Local Illumination

CMSC 435/634

Illumination

- Effect of light on objects
- Mostly look just at intensity
  - Apply to each color channel independently
- Good for most objects
  - Not fluorescent
  - Not phosphorescent

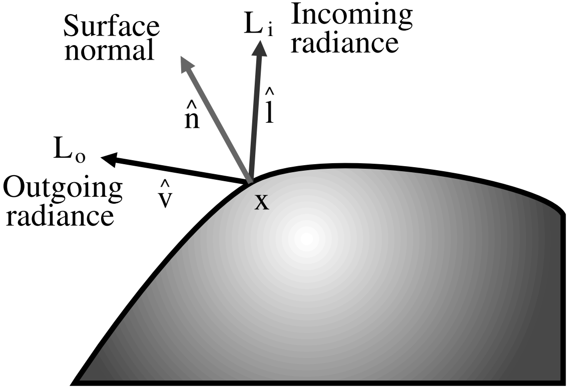
Local vs. Global

- Local
  - Light sources shining directly on object
- Global
  - Lights bouncing from objects onto other objects
  - Ambient Illumination
    - Approximate global illumination as constant color
    - Typically $\sim$ 1% of direct illumination

BRDF

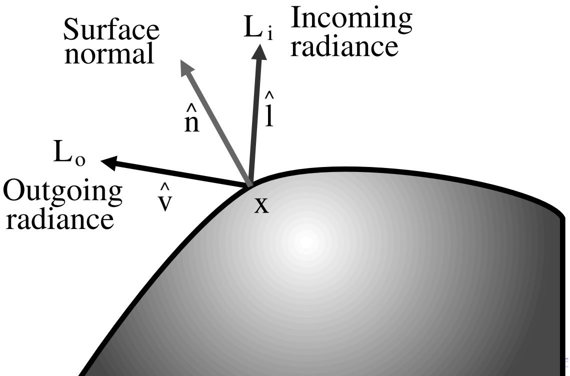
Bidirectional Reflectance Distribution Function

How much light reflects from L_i to L_o



Physically Plausible BRDF

- Positive
- Reciprocity
  - Same light from L_i to L_o as from L_o to L_i
- Conservation of Energy
  - Don't reflect more energy than comes in



Plotting BRDFs

- Polar plot of reflectance strength
  - For **one** view direction, showing light directions
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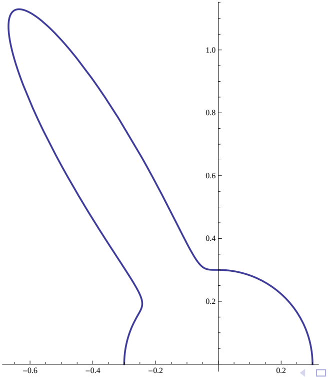
- Reciprocity – same if you swap view and light



Rendering Equation

Integral of all Incoming Light

$$L_o(\hat{v}) = \int_{\Omega(\hat{n})} f_r(\hat{v}, \hat{l})\, L_i(\hat{l})\, \hat{n} \cdot \hat{l}\, d\omega(\hat{l})$$

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$L_i(\hat{l})$	incoming light from direction $\hat{l}$
$\hat{n} \cdot \hat{l}\, d\omega(\hat{l})$	projection of differential solid angle onto surface

Rendering Equation for Point Lights

Sum for Each Light

$$L_o(\hat{v}) = \sum_i f_r(\hat{v}, \hat{l}_i)\, L_i\, \hat{n} \cdot \hat{l}_i$$

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$\hat{l}_i$	incoming light direction for light i

Results

- Integrating full environment
- Light at one point, black elsewhere

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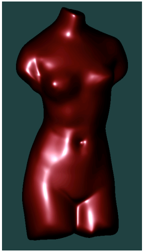

Decomposing BRDFs

- Decompose BRDF into convenient parts
- Typical breakdown:
  - Diffuse (view independent)
  - Specular (view dependent near reflection)
  - Others less common, often ignored (e.g. retro reflection)

