# Lighting and Shading II

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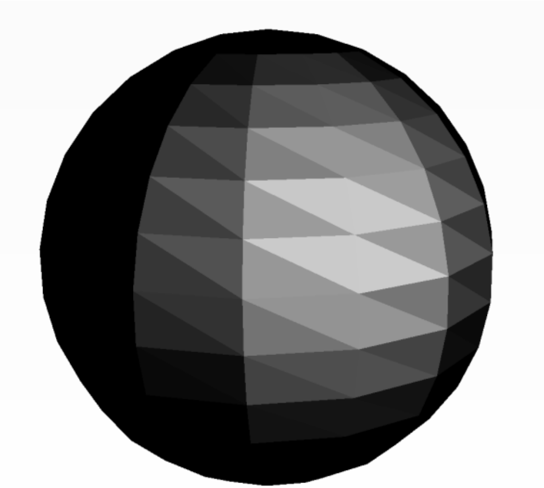
ETH zürich

cgl

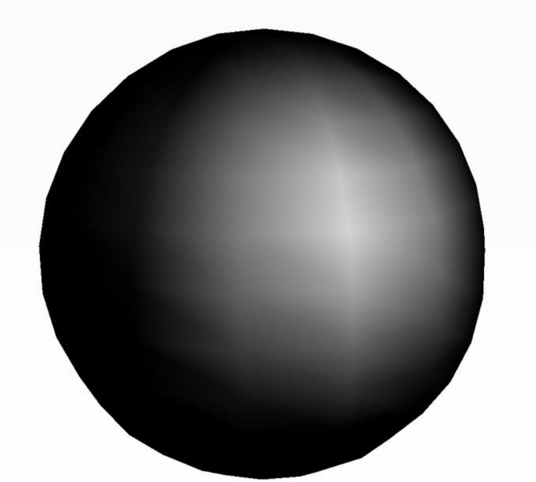
# Shading Models

- Flat Shading
  - One color per primitive



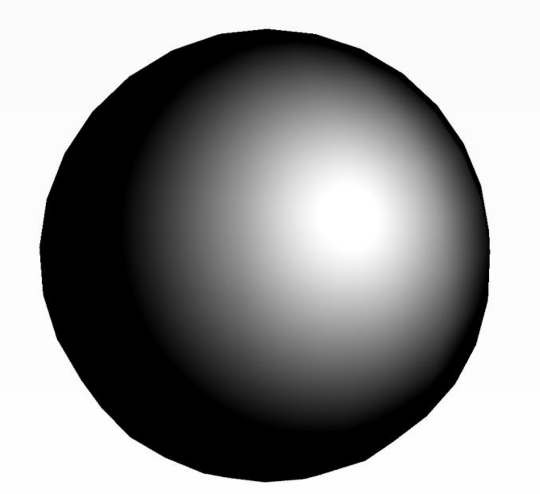
# Shading Models

- Gouraud Shading
  - Linear interpolation of vertex intensities



# Shading Models

- Phong Shading
  - Linear interpolation of vertex normals

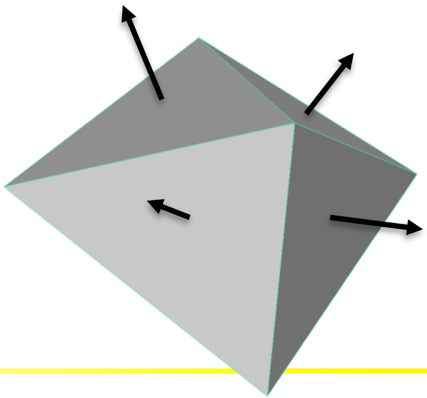


# Shading Models

- In screen space
  - Flat shading
  - Gouraud Shading
- In object space
  - Phong Shading
- Impacts performance

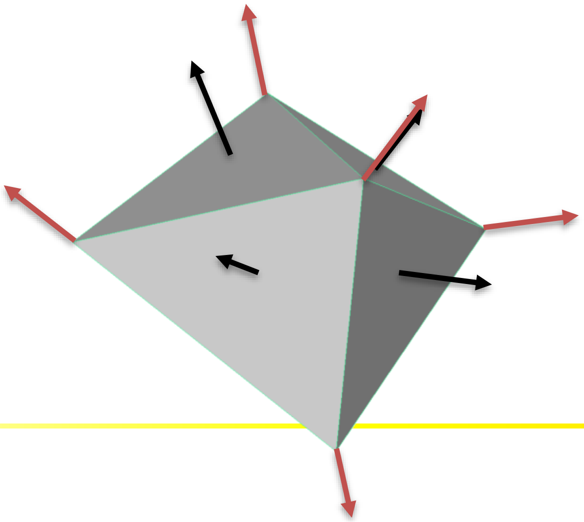
# Gouraud Shading

- Calculate face normals



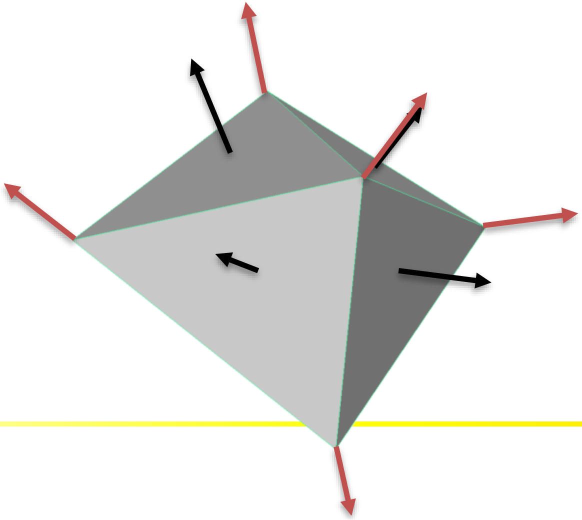
# Gouraud Shading

- Calculate face normals
- Calculate vertex normals by averaging



# Gouraud Shading

- Calculate face normals
- Calculate vertex normals by averaging
- Evaluate illumination model for each vertex



