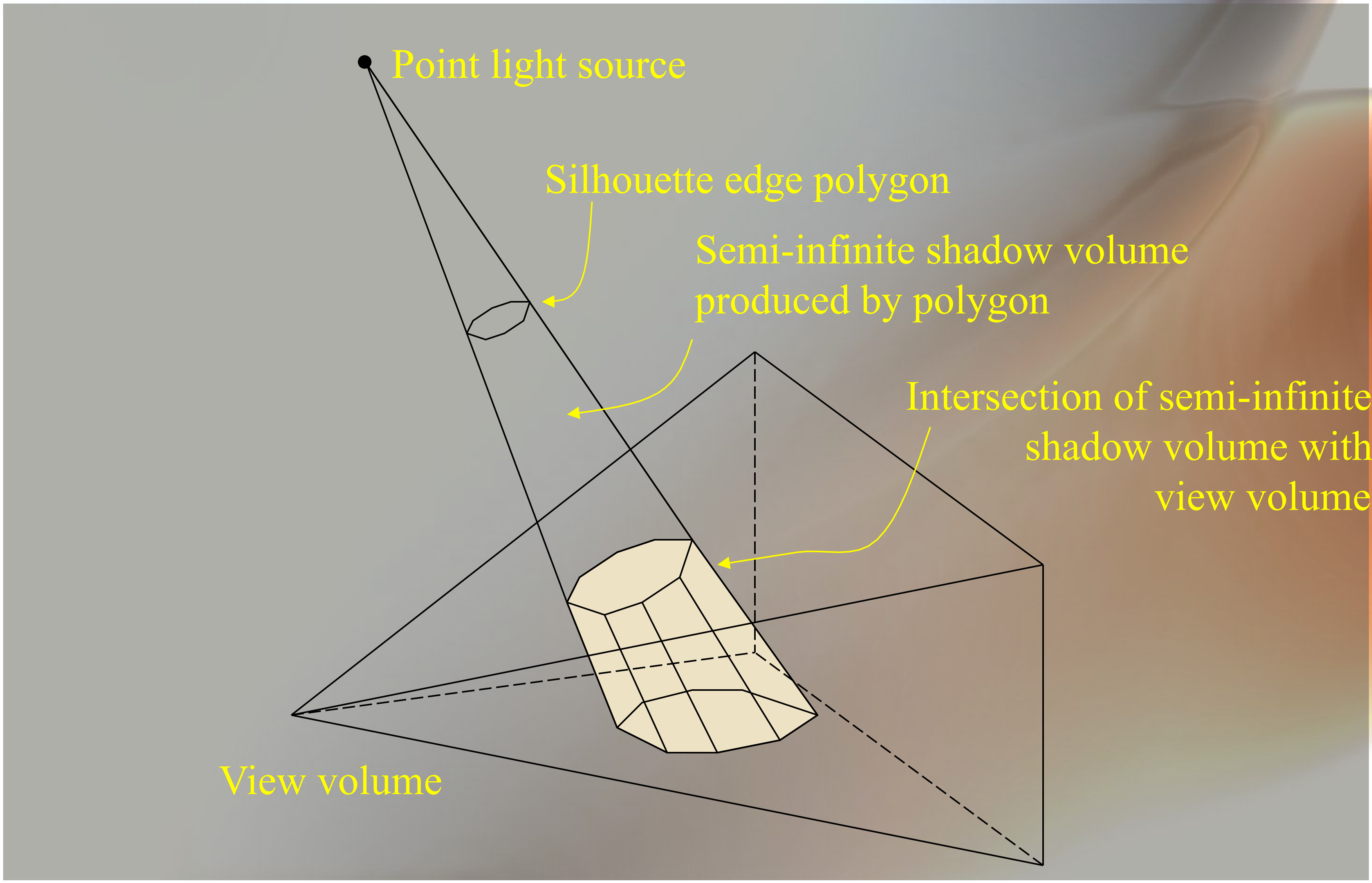
Shadows

- Shadows are a consequence of light and substance.
- Shadows help depth perception and spatial relationships.
- Shadows can be hard- or soft-edged.
- Various shadow algorithms:
  - Finding silhouette edges and creating shadow polygons
  - Ray tracing
  - Radiosity

