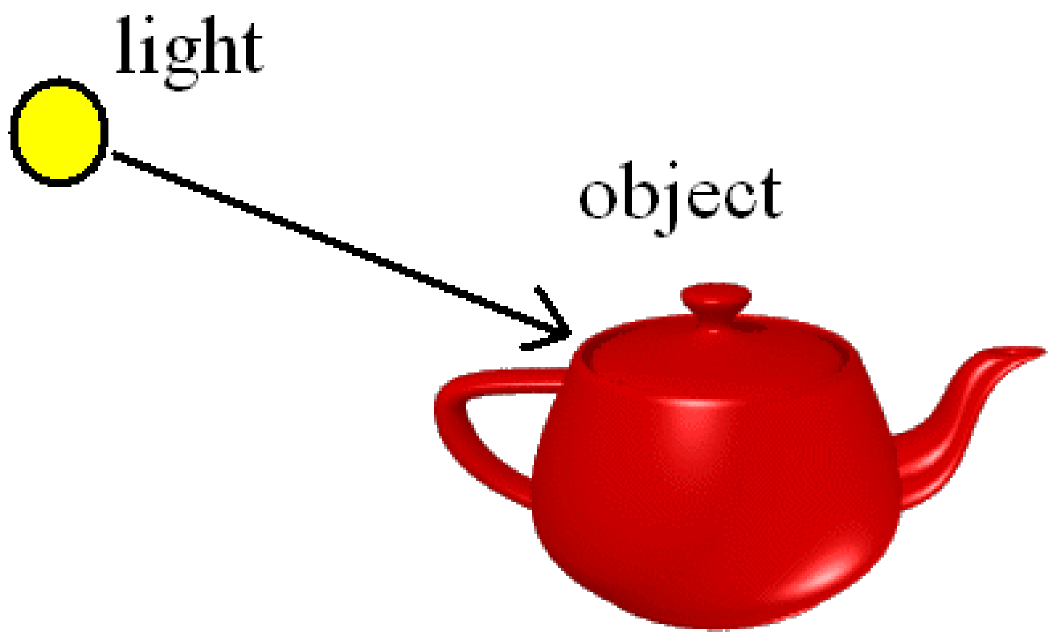
Introduction

Illumination and Shading

A number of different types of light sources exist to provide customization for the shading of objects. Upon rendering a scene a number of different lighting techniques will be used to make the rendering look more realistic.

Overview

- Model for calculating light intensity(color) at a single surface point as an ***illumination model*** or a ***lighting model***)
- Shading (how to color the whole surface)?



LIGHT SOURCES

- Light can be emitted through either self-emission or reflection.
- Light sources are categorized by their light emitting direction and the energy emitted at each wavelength – determining the color of the light.

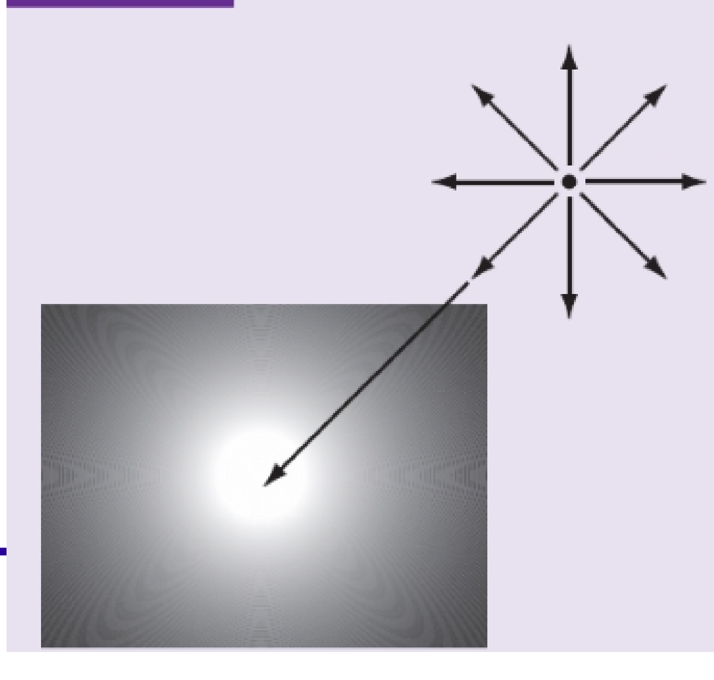
LIGHT SOURCES

- Objects can absorb or reflect light emitted from a light source depending on the reflecting object's material properties.
- Light will thus only be 'visible' when illuminated surfaces have the ability to reflect or absorb the said light.
- Material properties are user-defined parameters built around rules determining the amount of scattering or reflection of incident light.