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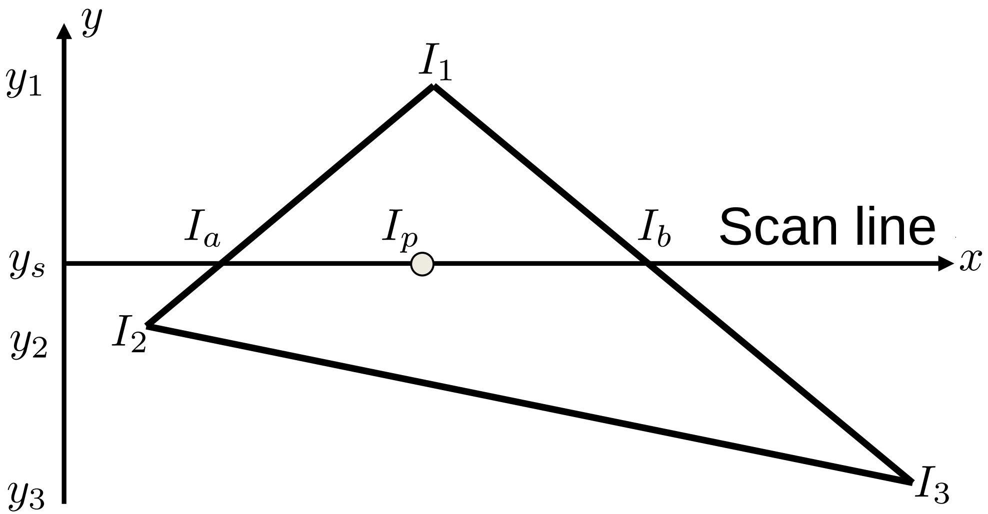
# Gouraud Shading

- Calculate face normals
- Calculate vertex normals by averaging
- Evaluate illumination model for each vertex
- Interpolate vertex colors bilinearly on the current scan line

