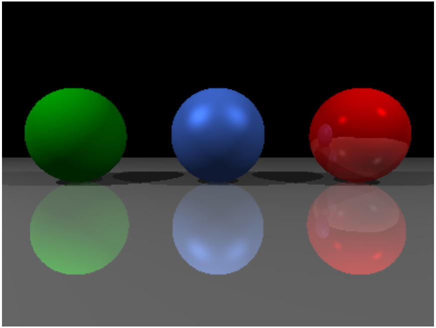
Ray Tracing Illumination

COSC342

Lecture 16
2 May 2017

Ray Tracing Lighting

- Phong lighting model
  - Ambient (background) light
  - Diffuse (shaded) surfaces
  - Specular (shiny) surfaces
- Coloured lights
- Shadows

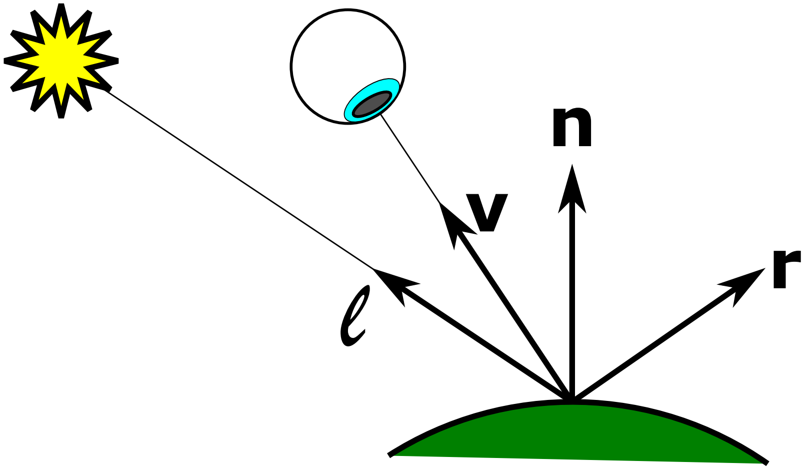


The Phong Illumination Model (review)

$$I_{\text{total}} = \underbrace{I_a k_a}_{\text{Ambient}} + \underbrace{I_d k_d(\hat{\mathbf{n}} \cdot \hat{\ell})}_{\text{Diffuse}} + \underbrace{I_s k_s(\hat{\mathbf{r}} + \hat{\mathbf{v}})^n}_{\text{Specular}}$$

- I_{total}: Light (colour) at some point on a surface
- I_a, k_a: Ambient light level and object colour
- I_d, k_d: Diffuse light level and object colour
- I_s, k_s: Specular light level and object colour
- n: Specular coefficient (high = hard, low = soft)
- $\hat{\mathbf{n}}$: Surface normal at the point
- $\hat{\ell}$: Unit vector from surface point to the light source
- $\hat{\mathbf{r}}$: Reflection of $\hat{\ell}$ around $\hat{\mathbf{n}}$
- $\hat{\mathbf{v}}$: Unit vector from the surface point to the view direction

The Phong Illumination Model (review)



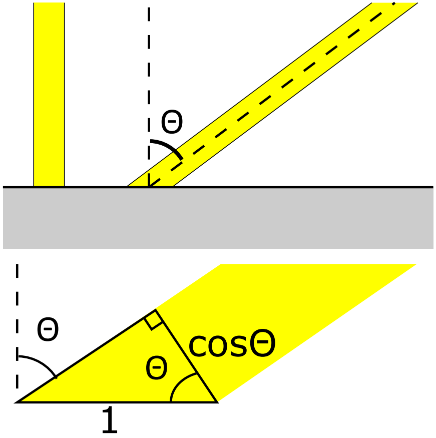
Diffuse Lighting

Diffuse term depends on $\hat{\mathbf{n}} \cdot \hat{\ell}$

- Recall that $\mathbf{a} \cdot \mathbf{b} = |a||b| \cos\theta$
- Unit vectors so lengths are 1
- Diffuse term depends on $\cos\theta$

Consider light hitting a surface:

- Light has energy, E / unit area
- Perpendicular rays: full energy
- Angle θ: $E\cos(\theta)$ / unit area



Diffuse and Specular Lighting

Light on a perfectly flat surface

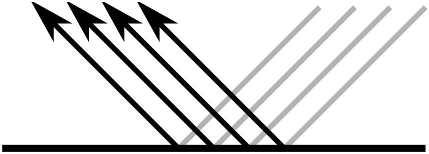
- Reflect off at the same angle
- Creates specular highlights

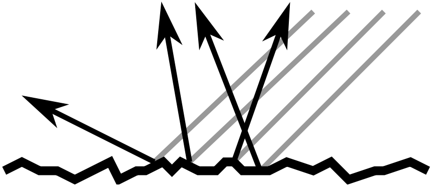
What about a rough surface?