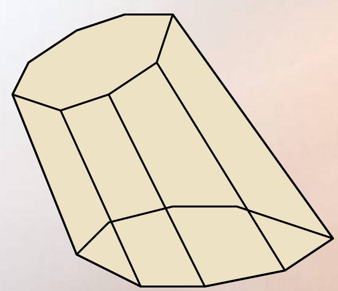
Shadow Volumes for Non-Ray-Traced Renderings



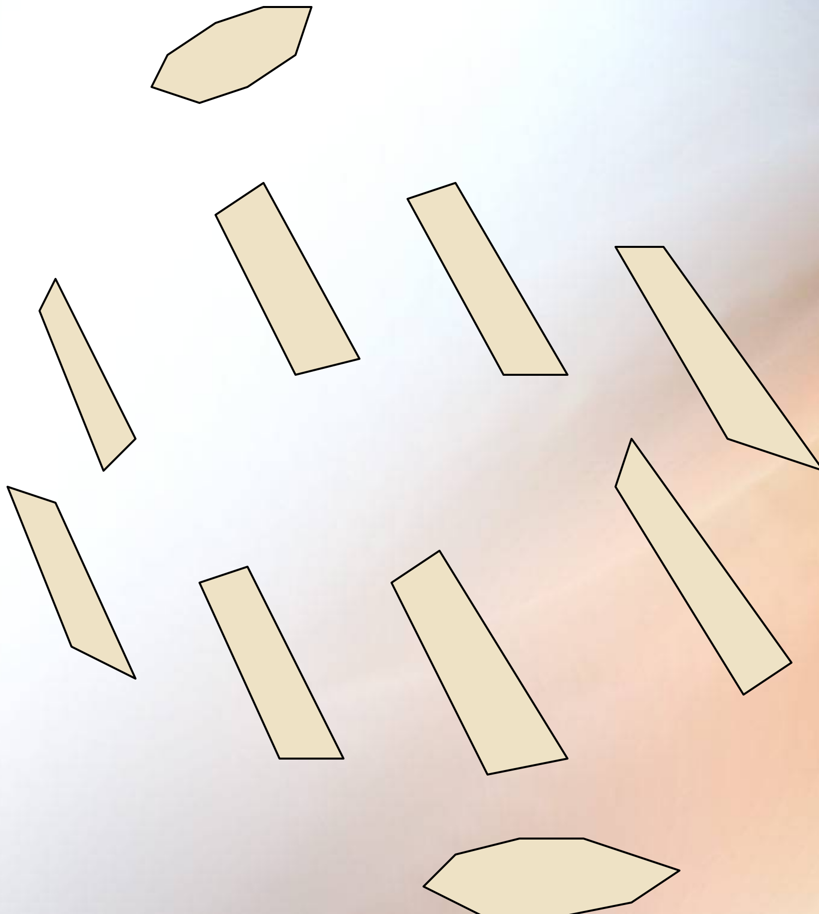
Clipping Shadow Volumes to View Pyramid to Form Shadow Polygons



