Illumination + Shading

Illumination models express the factors determining a surface's color at a given point.
Shading model determines when the illumination model is applied and what arguments it will receive.
(Unfortunately, the two terms are often used interchangeably).

Ambient Light

This is a diffuse, nondirectional source of light due to multiple reflections of light from the many surfaces present in the environment.

$$I = I_a k_a$$

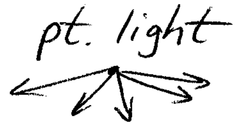
I_a: intensity of ambient light (constant for all objects)

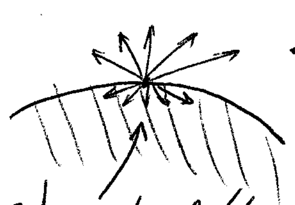
k_a: ambient reflection coef. ([0,1]) (material property) characterizing the surface material. This is an empirical convenience. Doesn't correspond to physical property of real materials

Ambient light accounts for all the complex ways in which light can reach an object that are not otherwise addressed by the IM. Surfaces are uniformly lit with ambient light.

Diffuse Reflection (aka Lambertian refl.)

Consider a point light source whose rays emanate uniformly in all directions from a single point.

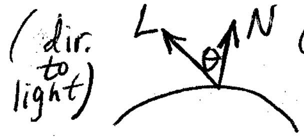




If all light is absorbed ⇒ black body
If all light is transmitted ⇒ visible only through refraction

Reflected light makes object visible

Lambertian reflection → dull, matte surfaces, such as chalk, exhibit diffuse (or Lambertian) reflection. These surfaces appear equally bright from all viewing angles because they reflect light with equal intensity in all directions.



$$I = I_p K_d \cos\theta \quad \leftarrow [0°, 90°]$$

$$= I_p K_d (N \cdot L) \quad \leftarrow \text{normalized}$$

I_p: point light source's intensity

K_d: diffuse-reflection coefficient [0,1]

Objects illuminated using a diffuse reflection model alone appear harsh (as when a flashlight illuminates an object in an otherwise dark room). Add ambient light:

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

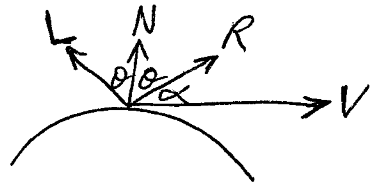
Specular Reflection

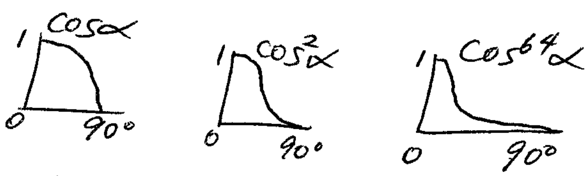
Responsible for highlights. Observed on any shiny surface and reflector (mirror)

* Phong's illumination model:

$$I = I_a k_a + I_p k_d (N \cdot L) + I_p k_s \cos^n \alpha$$

(n ← material's specular reflection exponent; k_s ← specular refl. coefficient [0,1])





For a perfect reflector, $n = \infty \Rightarrow$ sharp falloff
$n = 1 \Rightarrow$ gentle falloff

Note:

$\cos\alpha = R \cdot V$ (for normalized R and V)

Cosine is needed because shiny surfaces reflect light differently in different directions (not like Lambertian surfaces)

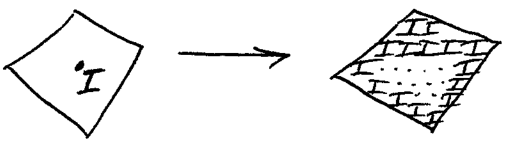
Speedup: use halfway vector $H = \frac{L+V}{2}$ in $H \cdot N$ (instead of $R \cdot V$)

Shading Models for Polygons

Constant shading → sample the value of the illumination equation once for each polygon and hold the value across the polygon to reconstruct the polygon's shade.

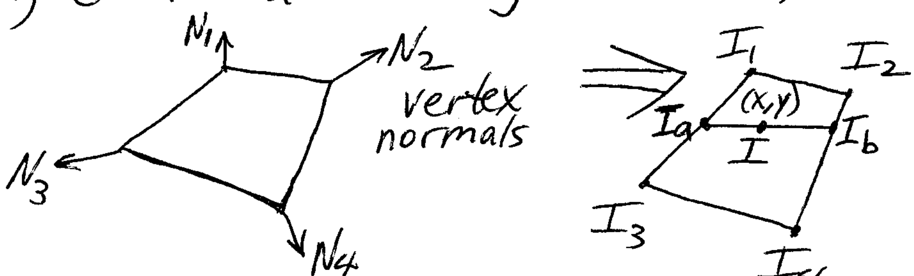
Truly valid if:

1) light source is at $\infty \Rightarrow N \cdot L$ = constant across face
2) viewer is at $\infty \Rightarrow N \cdot V$ = constant across face
3) polygon is actual surface being modeled (not an approximation)



Interpolated Shading → sample the value of the illumination equation at a few pts. (vertices) and interpolate across polygon

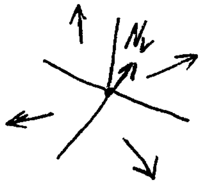
1) Gouraud shading (intensity interpolation shading)



$$I_a = I_1 + (I_3 - I_1)\left(\frac{y - y_1}{y_3 - y_1}\right)$$

$$I_b = I_2 + (I_4 - I_2)\left(\frac{y - y_2}{y_4 - y_2}\right)$$

$$I = I_a + (I_b - I_a)\left(\frac{x - x_a}{x_b - x_a}\right)$$

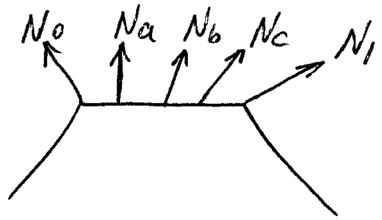


$$N_v = \sum_{i=1}^{n} \frac{N_i}{\left|\sum_{i=1}^{n} N_i\right|}$$

← vertex normal is avg of polygon facet normals that share that vertex

2) Phong Shading (normal-vector interpolation shading)

Interpolates the surface normal vector, rather than intensity.



Recompute illumination equation at each pixel using interpolated normal

Both Gouraud and Phong shading are scanline algorithms.