# Gouraud Shading

- Interpolate vertex colors bilinearly on the current scan line



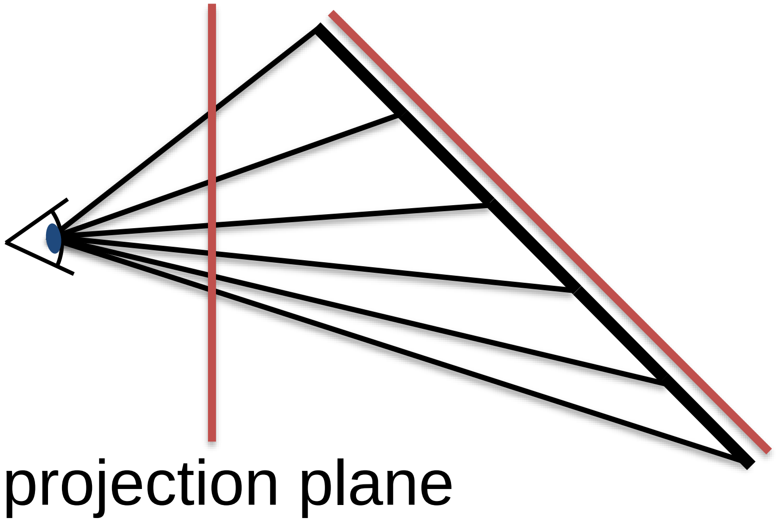

$$I_a = I_1 - (I_1 - I_2)\frac{(y_1 - y_s)}{(y_1 - y_2)}$$

$$I_b = I_1 - (I_1 - I_3)\frac{(y_1 - y_s)}{(y_1 - y_3)}$$

$$I_p = I_b - (I_b - I_a)\frac{(x_b - x_p)}{(x_b - x_a)}$$

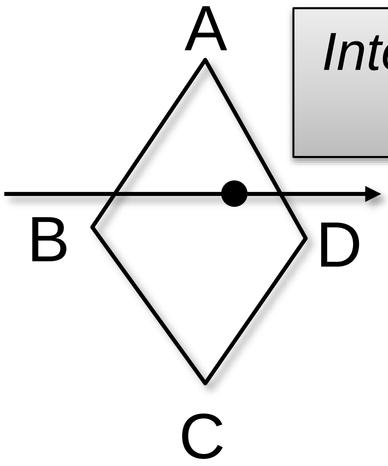
# Gouraud Shading

- Problems with scan line interpolation
  - Perspective distortion

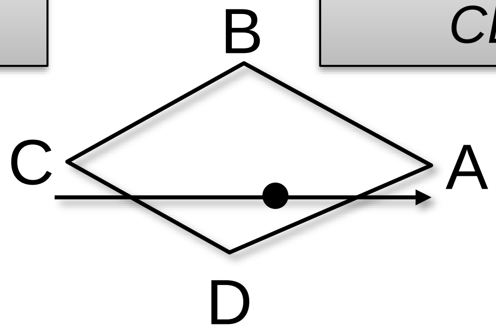


# Gouraud Shading

- Problems with scan line interpolation
  - Orientation Dependence



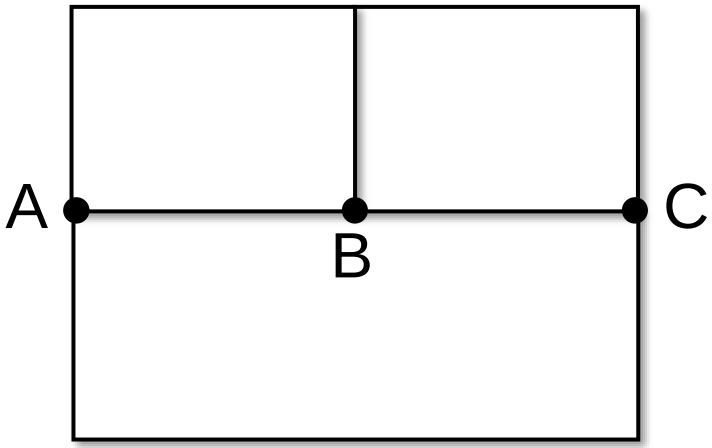

*Interpolate between AB and AD*




*Interpolate between CD and AD*

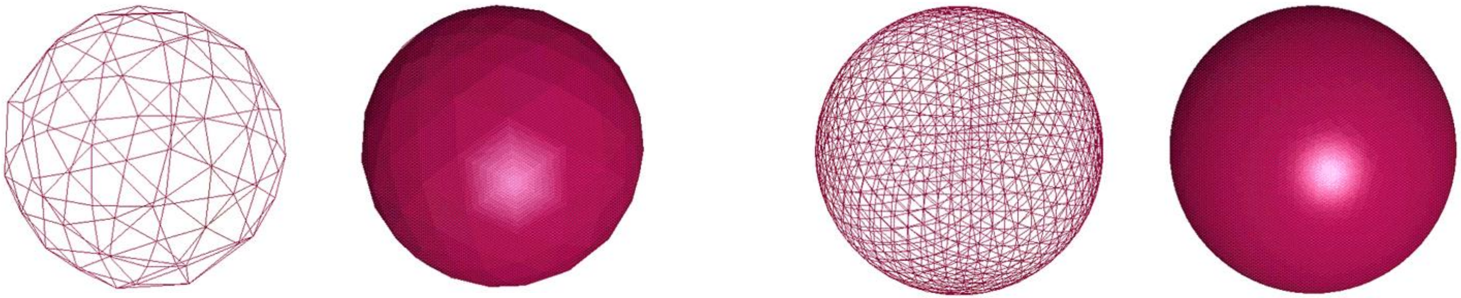
# Gouraud Shading

- Problems with scan line interpolation
  - Shared Vertices



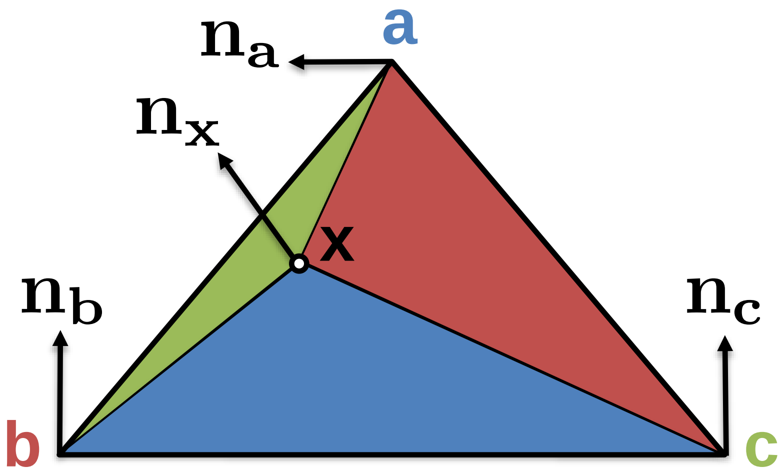
# Gouraud Shading

- Quality depends on the size of primitives

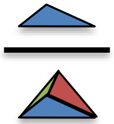
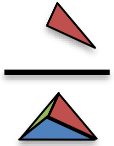


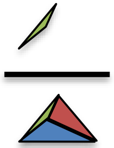
# Phong Shading

- Barycentric Interpolation of normals on the triangles



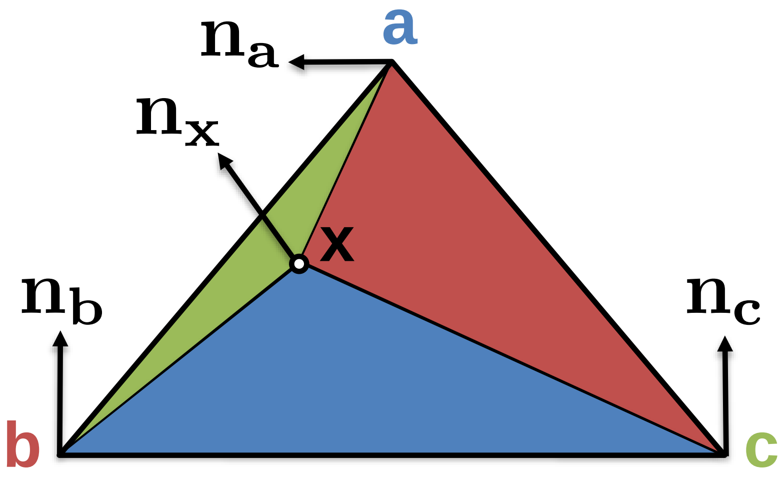

$$\mathbf{n_x} = \lambda_{\mathbf{a}}\mathbf{n_a} + \lambda_{\mathbf{b}}\mathbf{n_b} + \lambda_{\mathbf{c}}\mathbf{n_c}$$

$\lambda_{\mathbf{a}} =$  $\lambda_{\mathbf{b}} =$ 

$\lambda_{\mathbf{c}} = 1 - \lambda_{\mathbf{a}} - \lambda_{\mathbf{b}} =$ 

# Phong Shading

- Barycentric Interpolation of normals on the triangles




Properties

Lagrange

$$\mathbf{x} = \mathbf{a} \implies \mathbf{n_x} = \mathbf{n_a}$$

Partition of unity

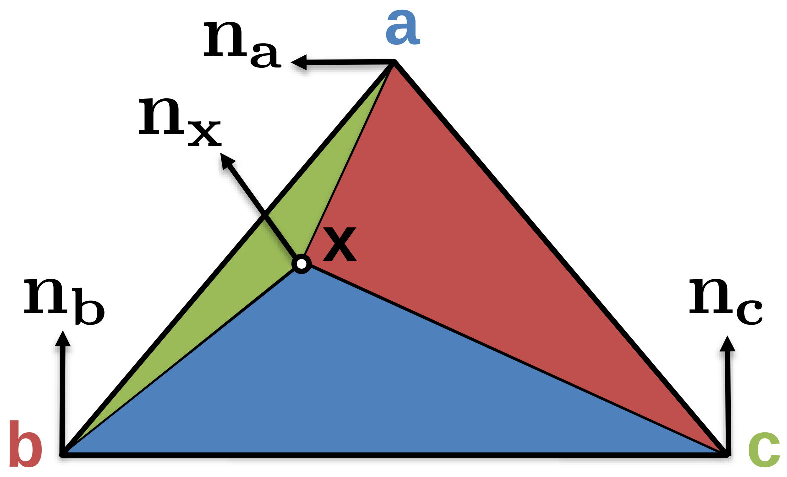
$$\lambda_\mathbf{a} + \lambda_\mathbf{b} + \lambda_\mathbf{c} = 1$$

Reproduction

$$\lambda_\mathbf{a} \cdot \mathbf{a} + \lambda_\mathbf{b} \cdot \mathbf{b} + \lambda_\mathbf{c} \cdot \mathbf{c} = \mathbf{x}$$