Point Lights

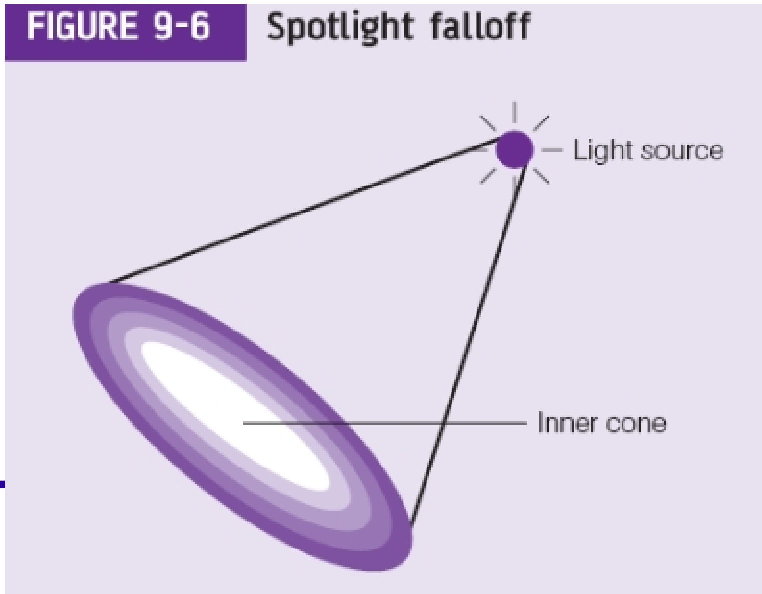
- A point light emits light uniformly in 360 degrees.
- Point lights have fixed color and position values and are omnidirectional in nature.

FIGURE 9-5 Point light illumination



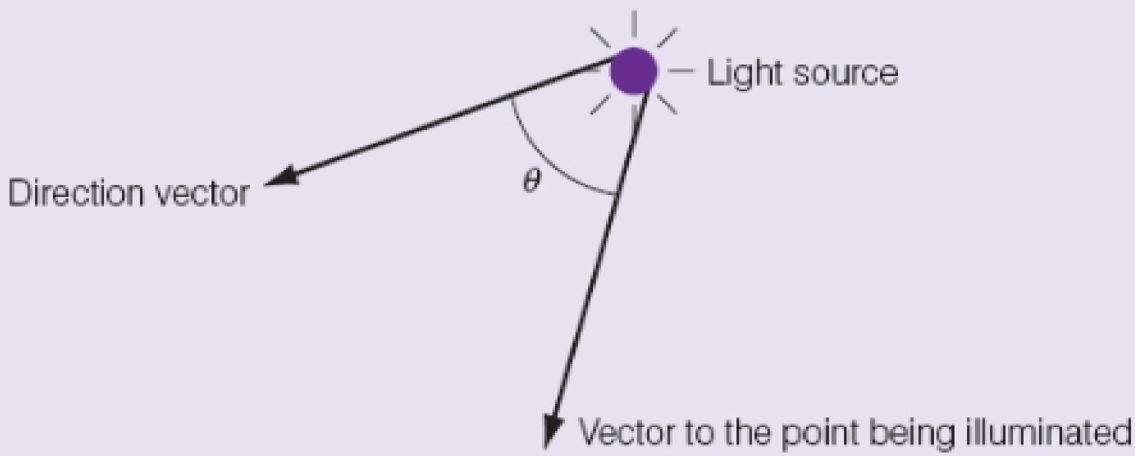
Spotlights

- Spotlights are specified by a color, spatial position and some specific direction and range in which light is emitted.
- A spotlight is basically a point light with its emitting light constrained within an angle range.



Spotlights

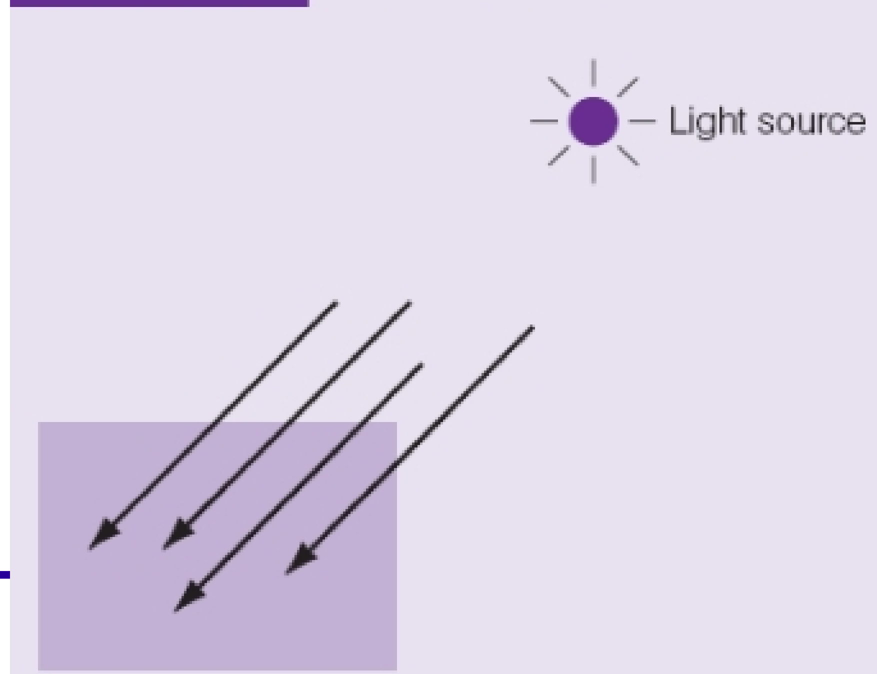
FIGURE 9-7 The relationship between the direction vector and the vector to the point being illuminated