- Light scatters in all directions
- Diffuse component does this

Most surfaces lie in between

- Diffuse + Specular parts
- A 'soft' reflection, $(\hat{\mathbf{r}} \cdot \hat{\mathbf{v}})^n$
- Brightest when $\hat{\mathbf{r}} = \hat{\mathbf{v}}$
- As $n \to \infty$ becomes sharper





Ambient Light

This models light hitting a surface

- Consider the room we are in
- Not all surfaces are directly lit
- But they are not totally dark

This is indirect illumination

- Light travels around the room
- It scatters off surfaces
- This is expensive to compute

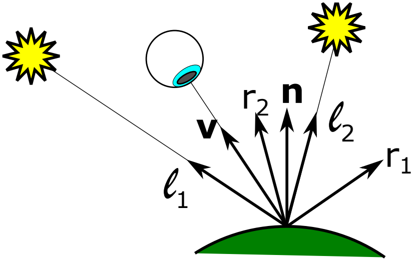
A simple solution

- Assume a ‘background’ light
- This is the same everywhere
- Shadows are now faintly lit

More realistic methods:

- Recursive ray/path tracing
- Radiosity, Photon mapping, Metropolis light transport, . . .

Multiple Light Sources



We assume for simplicity that the I_d and I_s are the same for each light.

$$I_{\text{total}} = I_a k_a + \sum_{i=1}^{N} I_i \left(k_{d,i}(\hat{\mathbf{n}} \cdot \hat{\ell}_i) + k_{s,i}(\hat{\mathbf{r}}_i \cdot \hat{\mathbf{v}})^n \right)$$

Coloured Lights and Objects

What do you see if I shine a magenta light onto a yellow ball?

- Real colour is rather complicated (as we've seen)
- Can get a long way with a fairly simple model:
  - Lights have red, green, blue intensities, I_r, I_g, I_b
  - Likewise ambient light has A_r, A_g, A_b
  - Surface has red, green, blue diffuse colour, r_d, g_d, b_d
  - The same for specular and ambient, r_s, g_s, b_s and r_a, g_a, b_a

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} A_r r_a \\ A_g g_a \\ A_b b_a \end{bmatrix} + \sum_{i=1}^{N} \begin{bmatrix} I_r \left(r_d(\hat{\mathbf{n}}_i \cdot \hat{\ell}_i) + r_s(\hat{\mathbf{r}}_i \cdot \hat{\mathbf{v}})^n \right) \\ I_g \left(g_d(\hat{\mathbf{n}}_i \cdot \hat{\ell}_i) + g_s(\hat{\mathbf{r}}_i \cdot \hat{\mathbf{v}})^n \right) \\ I_b \left(b_d(\hat{\mathbf{n}}_i \cdot \hat{\ell}_i) + b_s(\hat{\mathbf{r}}_i \cdot \hat{\mathbf{v}})^n \right) \end{bmatrix}$$

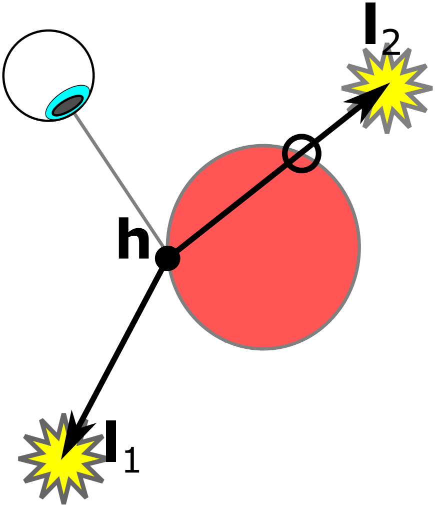
Shadows

Not every light hits every surface

- Light is blocked by objects
- This creates shadows
- This is (fairly) easy with rays

We cast *shadow rays* to do this

- We hit an object at $\mathbf{h}$
- There is a (point) light at $\mathbf{l}$
- Cast the ray $\mathbf{h} + \lambda(\mathbf{l} - \mathbf{h})$
- Look for hits with the new ray
- If $\lambda \in (0, 1)$, there is a shadow



Types of Light

We have used naïve point lights:

- Cast light in all directions
- Ignored distance to light

Light energy decays with distance

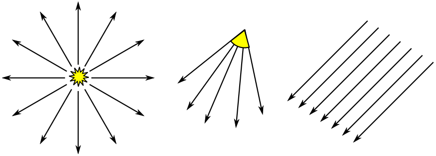
- This is an inverse-square law
- If energy E_0 at $d = 1$:

$$E = \frac{E_0}{d^2}$$

- How much light at $d = 0$?

Other common types:

- Spot lights: limited angle
- Directional lights: parallel rays



'Sun' lights

- Directional light 'at infinity'
- Constant brightness
- How to compute shadows?