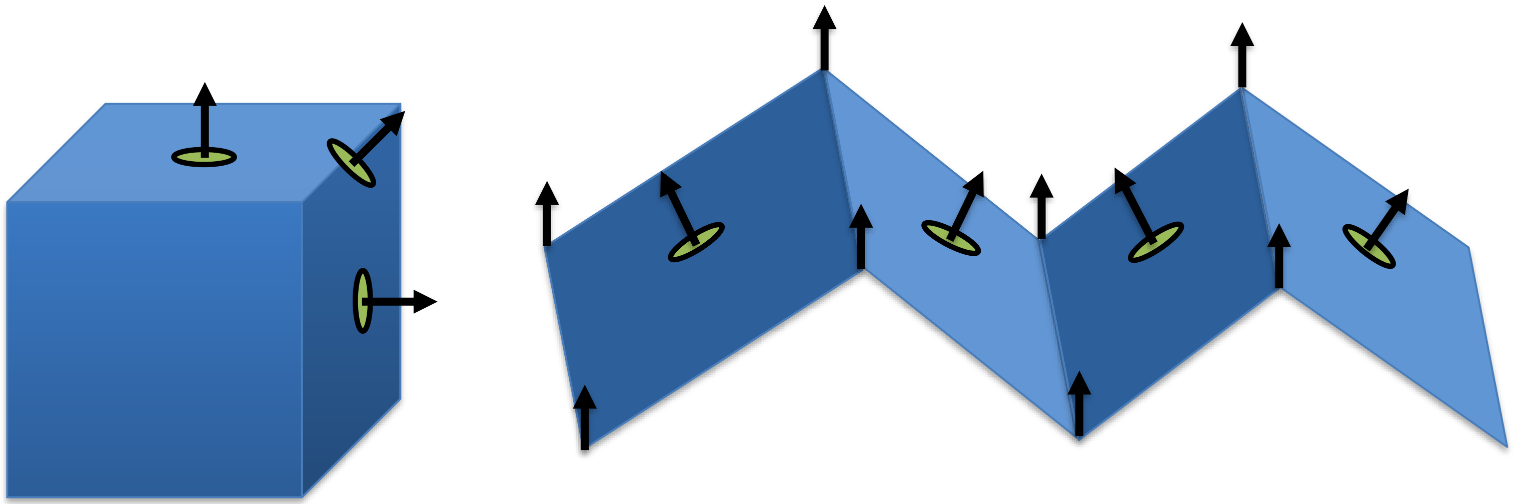
# Phong Shading

- Barycentric Interpolation of normals on the triangles
- Color of **x** is determined by the interpolated normal



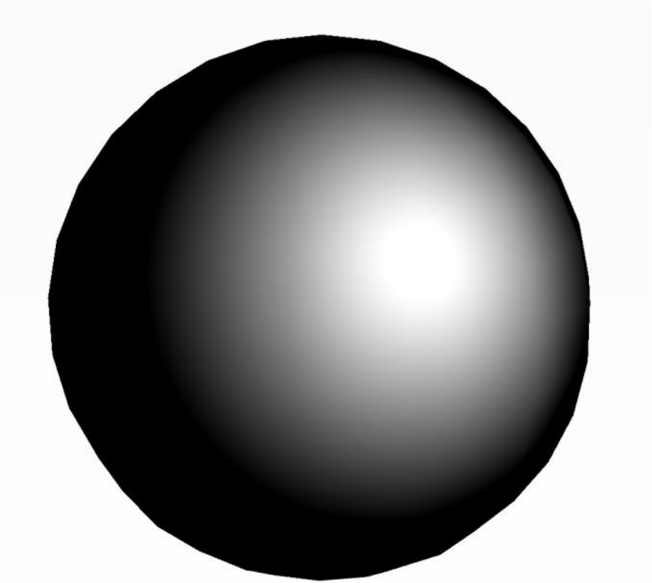
# Phong Shading

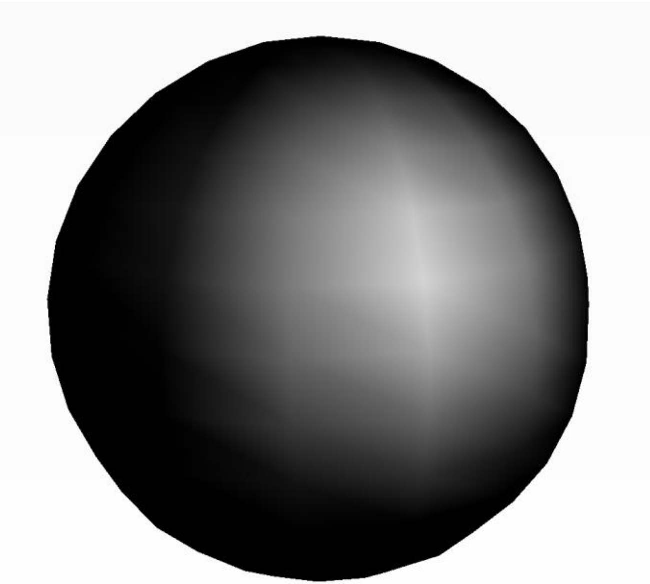
- Problem: normal not defined/representative



