Illumination Models for Graphics

CS 211A

Can be very complex

- The incoming light can come from a source, or bouncing off another object, or after multiple bounces
- Sources can be extended
- Multiple interactions between light and surface

Very simple models

- Assumes point light source
- Models only the direct illumination from the source
  - Does not consider light reaching after bouncing off other objects
- Illumination models evaluated only at the **vertices**

For every vertex

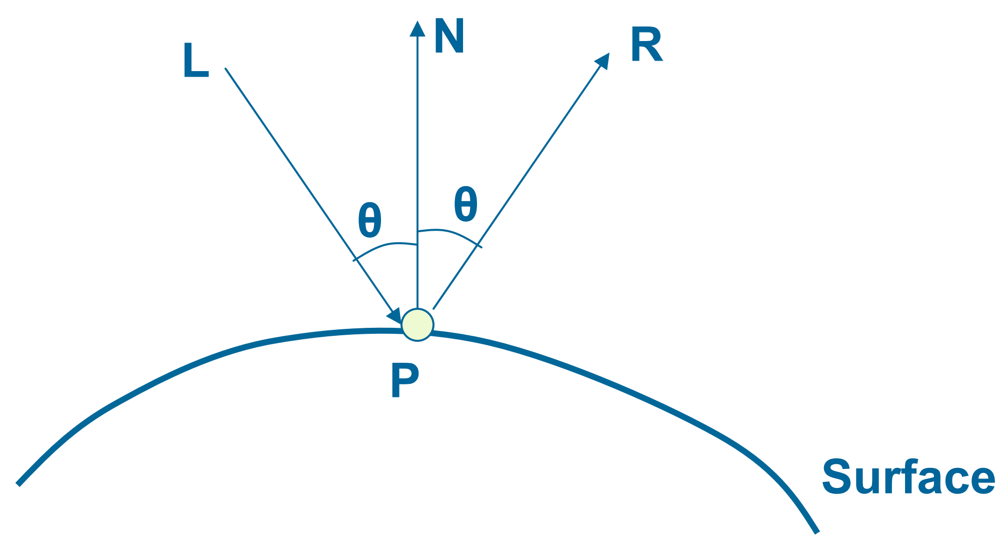
- Ambient component
- Diffused component
- Specular component

Ambient Component

- Equal amount of light from all directions
- Approximates the indirect illumination
- $I_a k_a$
  - I_a = intensity of ambient light
  - k_a= percentage of the light reflected by the object

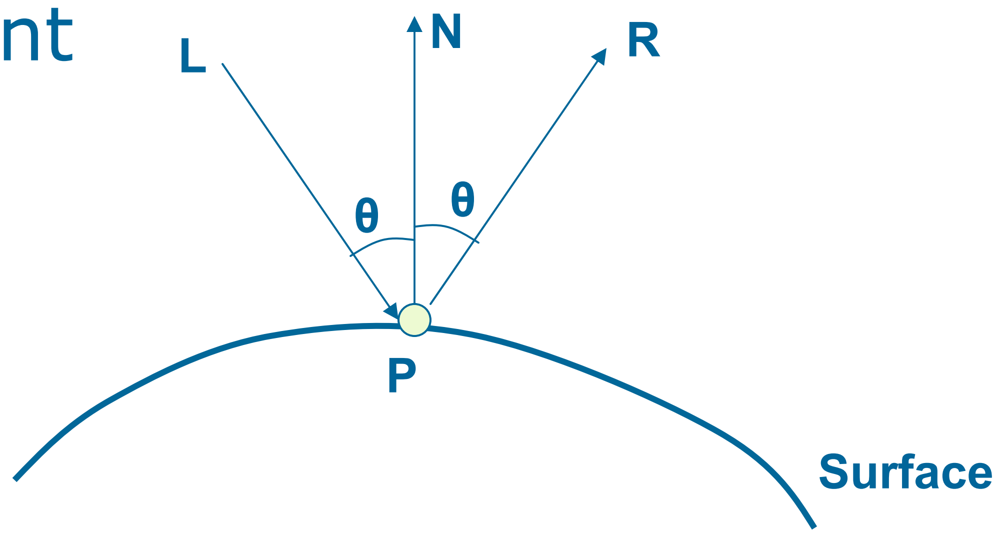
Lighting at a point on surface

- $I = I_d k_d \cos\theta$
  - I_d = intensity of light
  - k_d = coefficient of diffuse reflection
- $I = I_d k_d (N.L)$



