Lighting and Shading

Computer Graphics and Visualization

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Definitions

Lighting: (or illumination) the perceived effect of light from light sources and surfaces, indirect and direct (luminous flux).

Often a confusion between lighting and shading

Lighting The process of computing the luminous intensity (outgoing light) at a particular 3D point.
Lighting model (Illumination or shading model)

Shading The process of assigning colors to pixels

Fundamentally

- CG is about modelling the interaction of electromagnetic energy within the objects of a scene.
- What we see, is the light (electromagnetic energy in the spectrum of visual light) that hits the eyes.
- Involves a number of things:
  - Material properties
  - Object position relative to lightsources and other objects
  - Feature of light sources

Lighting

Empirical illumination model

- Tries to formulate approximations of observed phenomenon
- Phong illumination model (OpenGL), Raytracing

Physically-based

- Models based on the actual physics of light interacting with matter
- Radiosity, Photonmapping

Components

Light sources

- Emitters of radiant energy
- Geometric attributes
  - Position, Direction, Shape
- Spectrum of emittance, Color
- Directional attenuation

Surfaces

- Reflecting spectrum (Color)
- Geometry (micro structure)
- Absorption
- Transparency

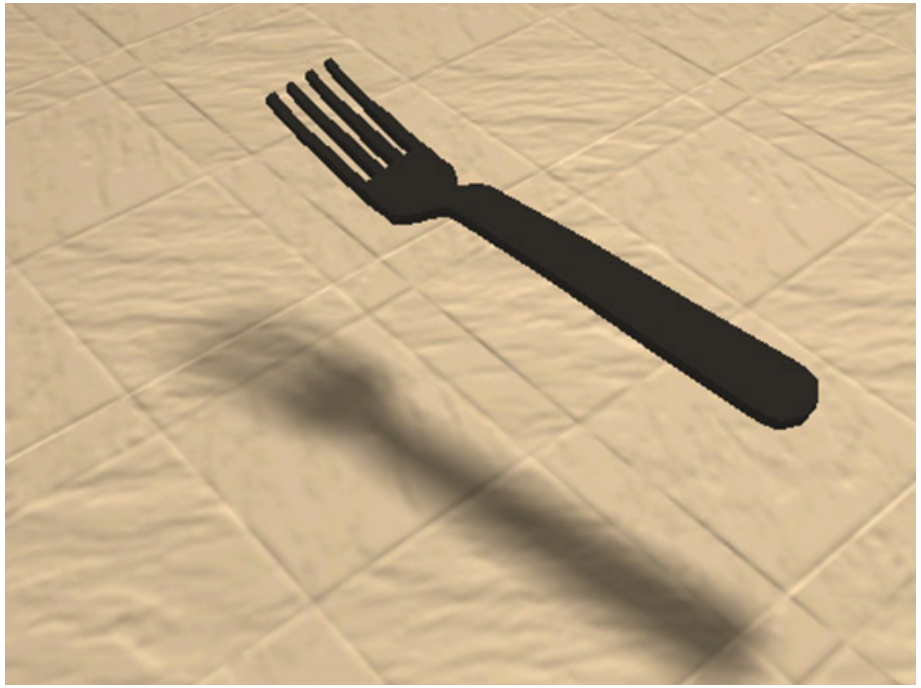
Surface properties

Surface properties

- Reflectance coefficients
  - When light hits a surface, parts of it is reflected and parts is absorbed.
- Transparency
  - For transparent surfaces some light are also transmitted through the material

Area Light Sources

- Occupies a 2D area
- Generates soft shadows



- Complicated to calculate

Simplifications

- Only direct illumination from the emitters to the reflectors of the scene
- Ignore geometry of emitters

- Let us assume we have opaque surfaces

Notation (1)

Light intensity

$$I = \begin{bmatrix} I_r \\ I_g \\ I_b \end{bmatrix}$$

- Light source
- Face reflecting light

Reflection coefficient ($0 \leq k \leq 1$)

$$k = \begin{bmatrix} k_r \\ k_g \\ k_b \end{bmatrix}$$

- How much light is reflected at the surface

Ambient Light Source

- Due to reflections onto other objects, even object that are not directly lit by a light source are visible
- To model indirect illumination a hack called Ambient light source is used
  - No position nor direction.
  - Constant for all surfaces in the scene
  - Can have color
  - Independent on objects orientation and position.
  - Surface properties are used to determine how much ambient light is reflected
- $I = I_a k_a$