# Phong Shading

- Phong vs. Gouraud shading



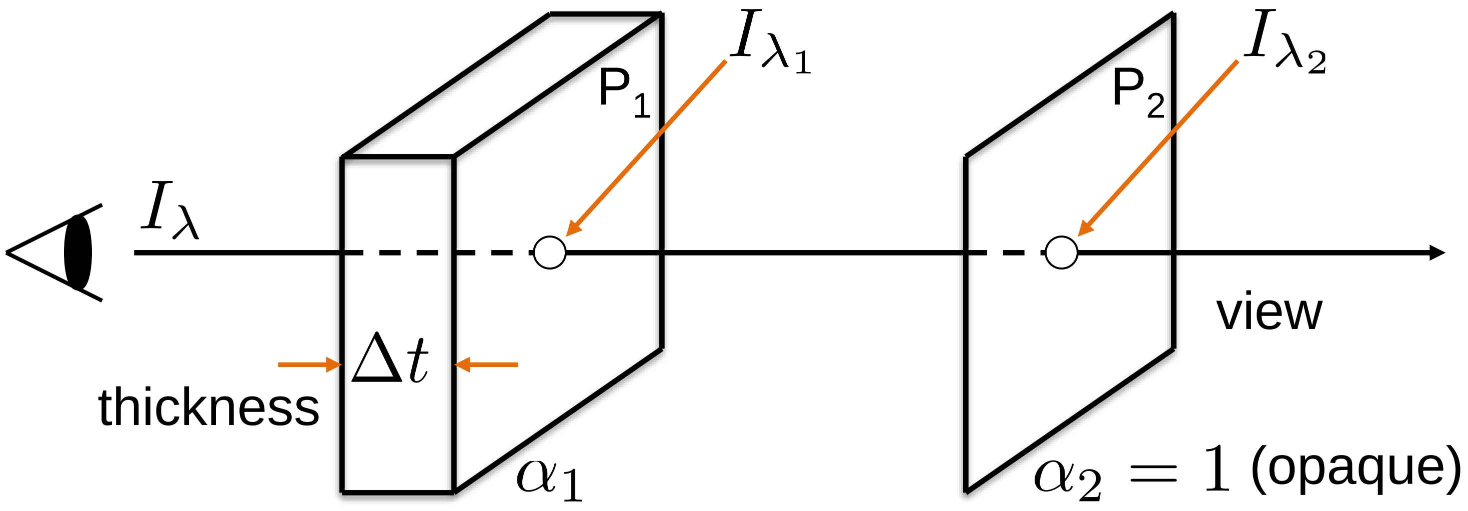


# Transparency

- Composite transparent objects
- Alpha blending
  - RGB**A** channels

# Transparency

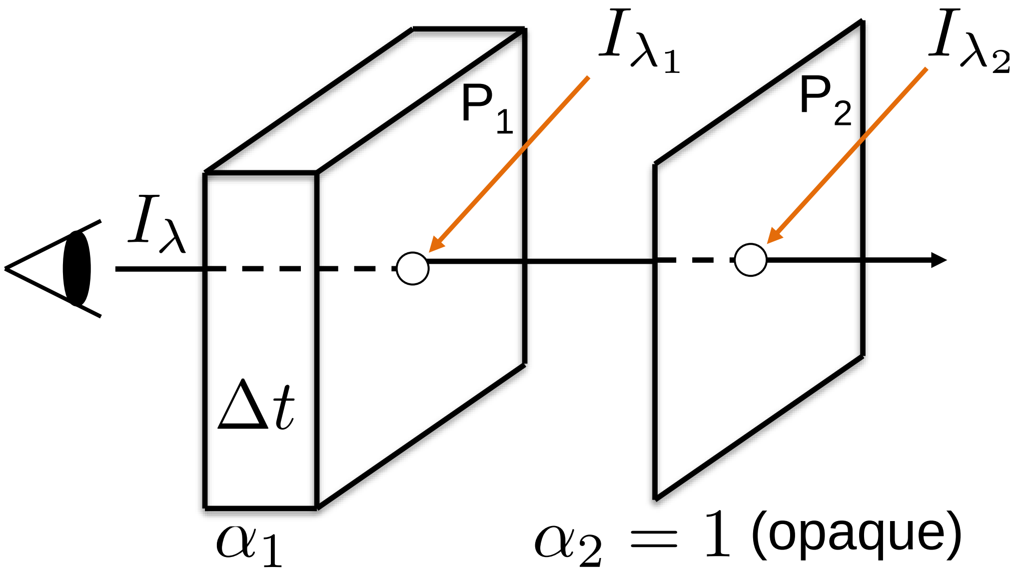
- Alpha blending
  - linearizes exponential attenuation of intensity




$\alpha$: absorption

# Transparency

- Alpha blending



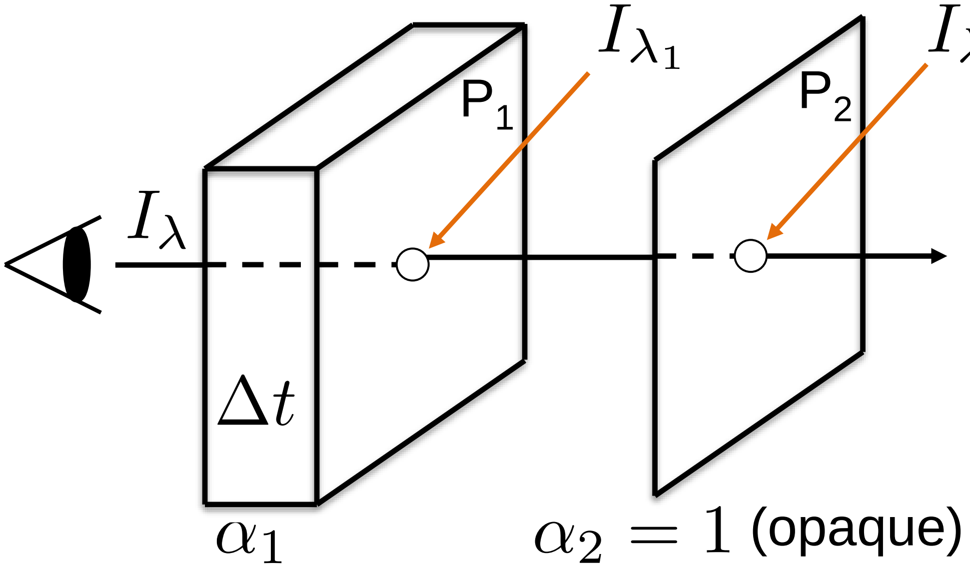

Intensity filtered by $P_1$

Emission of $P_1$

$$I_\lambda = \boxed{I'_{\lambda_1}} + \boxed{I'_{\lambda_2}}$$
$$= I_{\lambda_1}\alpha_1\Delta t + I_{\lambda_2}e^{-\alpha_1\Delta t}$$

# Transparency

- Alpha blending




$$I_\lambda = I_{\lambda_1}\alpha_1\Delta t + I_{\lambda_2}e^{-\alpha_1\Delta t}$$

Linearization

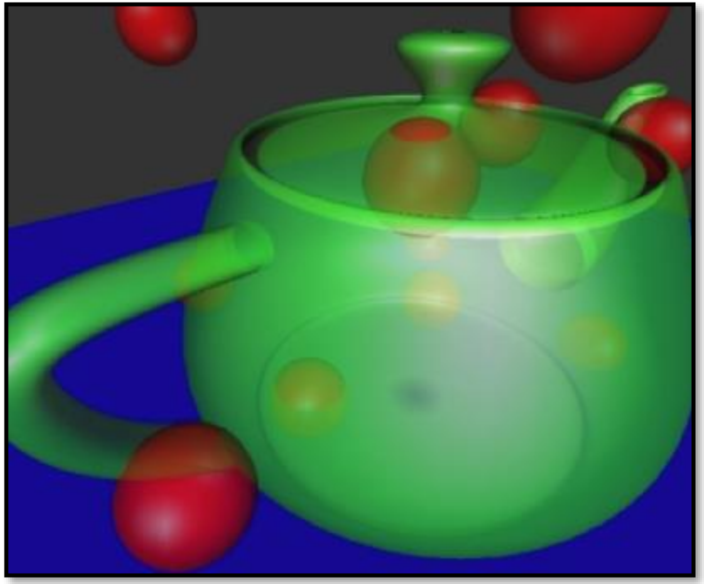
$$I'_{\lambda_2} = I_{\lambda_2}(1-\alpha_1\Delta t)$$