Diffused Component

- $I = I_d k_d (N.L)$
- $I_d(N.L)$ is like the irradiance
- k_d is like the reflectivity
- No dependency on viewer
  - View independent



Ambient and Diffused Lighting

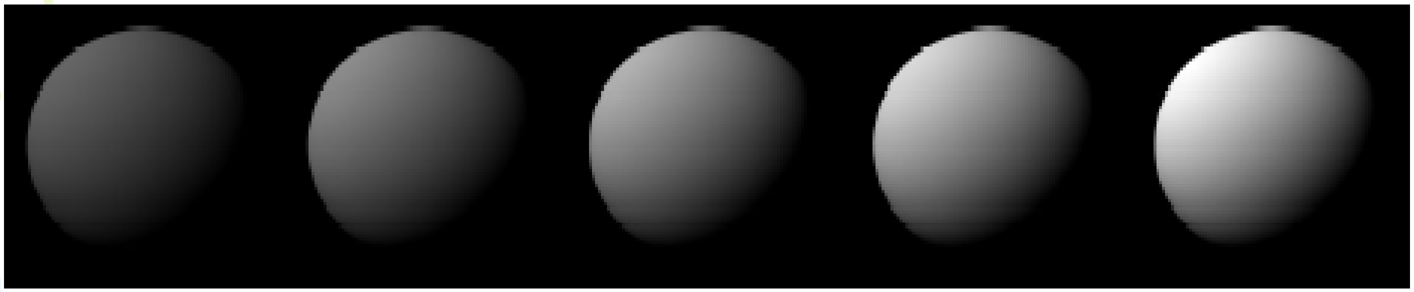


FIGURE 10. Diffuse reflection for $k_d = 0.4, 0.55, 0.7, 0.85, 1.0$.
(© [AW94] Figure 14.03)

$$I = I_p k_d (N.L)$$

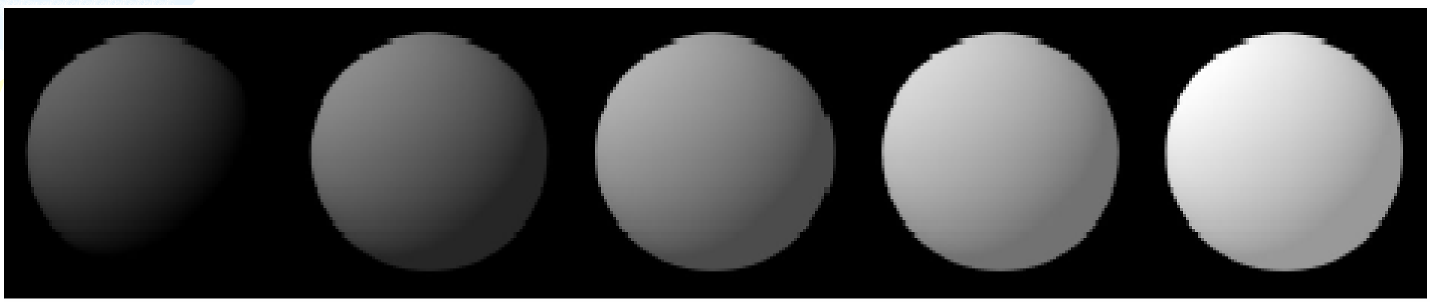
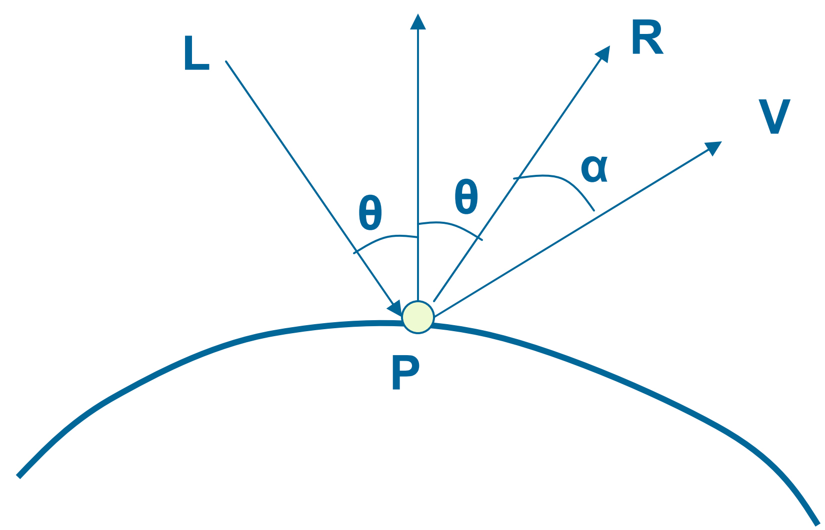