Point Light Source

- Approximates a (very small) light bulb
- Attributes
  - Position
  - Color
- Light are generated radially

Reasonable approximation for sources that are small compared to objects in the scene

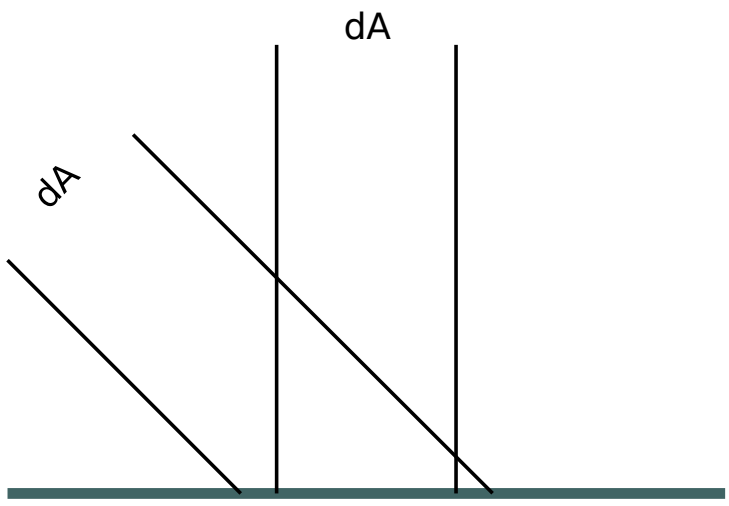
Notation (2)

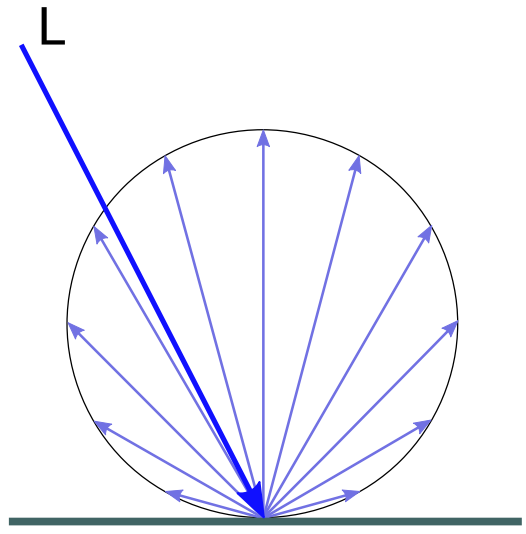
At a particular point on a surface

- **n** is the surface normal
- **l** is the direction to the light source
- **r** is the direction of reflection
- **v** is the direction to the viewer
- θ is the angel between **n** and **l**
- ϕ is the angle between **n** and **v**
- α is the angle between **r** and **v**

Lambertian Surface

- Incoming light is
  - spread over a surface proptional to $\cos\,\theta$
  - reflected in all direction but proptional to $\cos\,\phi$
- Outgoing light is
  - accumulated from a surface proportional to $1/\cos\,\phi$