Result

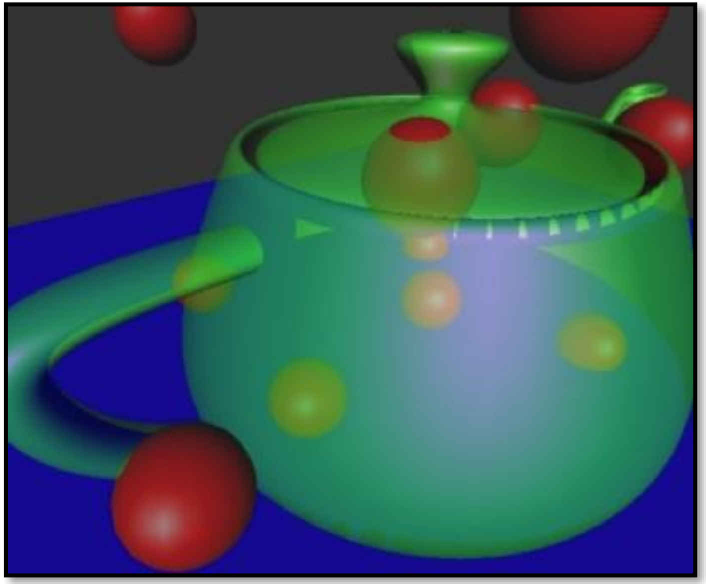
$$I_\lambda = I_{\lambda_1}\alpha_1 + I_{\lambda_2}(1-\alpha_1)$$

# Transparency

- Problem: rendering order



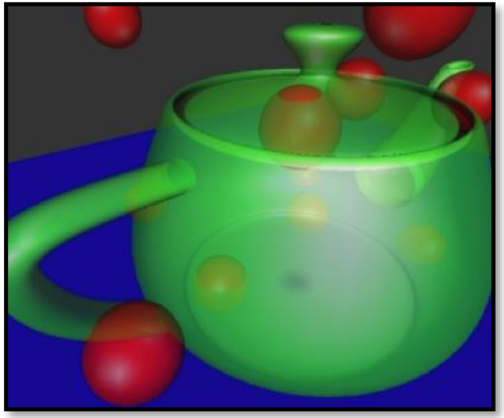
Correct



Incorrect

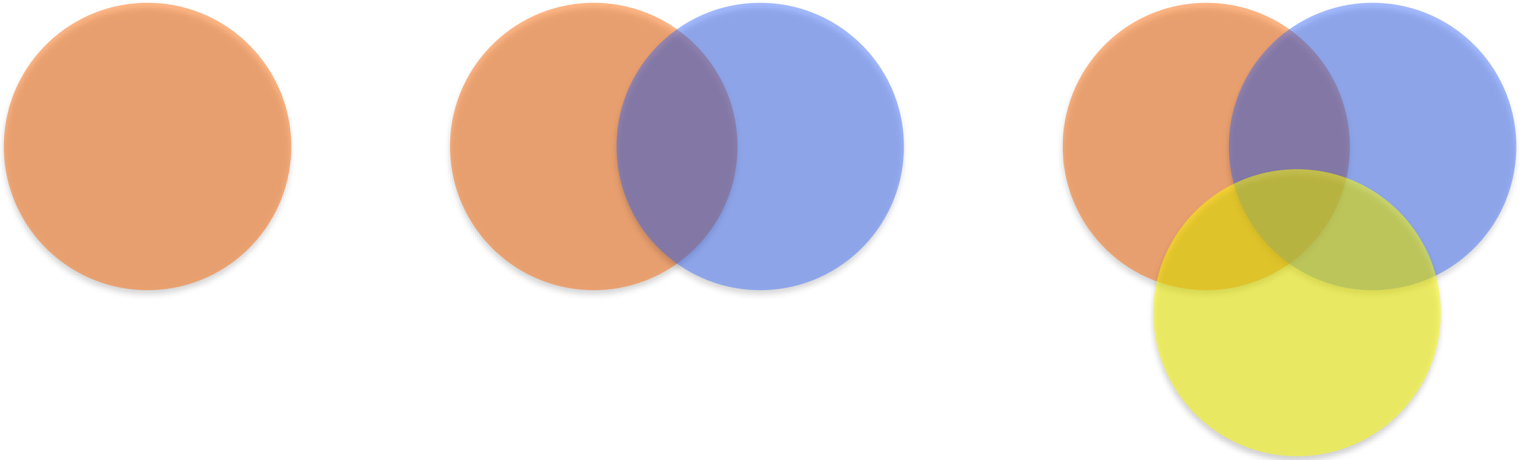
# Transparency

- Problem: rendering order
  - Object-order rendering
  - We need: sorted traversal of polygons