Parallel Lights

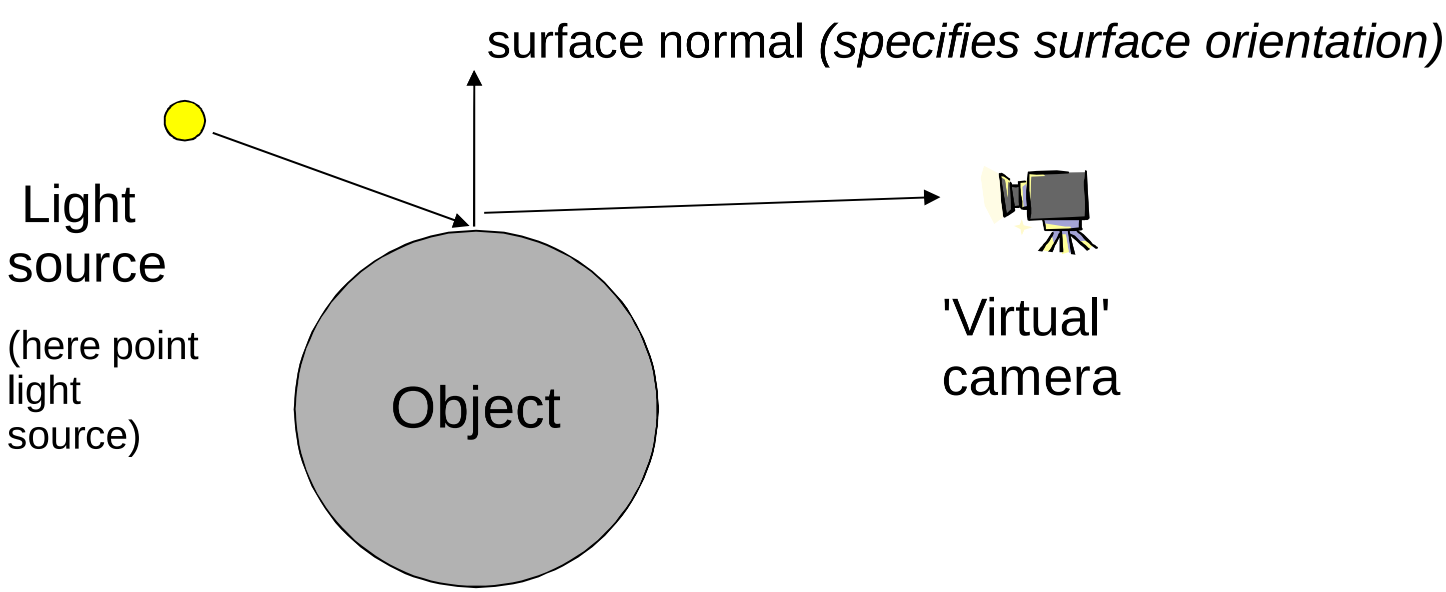
- A parallel or directional light illuminates objects through a series of parallel light rays.
- These light sources can be considered as point lights located a significant distance from the surface of an object.

FIGURE 9-8 A parallel light



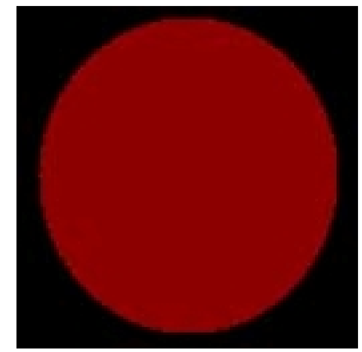
Basic Illumination Model

- Simple 3 parameter model
  - **Ambient :** 'background' illumination
  - **Specular :** bright, shiny reflections
  - **Diffuse :** non-shiny illumination and shadows