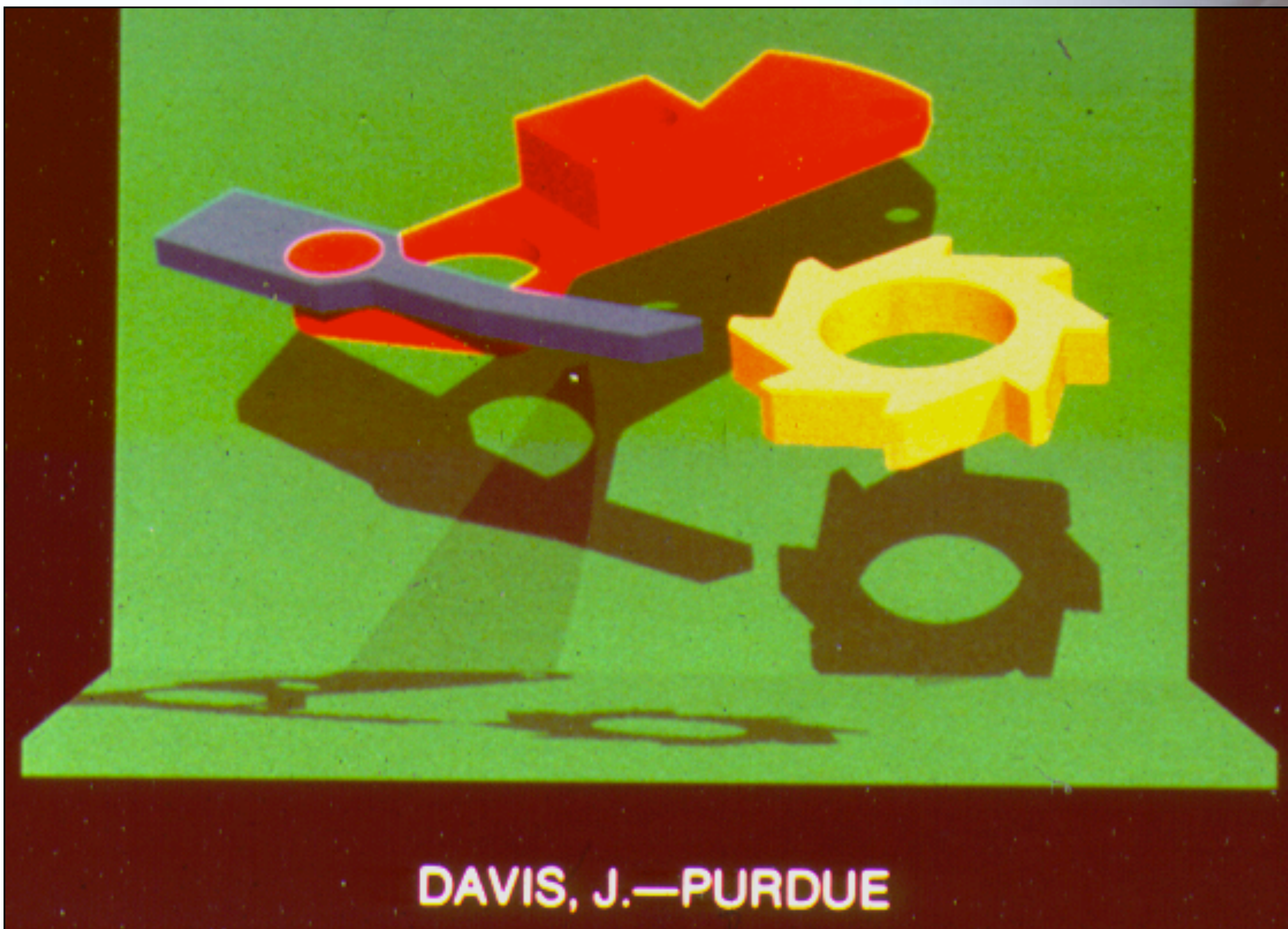
Clipped Shadow Volume Polygons Added to Scene



E.g., these polygons (exploded view):