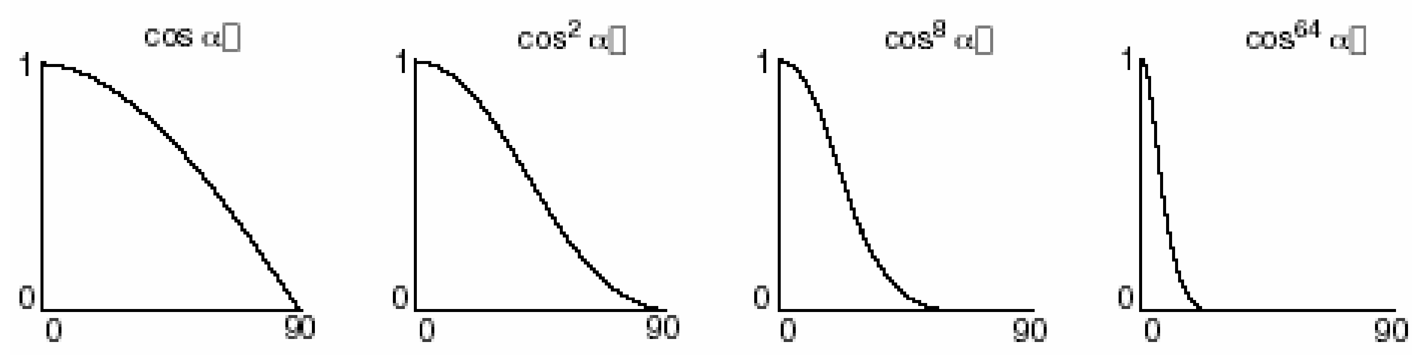
FIGURE 11. Ambient and diffuse reflection with $k_d = 0.4$ and $k_a = 0.0, 0.15, 0.3, 0.45, 0.6$.
(© [AW94] Figure 14.04)

$$I = (I_a k_a + I_p k_d (N.L))$$

Specular Component

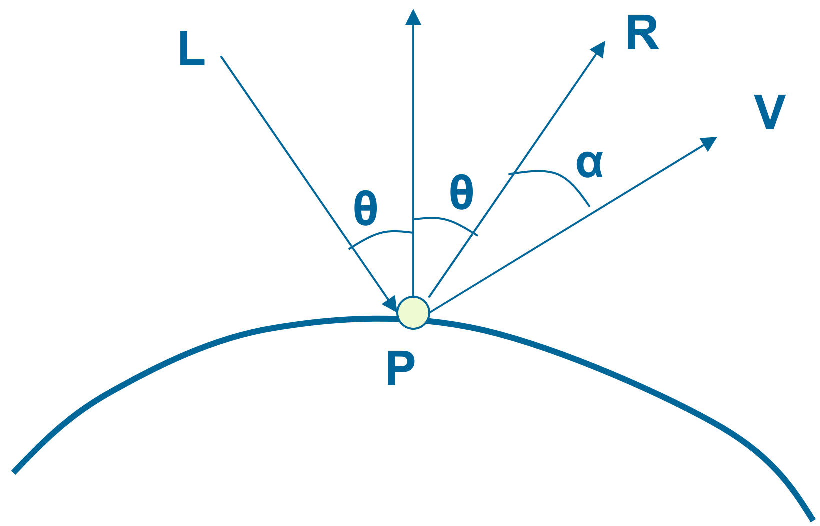
- $I_s k_s Cos^n(\alpha)$
- $Cos(\alpha)$: fall off as V moves away from R
- n gives the sharpness