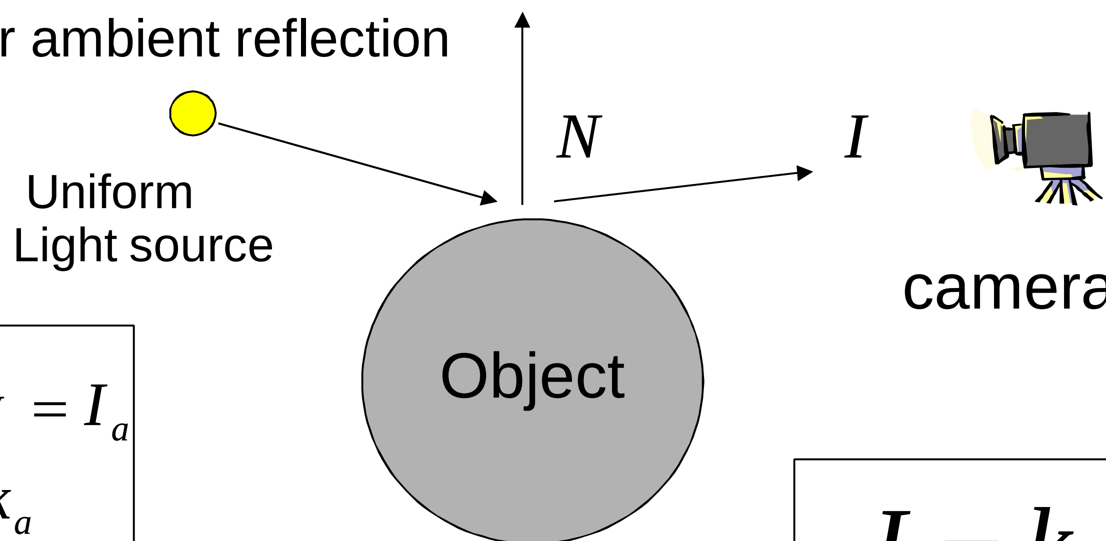


Ambient Lighting

- A surface that is not exposed directly to a light source still will be visible it nearby objects are illuminated.
- Light from the environment
- light reflected or scattered from other objects
- Result: **globally uniform colour for object**
  - I = resulting intensity
  - I_a = light intensity
  - k_a = reflectance or ambient reflection coefficient



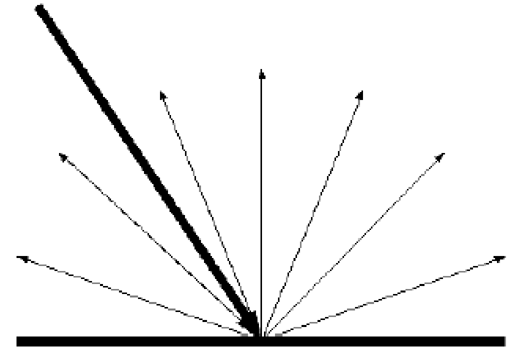
Example: sphere



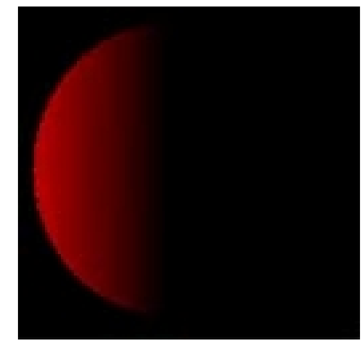
$$\text{Light Intensity} = I_a$$
$$\text{reflectance} = k_a$$

$$I = k_a I_a$$

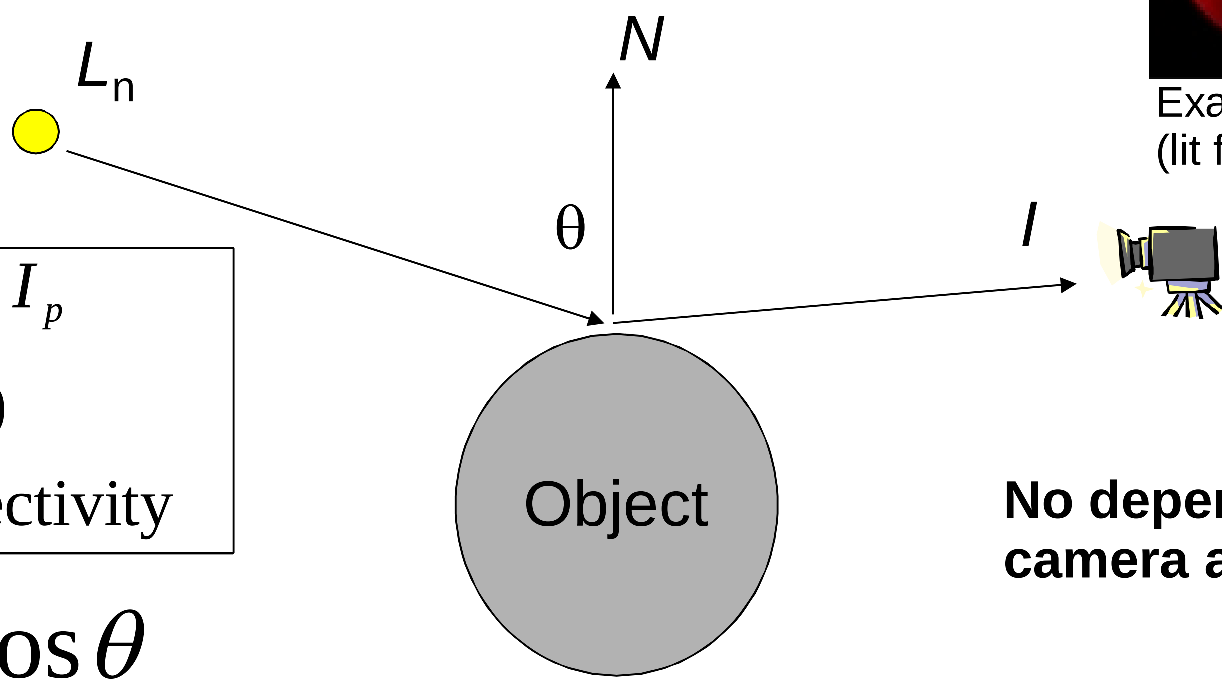
Diffuse Lighting



- Also known as Lambertian reflection
  - Illumination by an point light source.
  - Object brightness varies one part to another depending on direction and distance of light source
  - considers the angle of incidence of light on surface Result: **lighting varies over surface with orientation to light**