Shadows Add Depth and Spatial Relationships



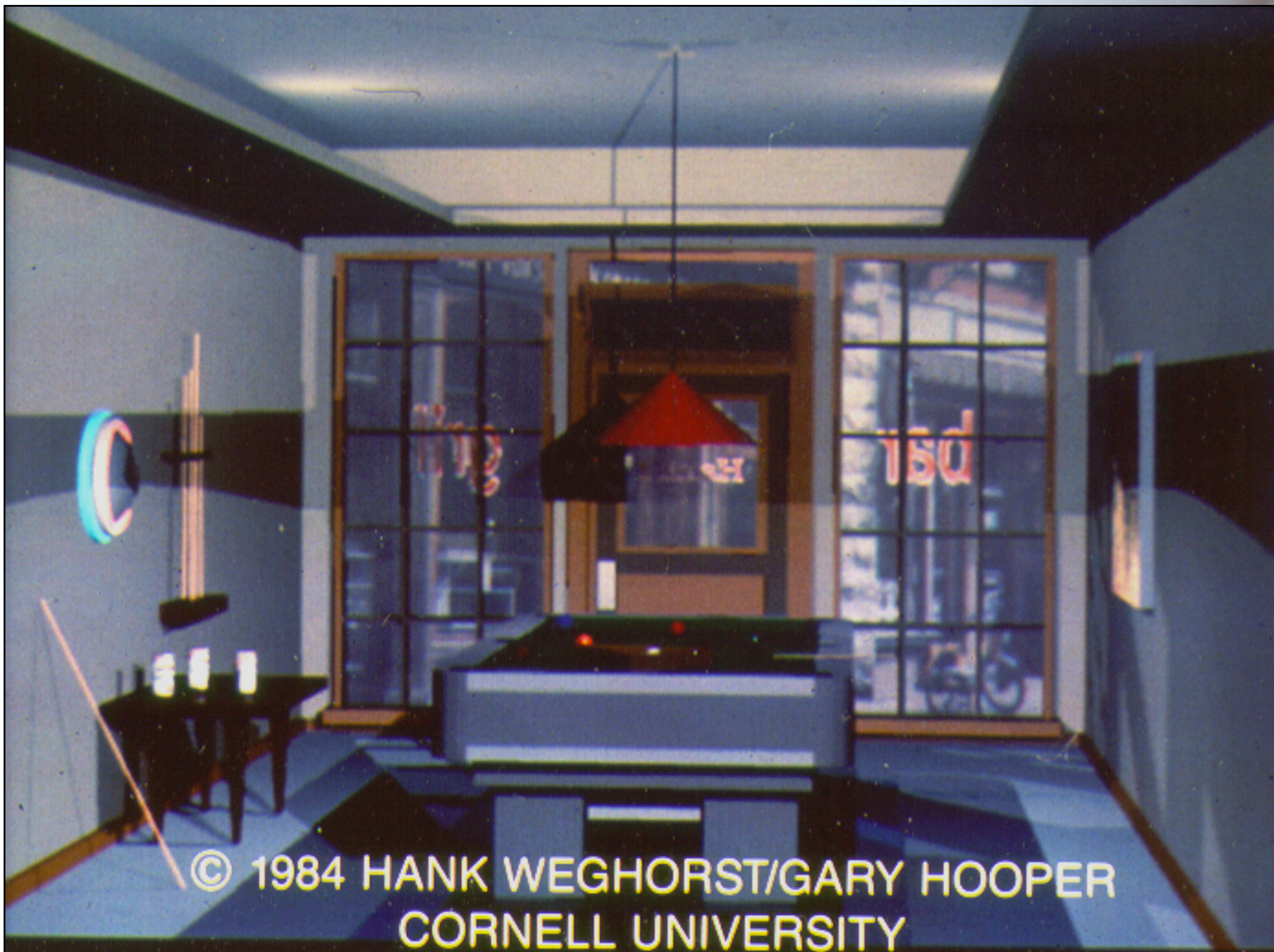
Shadows Help Show Contacts

Shadows Show Us Where Lights Might Be

Shadows Accent Otherwise Like Color Features

Sunbeams as Polyhedral Channels and Light Density

Light and Shadow over the Edge of Believability



Soft Shadows (Before Radiosity)