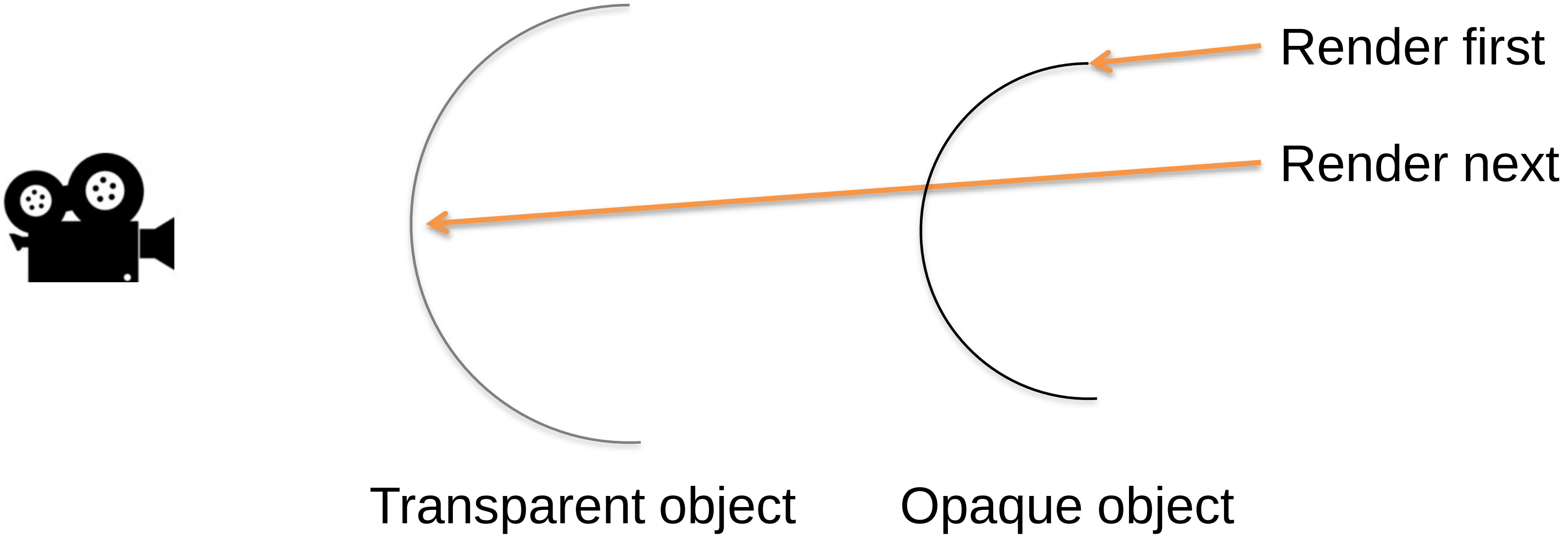
# Transparency

- Back to front rendering



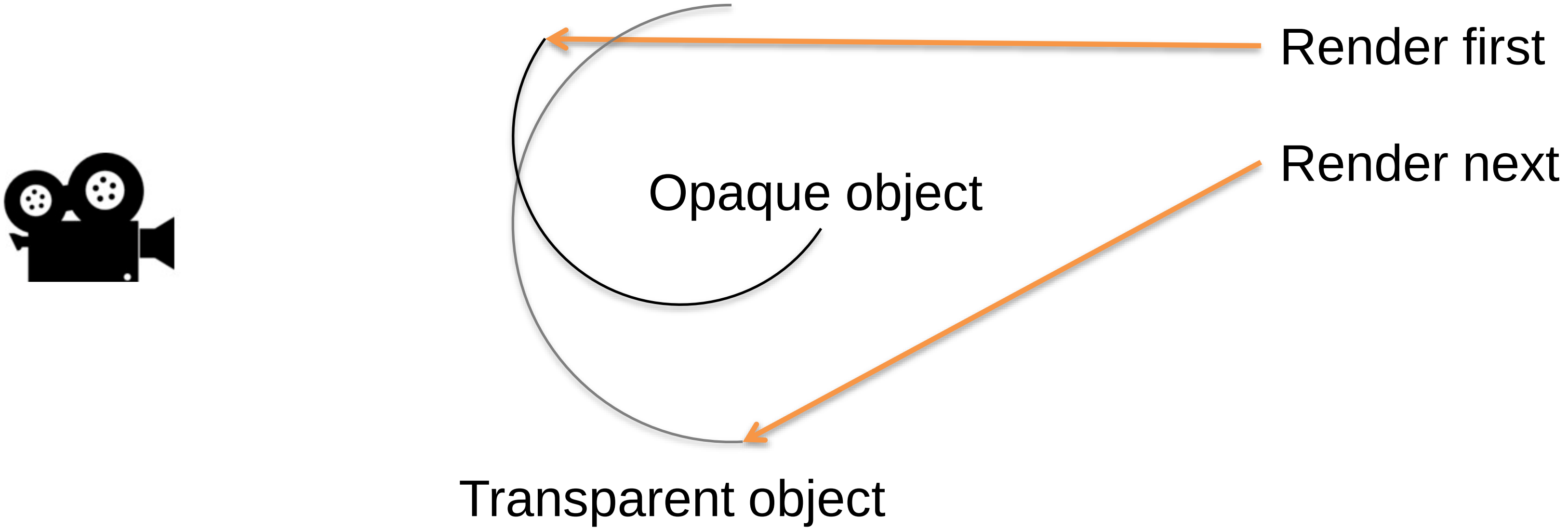
# Transparency

- Back to front rendering



# Transparency

- Problems with back to front rendering

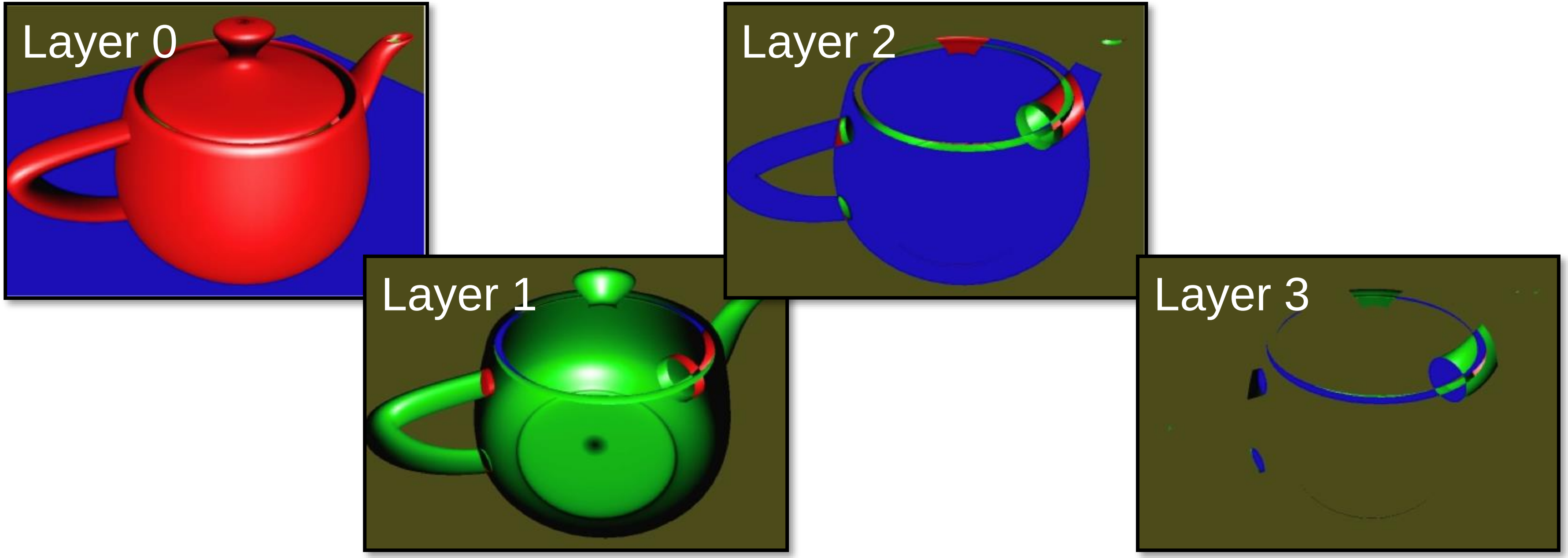


# Transparency

- Solution: depth peeling
  - Multiple passes
  - Each pass renders the next closest fragment