Example: sphere (lit from left)



Light Intensity $= I_p$

$\cos\theta = (\bar{N} \bullet L_n)$

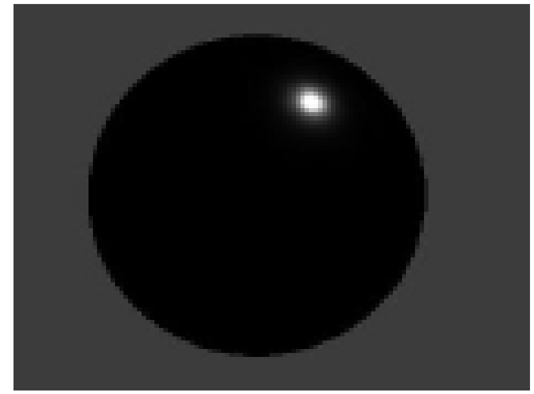
k_d : diffuse reflectivity

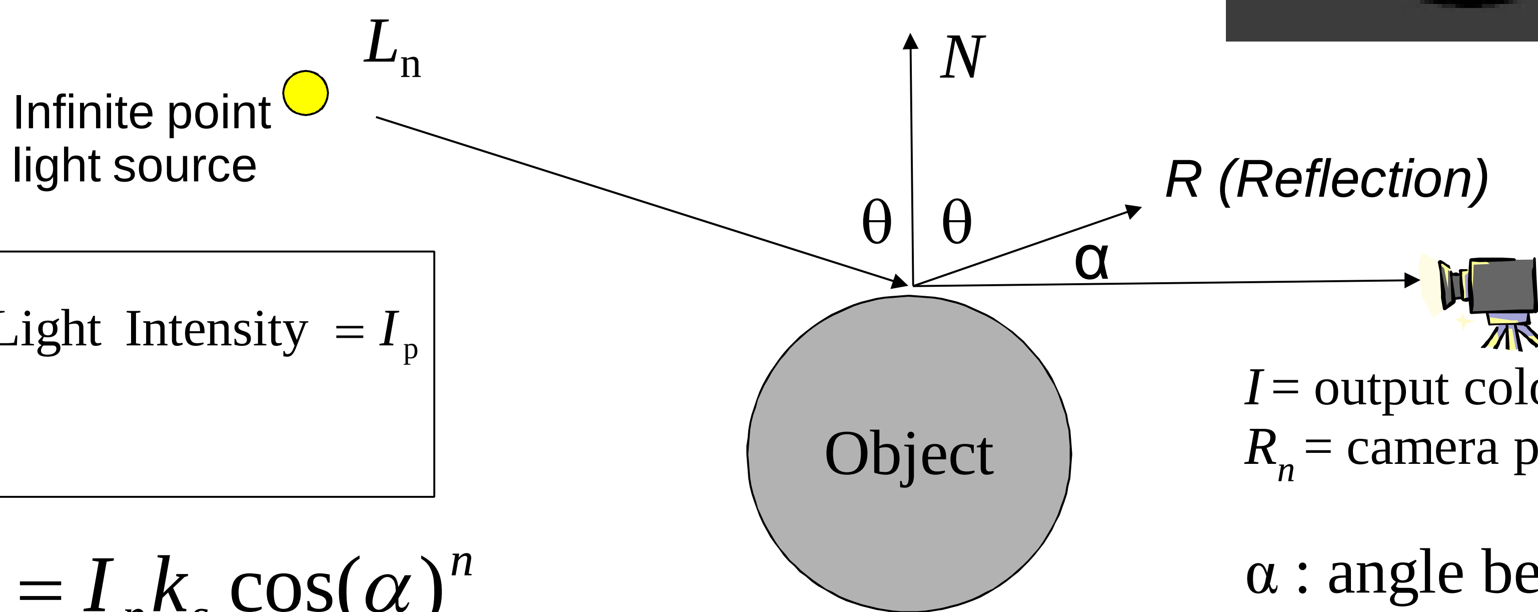
$$I = I_p k_d \cos\theta$$

No dependence on camera angle!

Specular Lighting

- Direct reflections of light source off shiny object ex. Polished metal, an Apple or persons forehead
  - specular intensity *n* = shiny reflectance of object
  - Result: **specular highlight on object**