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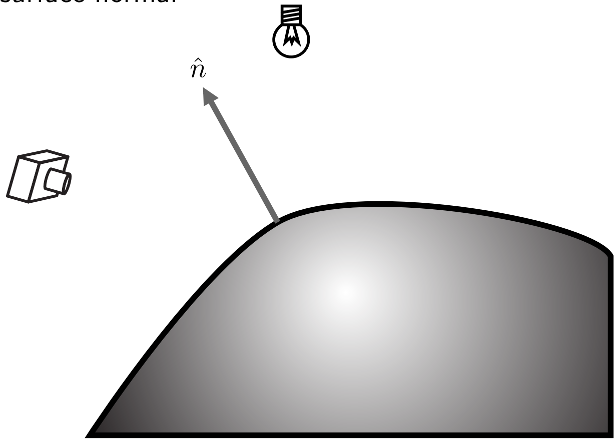
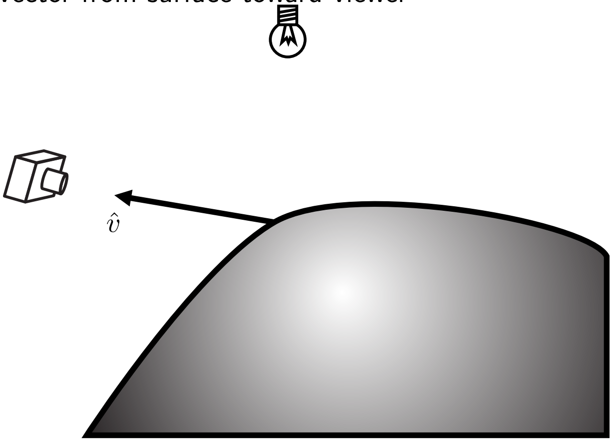
Important directions

$\hat{n}$: Unit surface normal



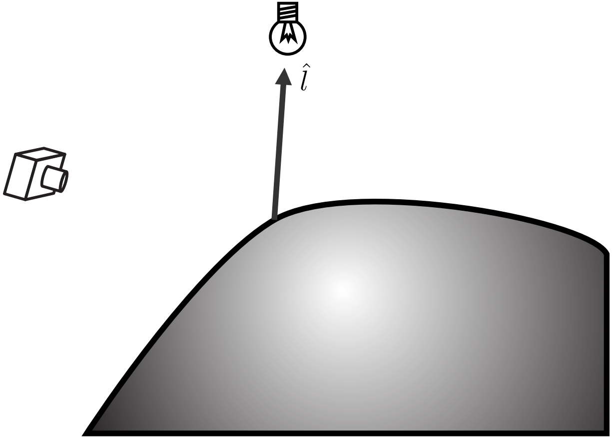
Important directions

$\hat{v}$: Unit vector from surface toward viewer



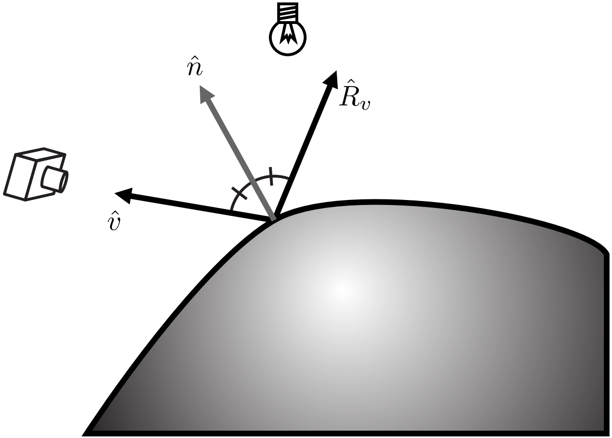
Important directions

$\hat{l}$: Unit vector from surface toward light



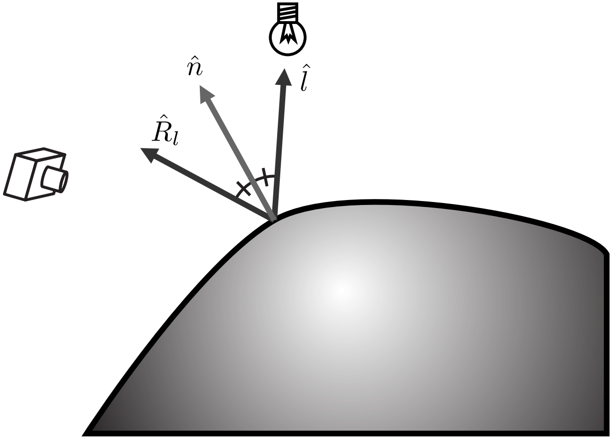
Important directions

$\hat{R}_v = 2\hat{n}(\hat{n} \cdot \hat{v}) - \hat{v}$: Direction of mirror reflection of view