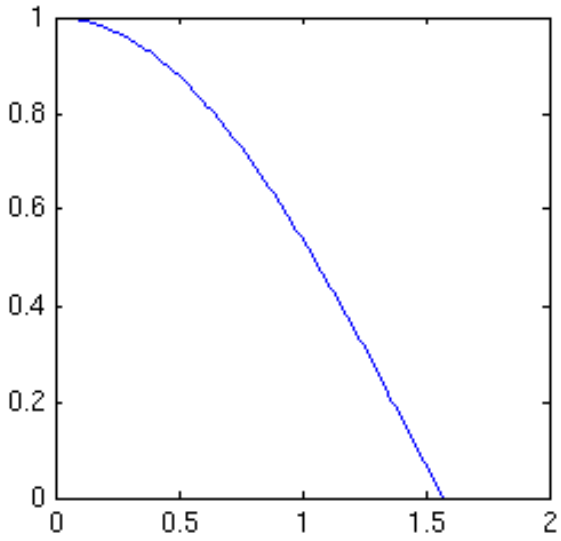


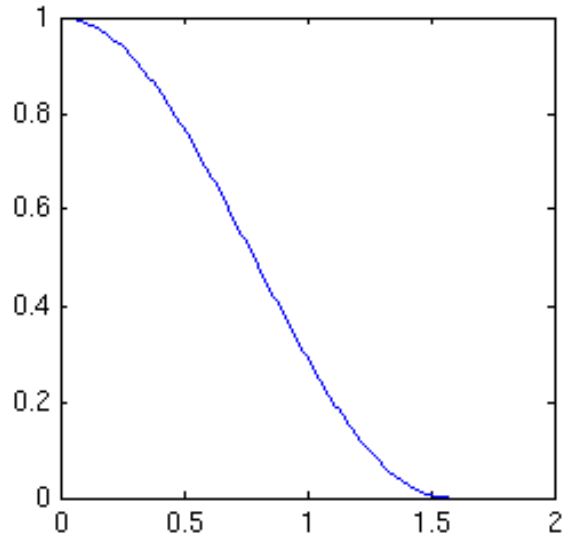


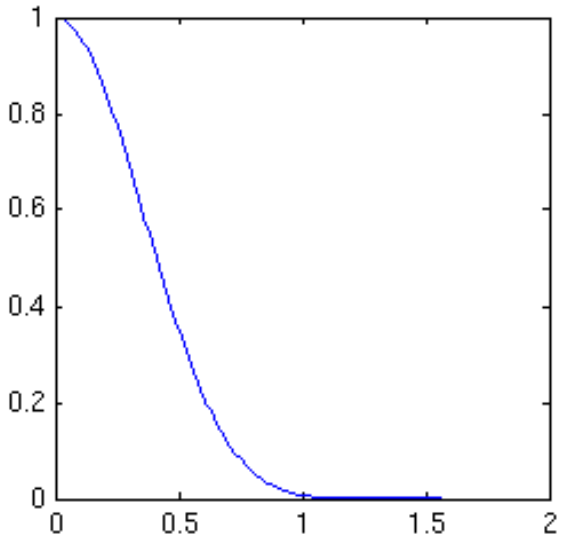
Specular light

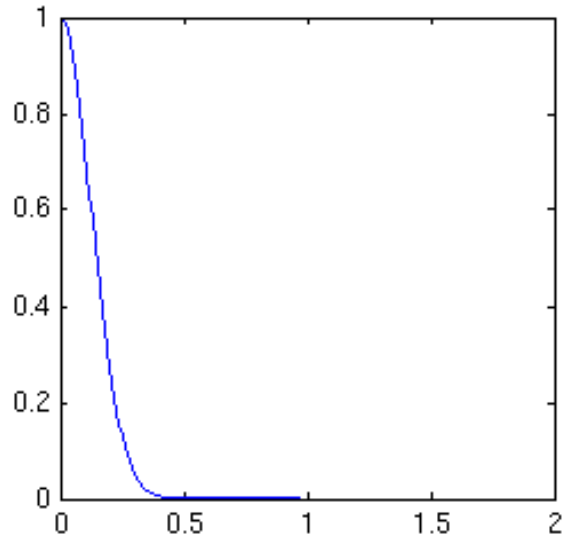
- Reflects along the reflection angle
  - Pure reflection exactly
  - Less reflection more spread
- Light propotional to $\cos \alpha = \mathbf{r} \cdot \mathbf{l}$
- $\mathbf{r} = 2\mathbf{n} \cdot \cos \theta - \mathbf{l}$
- ”Shininess” approximated with $\cos^n \alpha$