Light Intensity $= I_p$

$$I = I_p k_s \cos(\alpha)^n$$

I = output color
R_n = camera position

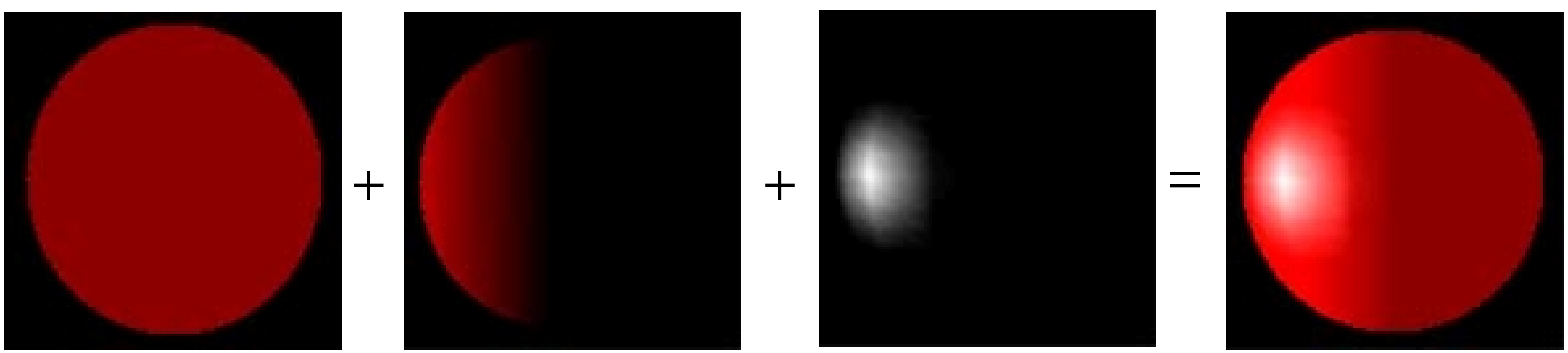
α : angle between R_n and S

No dependence on object colour.

Combined Lighting Models

- Summing it altogether : Phong Illumination Model

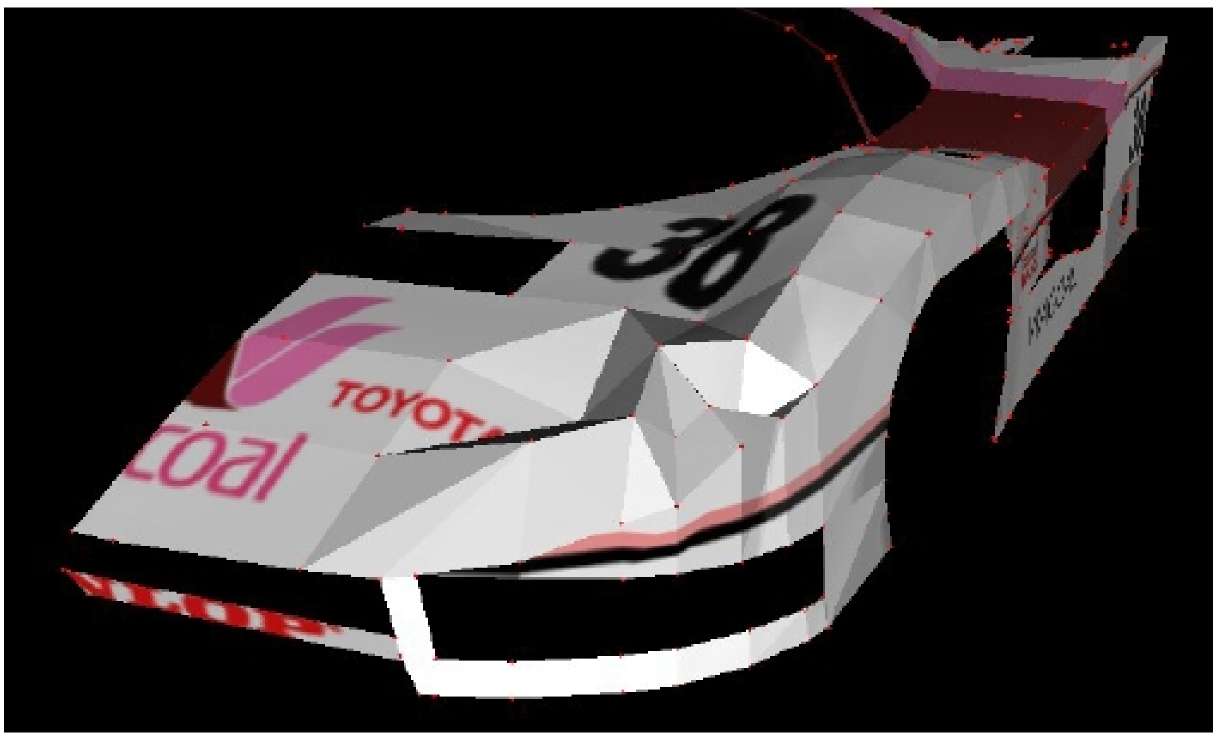
$$I_{\lambda} = I_a k_a + I_p [k_d \cos\theta + k_s \cos^n \alpha]$$