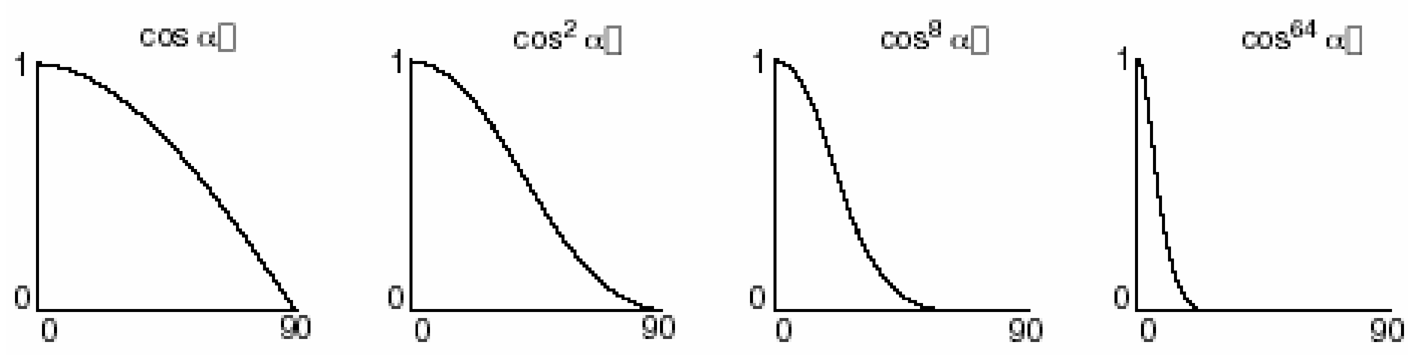




Specular Component

- R depends on L
- Depends on both V and L
- Like the BRDF
- n controls the view-dependency also