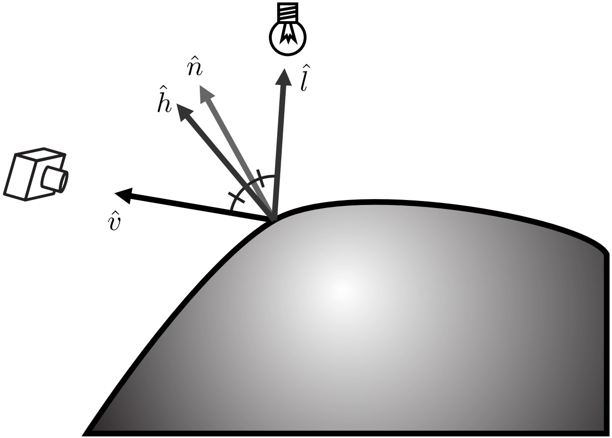
Important directions

$\hat{R}_l = 2\hat{n}(\hat{n} \cdot \hat{l}) - \hat{l}$: Direction of mirror reflection of light



Important directions

$\hat{h} = (\hat{v} + \hat{l})/|\hat{v} + \hat{l}|$: Normal direction that would reflect $\hat{v}$ to $\hat{l}$

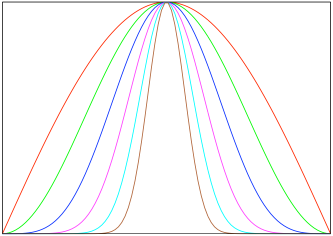


Diffuse

- Also called Lambertian or Matte
- BRDF constant
- Total reflectance: $\sum_i Kd\, L_i\, \hat{n} \cdot \hat{l}_i$

Phong

- Strongest where $\hat{R}_l$ lines up with $\hat{v}$ or $\hat{R}_v$ lines up with $\hat{l}$
- Total reflectance: $\sum_i Ks\, L_i\, (\hat{R}_v \cdot \hat{l}_i)^e$
- BRDF: $(\hat{R}_v \cdot \hat{l}_i)^e / (\hat{n} \cdot \hat{l})$
- Non-physical
  - Too much energy; division by $\hat{n} \cdot \hat{l}$ breaks reciprocity



Specular Microfacets

- Imagine random mirrored *microfacets*
- Probability facet has normal $\hat{h}$
  - Normal Distribution Function (NDF)
- Proportion of light or view blocked (geometry term)
  - Blocked light = *shadowing*
  - Blocked view = *masking*
- Fresnel term

Cook-Torrance

- Beckmann Distribution = Gaussian distribution of slope
- Shadow/Mask based on symmetric V-shaped microfacets
- BRDF: $\frac{D(\hat{n},\hat{h})\,G(\hat{n},\hat{v},\hat{l})\,F(\hat{v},\hat{l})}{\pi\;\hat{n}\cdot\hat{v}\;\hat{n}\cdot\hat{l}}$,
- Total reflectance: $\sum_i Ks\,\frac{D(\hat{n},\hat{h}_i)\,G(\hat{n},\hat{v},\hat{l}_i)\,F(\hat{v},\hat{l}_i)}{\pi\;\hat{n}\cdot\hat{v}}\,L_i$

Blinn-Phong

- Alternate formulation for Phong, similar behavior
- Strongest where $\hat{h}$ lines up with $\hat{n}$
- Total reflectance: $\sum_i Ks\, L_i\, (\hat{n} \cdot \hat{h}_i)^e$
- Better: think of as NDF
  - Normalize: $\frac{e+2}{2\pi}(\hat{n} \cdot \hat{h}_i)^e$
  - Combine with other terms
  - $\sum_i Ks\, L_i\, \frac{e+2}{2\pi}(\hat{n} \cdot \hat{h}_i)^e\, \hat{n} \cdot \hat{l}_i$

When to Compute

- *Gouraud Shading* = Compute per-vertex & interpolate
  - Lose sharp highlights
  - Subject to *Mach banding*
- *Phong Shading* = Interpolate normals & compute per-pixel

Gouraud

Phong

Phong Shading

- Phong shading can refer to lighting model **or** interpolation
- To save confusion:
  - *Phong lighting*
  - *Phong interpolation*