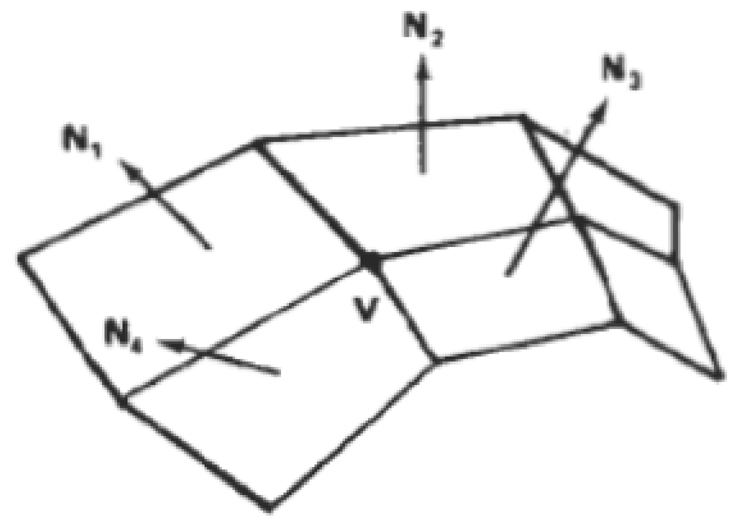


Ambient (colour) | Diffuse (directional) | Specular (highlights) | R_c

Flat Shading
/ Constant-Intensity Shading

- Single intensity is calculated for each polygon. All points over the surface of the polygon are then displayed with the same intensity value.

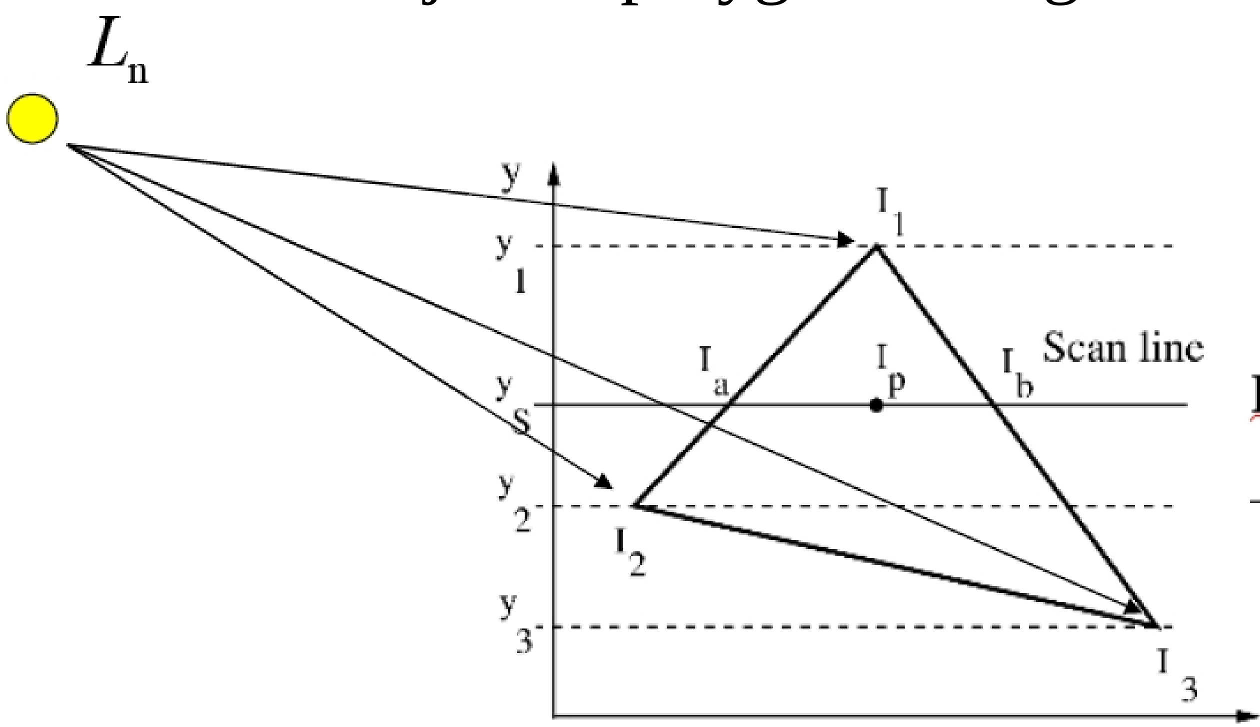




- The object is a polyhedron and is not an approximation of an object with a curved surface.
- All light sources illuminating the obpzt are suficiently far from the surface so that N . L and the attenuation function are constant over the surface.
- The viewing position is sufficiently far from the surface so that V R is constant over the surface.

Gouraud Shading (Smooth Shading)

- Compute the color at each vertex first
- Compute the color inside the polygon by interpolating the colors of the vertices composing the polygon
- Intensity values for each polygon are matched with the values of adjacent polygons along the common edges.