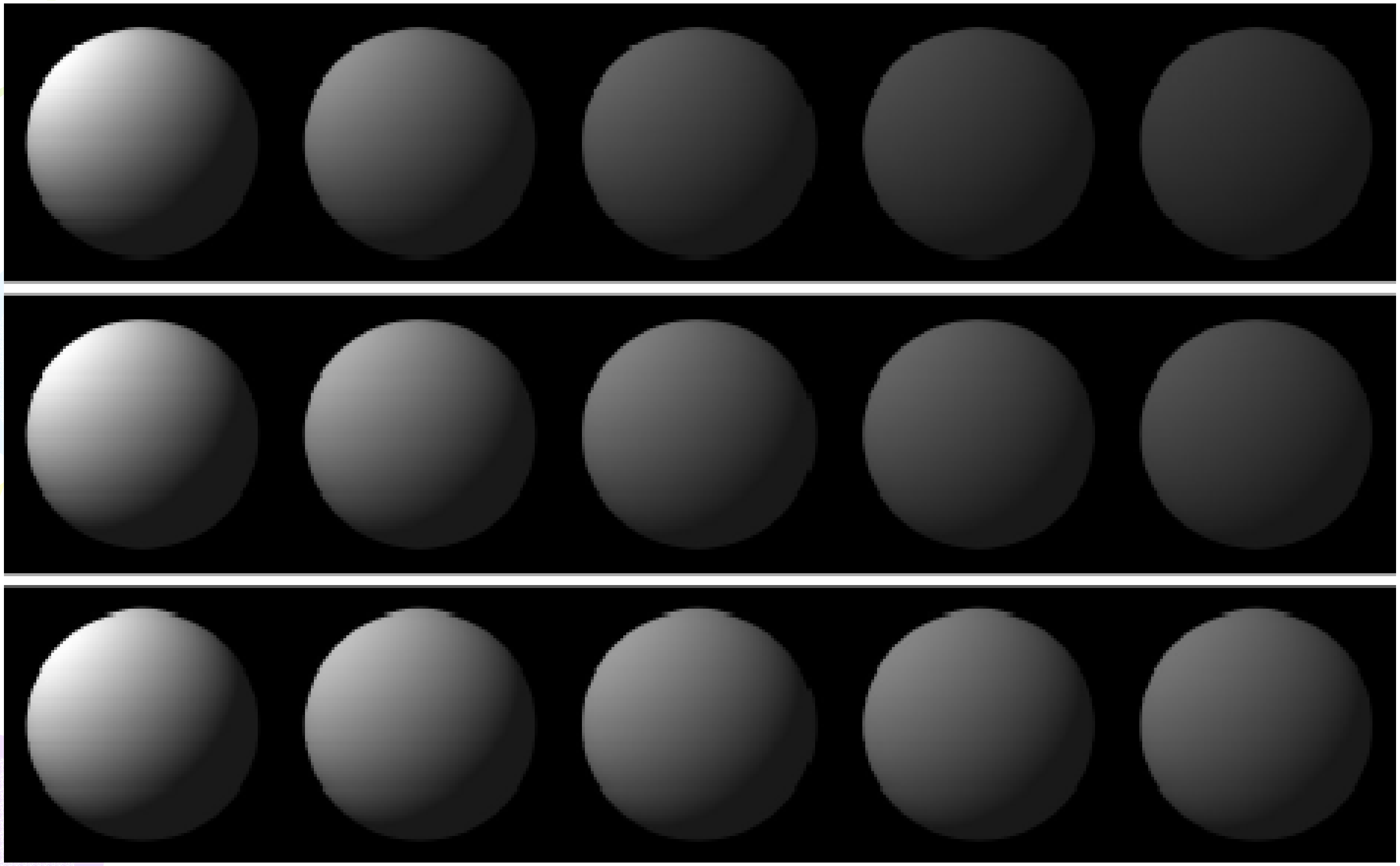
Providing Control

- Providing enough control so that one can simulate effect via trial and error of many different parameters
- May be not be close to the physical phenomenon
- For e.g. Different brightness of the same light can be used for different component computation

Attenuation Control

- Diffused component
- $I = I_d f_{att} k_d (N.L)$
  - $f_{att} = 1/(a+bd+cd^2)$
    - d = distance of light from the surface
    - a, b and c are user defined constants

Attenuation of Light



a=0, b=0, c=1

a=0.25, b=0.25, c=0.5

a=0, b=1, c=0

→ Increasing distance from the light source

Other issues

- $(I_a k_a + I_d k_d (N.L) + I_s k_s Cos^n(\alpha))O$
- For different channels
  - Do the same operation for all channels
- Multiple lights
  - Only one ambient light source
  - Multiple point light sources
    - Addition of light from different light sources

Ambient

Ambient + Diffuse

Ambient + Diffuse + Specular

What is Shading?

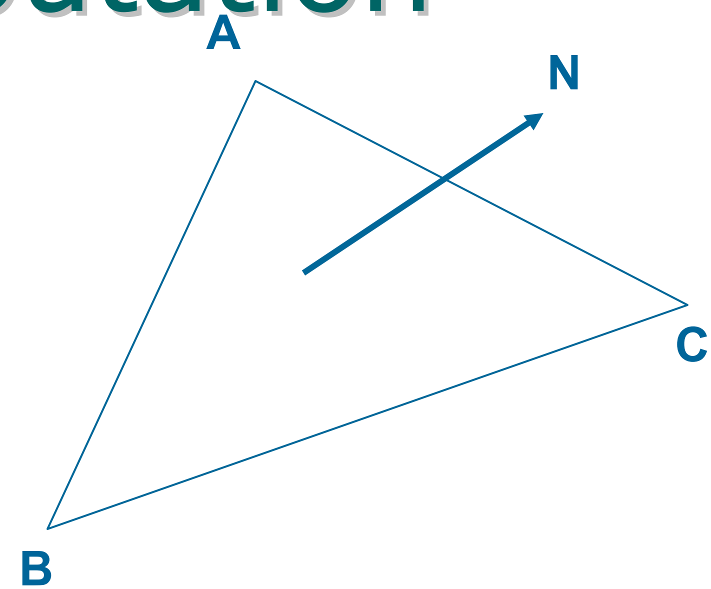
- Illumination model
- How do we use these models to ***shade*** the triangles in the graphics pipeline?
- How did we generate the picture on the right?