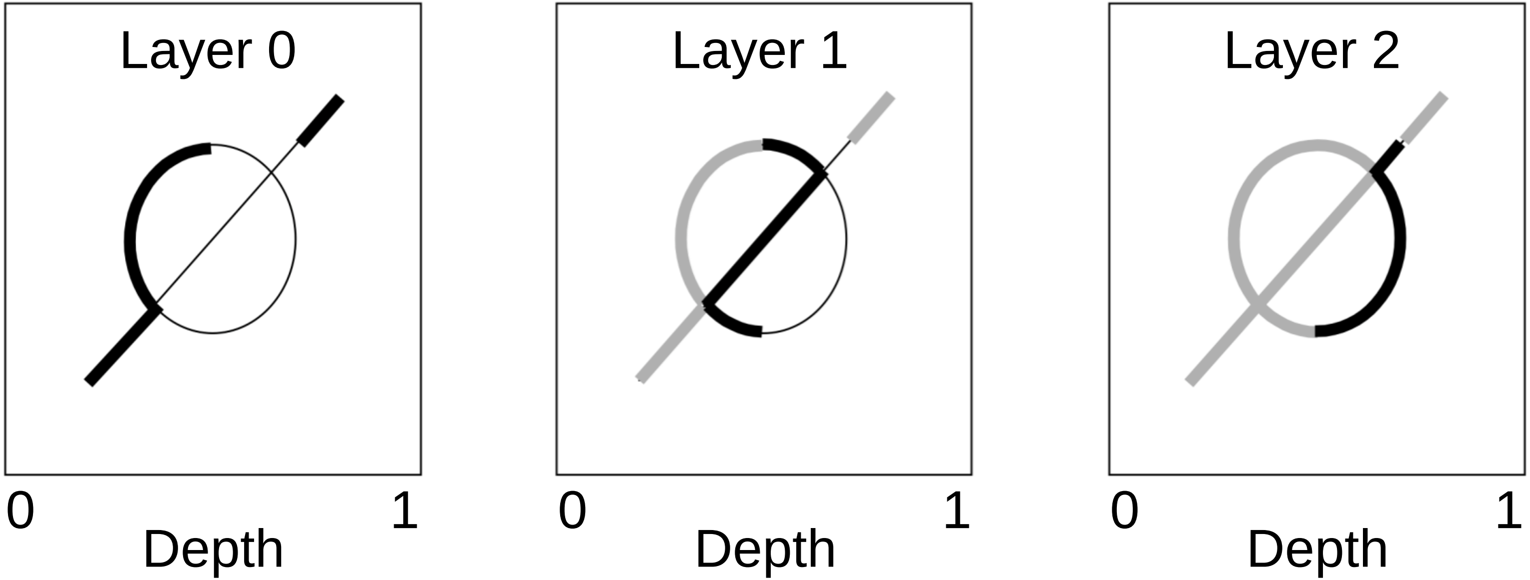
# Transparency

- Solution: depth peeling



# Transparency

- Solution: depth peeling



# Transparency

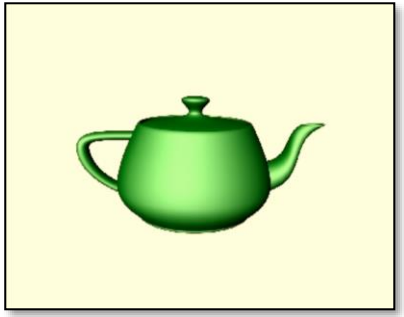
- Solution: depth peeling

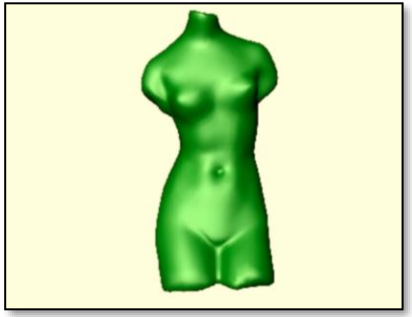
# Further Lighting Models

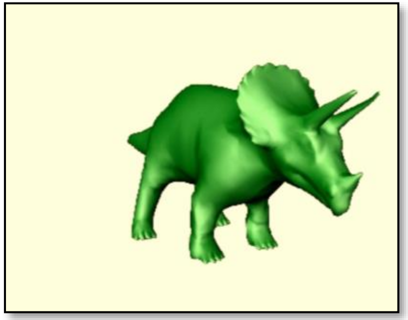
- Cook-Torrence
  - Metal objects
  - Replace the specular term
  - Reflection from micro facets
  - Self-shadowing effects

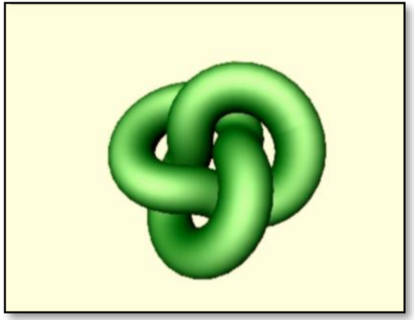
# Further Lighting Models

- Cook-Torrence
  - Metal objects



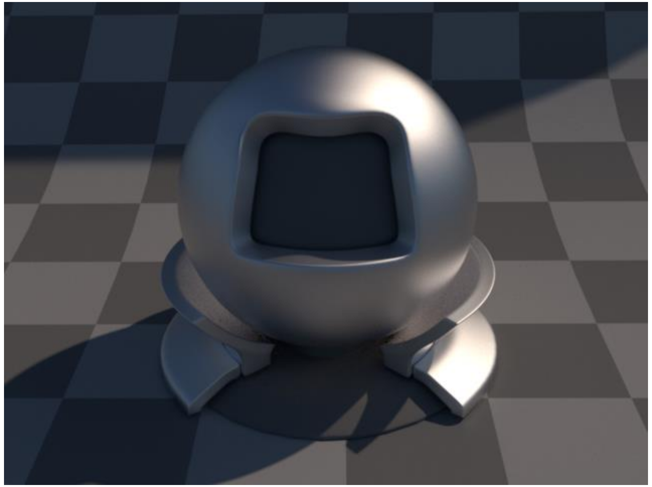




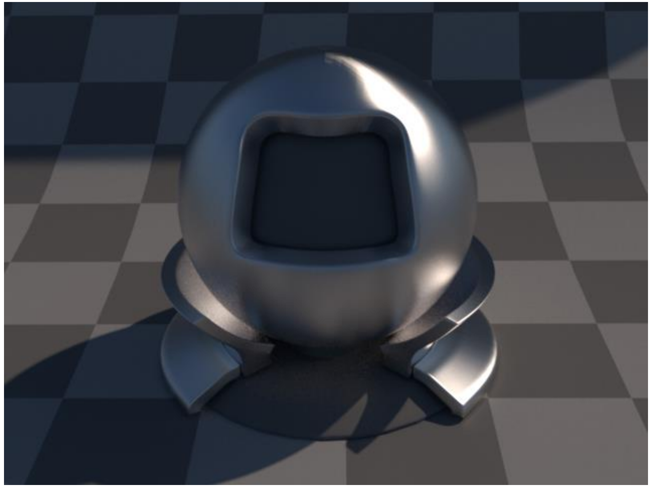


# Further Lighting Models

- Ashikhmin (anisotropic)



Isotropic microfacet distribution



Anisotropic micro facet distribution (au=0.3, av=0.1)