Cosine Values

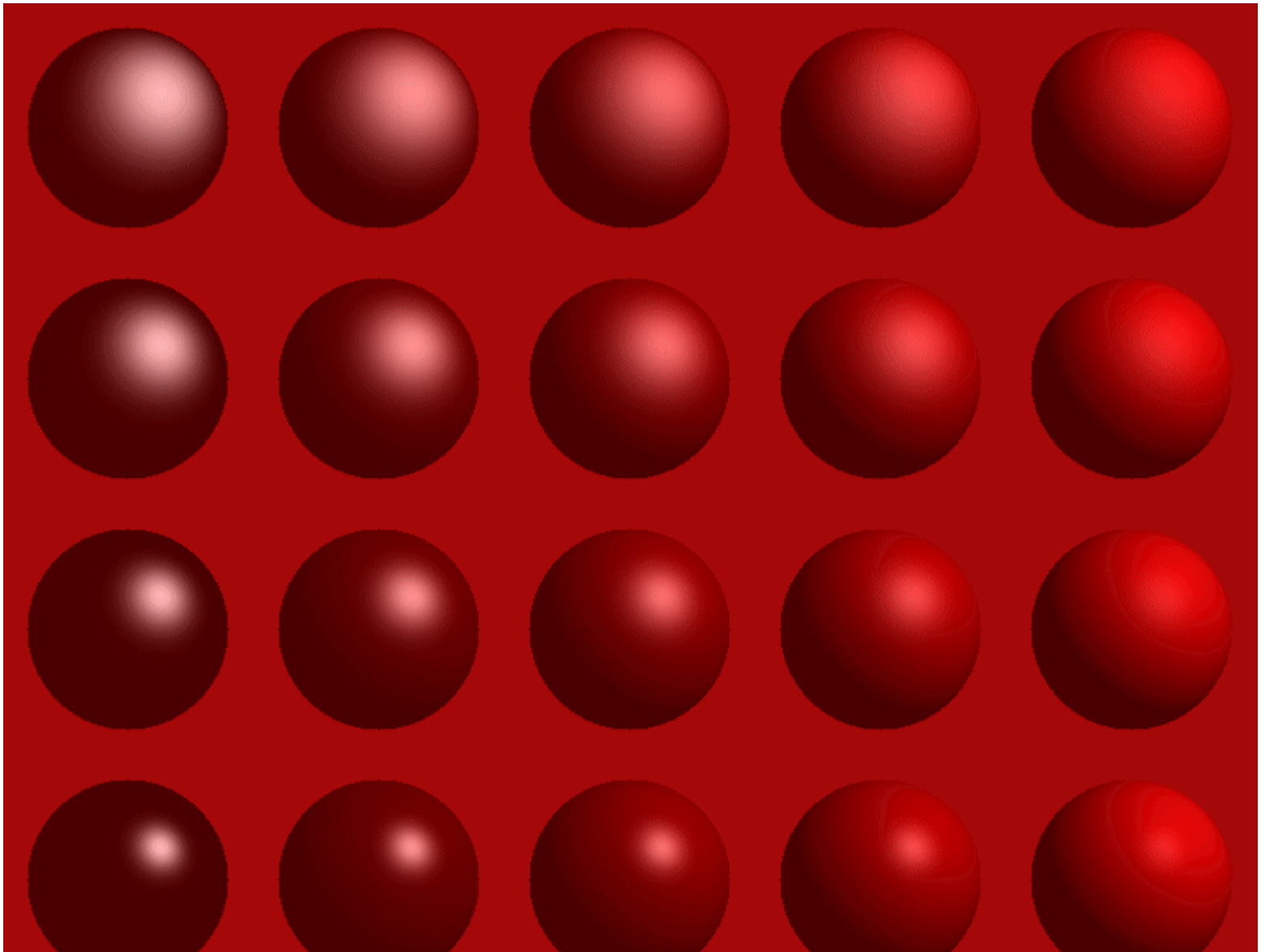








Diffuse and Specular Component



Surface Lighting Effects

Ambient Lighting model

- Light coming from other objects

$$I_{\text{ambient}} = I_a k_a$$

Diffuse Lighting model

- Light reflected equally in all directions

$$I_{\text{diffuse}} = I_l k_d \cos\theta = I_l k_d (\mathbf{n} \cdot \mathbf{l})$$