Method

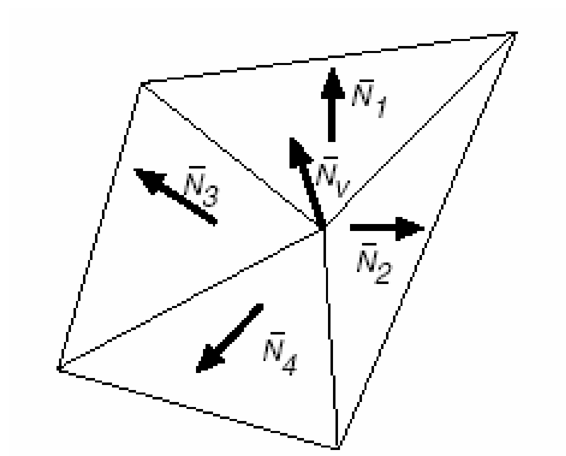
- Evaluate illumination model at the vertices of the triangles
  - After model-view transformation
- Use interpolation to color the interior of the triangles during rasterization
  - Different shading methods use different interpolation
- Assume that the polygonal models approximate smooth surfaces

Normal Computation

- Normal of a triangle
  - $N = (B-A) \times (C-A)$
    - Vertices are in anticlockwise direction with respect to normal



- Normal of a vertex
  - Average of all the triangle incident on the vertex
  - $N_v = (N_1+N_2+N_3+N_4)/4$

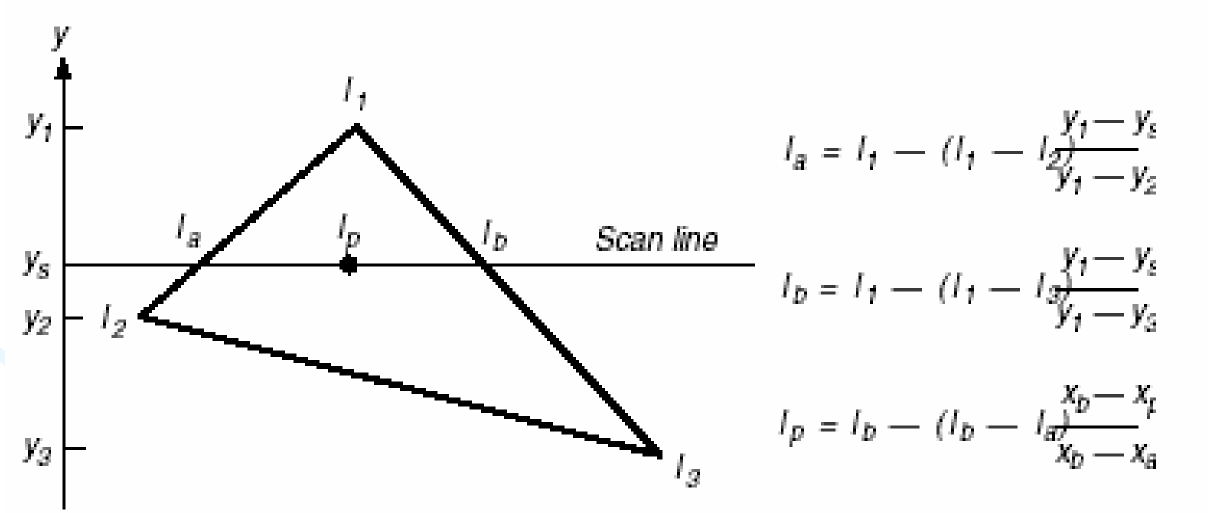


Constant/Flat/Faceted Shading

- Illumination model applied once per triangle
- Using normal of the triangle
- Shade the whole triangle uniformly
  - Color associated with triangles and not vertices

Gouraud Shading

- Interpolating illumination between vertices
  - Calculate the illumination using vertex normals at vertices
  - Bilinear



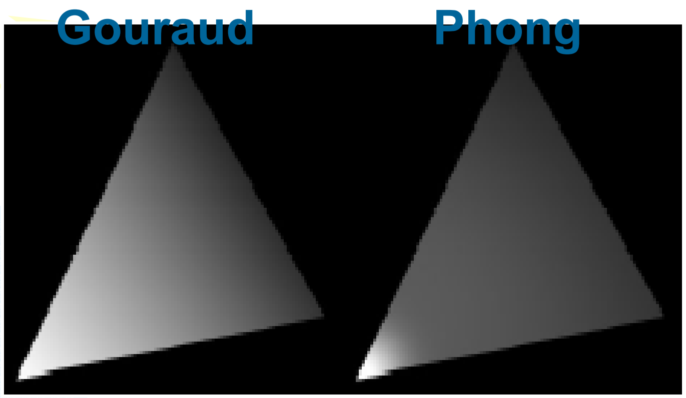
Gouraud Shading

- Edges get same color, irrespective of which triangle they are rendered from
  - Shading is continuous at edges
- Tends to spread sharp illumination spots over the triangle

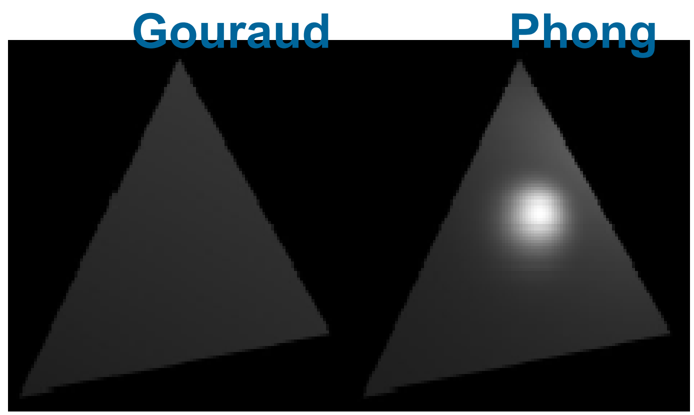
Phong Shading

- Interpolate the normal across the triangle
- Calculate the illumination at every pixel during rasterization
  - Using the interpolated normal
- Slower than Gouraud
- Does not miss specular highlights
  - Good for shiny specular objects

Gouraud vs. Phong Shading



Spreads highlights across the triangle



Misses a highlight completely

Flat Shading

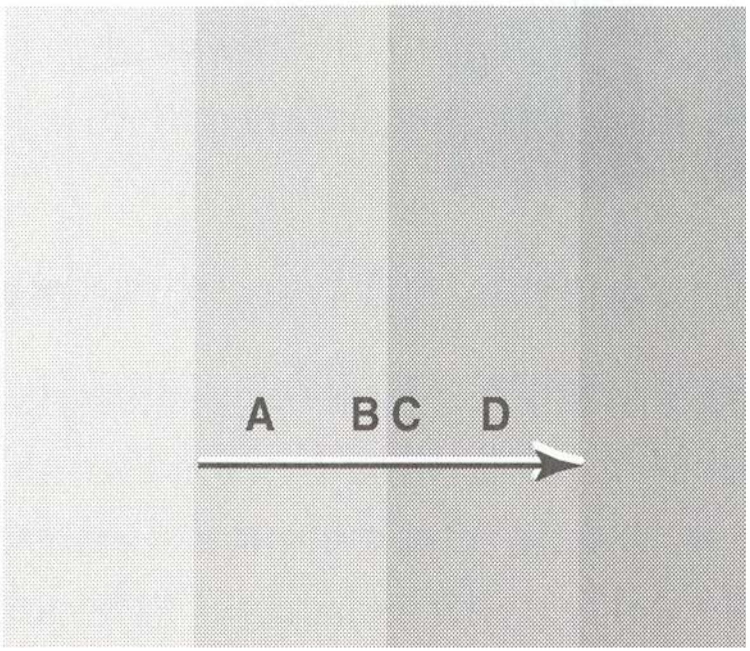
Gouraud Shading

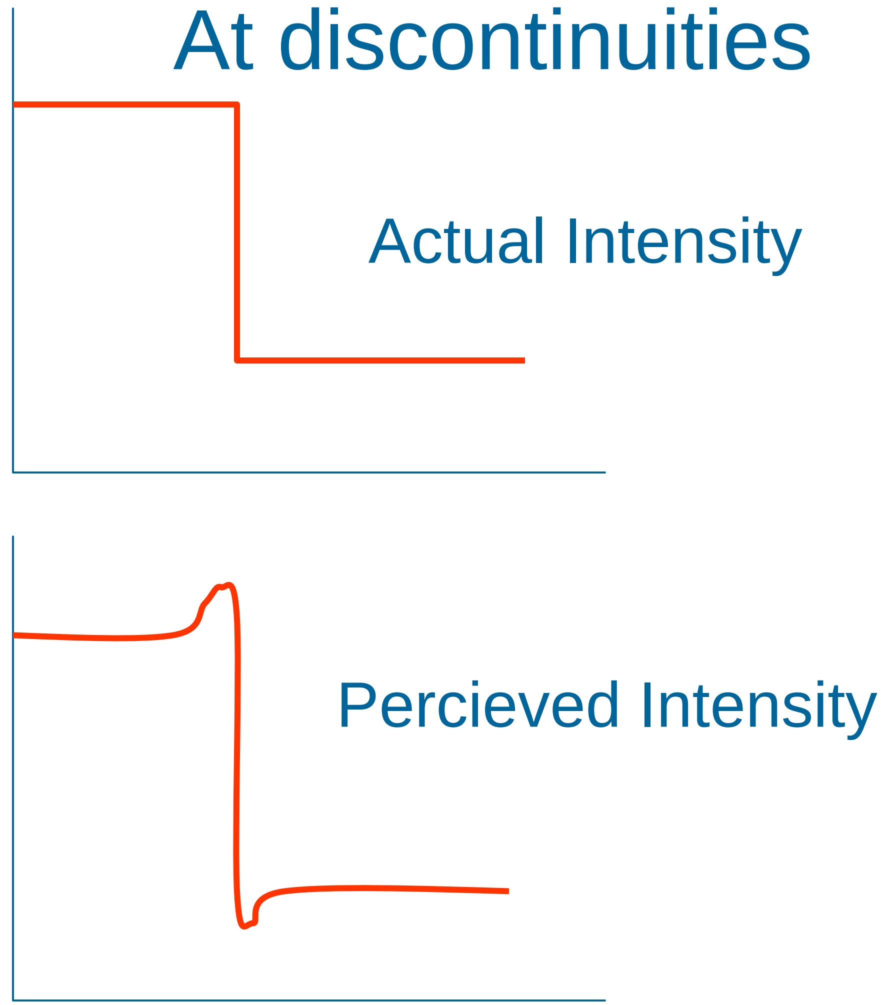
Phong Shading

Shading

- Independent of the Illumination model used
- Phong Shading and Phong Illumination
- Artifacts
  - Piecewise planar approximation
  - Screen Space Interpolation
- Simple and hence widely used

Artifacts: Mach Bands