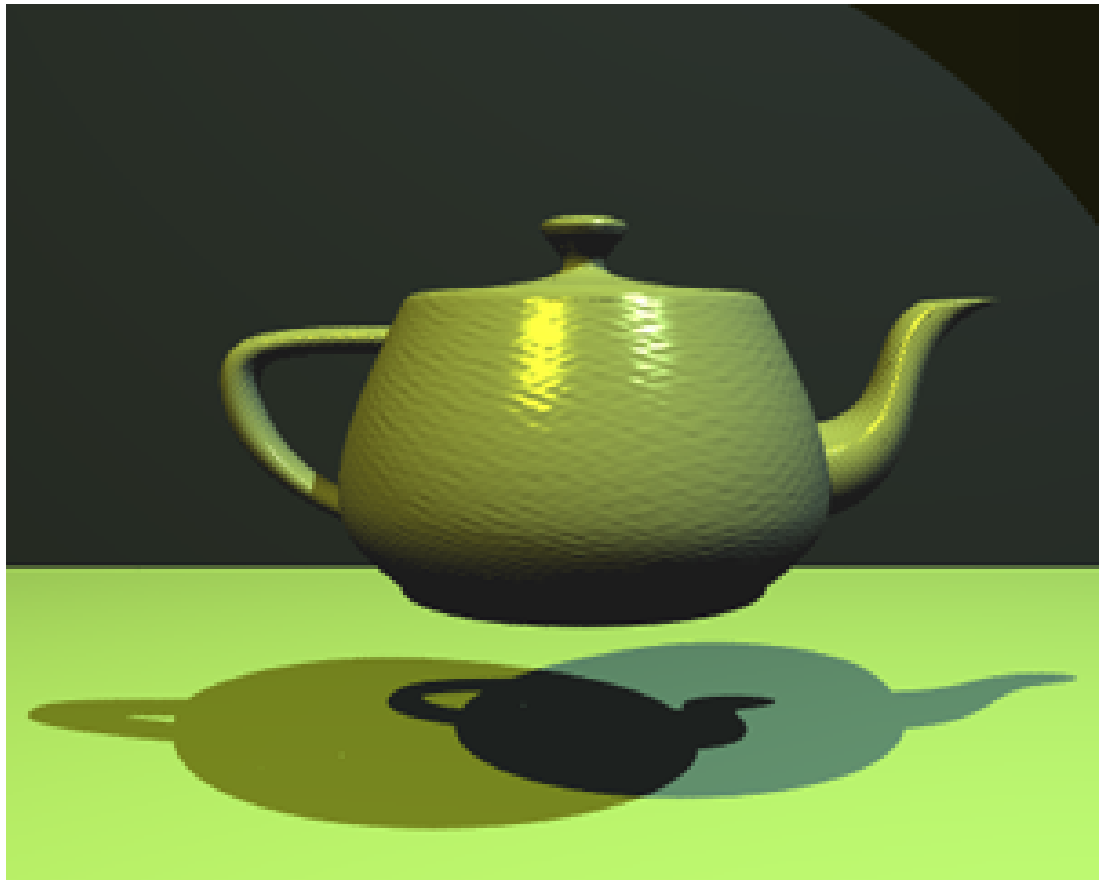
Specular Lighting model

- Light reflected in the area of the reflection vector between the view and light vector

$$I_{\text{specular}} = I_l k_s \cos^n \alpha = I_l k_s (\mathbf{r} \cdot \mathbf{v})^n$$

Phong Lighting Model

$$I = I_a k_a + \sum_{i=1}^{n_{\text{lights}}} I_i \left(k_d (\mathbf{n} \cdot \mathbf{l}) + k_s (\mathbf{r} \cdot \mathbf{v})^{n_i} \right)$$



Blinn-Phong Lighting Model

- Avoid calculating **r** by replacing $\mathbf{r} \cdot \mathbf{v}$ with $\mathbf{n} \cdot \mathbf{h}$

$$\mathbf{h} = \frac{\mathbf{l}+\mathbf{v}}{|\mathbf{l}+\mathbf{v}|}$$

- Halfway angle ψ slightly smaller than ϕ
- Default in fixed-function pipelines