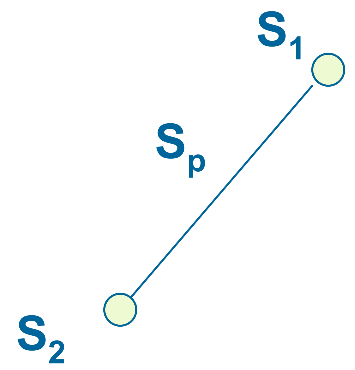




Artifacts: Mach Bands

- Common in flat shading since shading is discontinuous at edges
- Also present in Gouraud shading
  - Gradient of the shading may change suddenly
- Phong shading reduces it significantly
  - But cannot be eliminated
  - At sharp changes in surface gradient

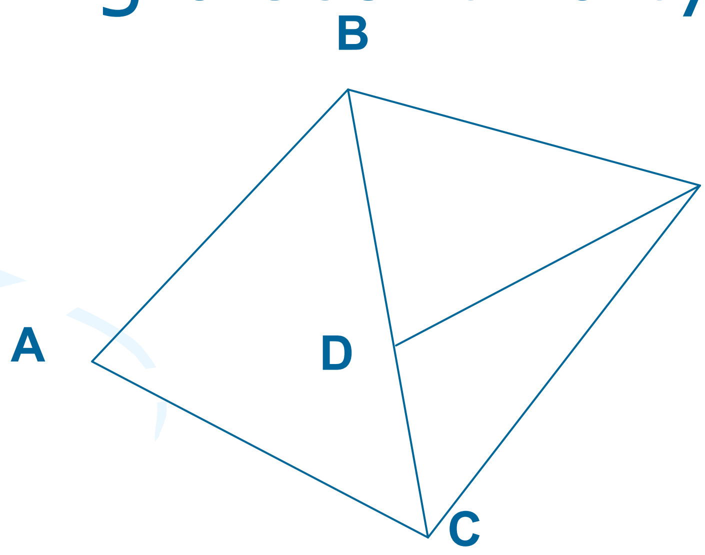
Artifacts: Screen Space Interpolation



- Shading is interpolated while rasterization
- $S_p = (S_1+S_2)/2$
  - $z_s \neq (z_1+z_2)/2$

Artifacts: T-junctions

- The shading at the T-junction are different when calculated from different triangles
- Shading discontinuity



Artifacts:Vertex Normals

- Vertex normal does not reflect the curvature of the surface adequately
  - Appear less flat than it actually is