$$I_a = I_1 - (I_1 - I_2)\frac{(y_1 - y_S)}{(y_1 - y_2)}$$

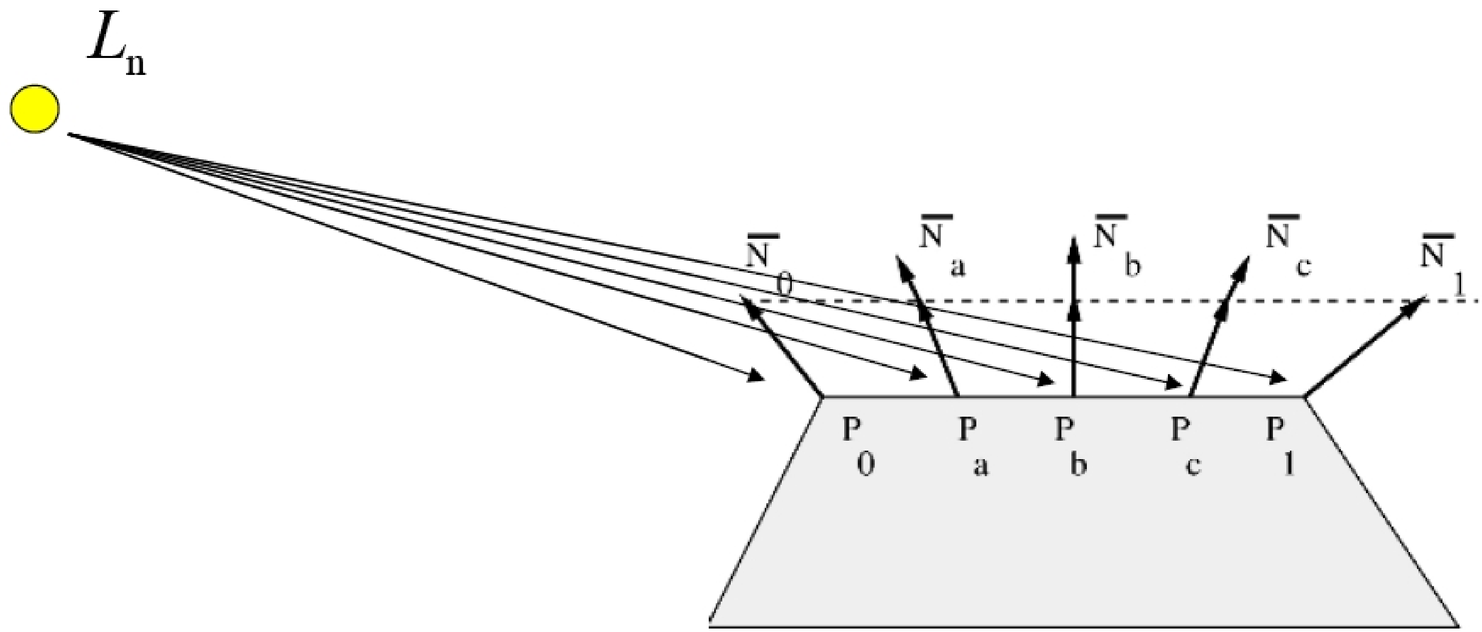
$$I_p = I_b - (I_b - I_a)\frac{x_b - x_p}{x_b - x_a}$$

$$I_b = I_1 - (I_1 - I_3)\frac{(y_1 - y_S)}{(y_1 - y_3)}$$

Gouraud shading model

Phong Shading

- interpolating the normal vectors at the vertices and
- Do the computation of illumination model at each surface point in the polygon



Phong shading model

It displays more realistic highlights on a surface and greatly reduces the Mach-band effect.

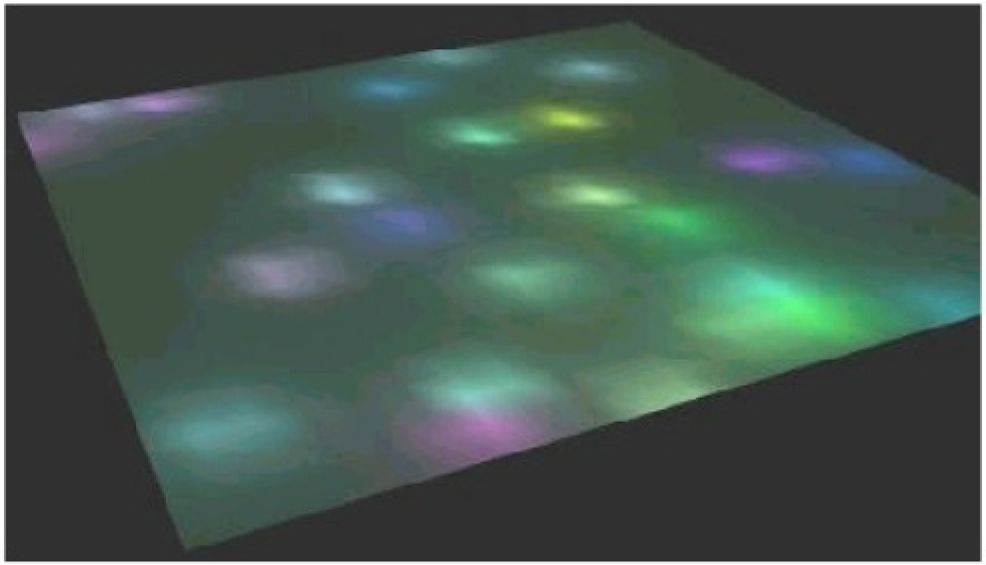
A polygon surface is rendered using Phong shading by carrying out the following steps:

- Determine the average unit normal vector at each polygon vertex.
- Linearly interpolate the vertex normals over the surface of the polygon.
- Apply an illumination model along each scan line to calculate projected pixel intensities for the surface points.

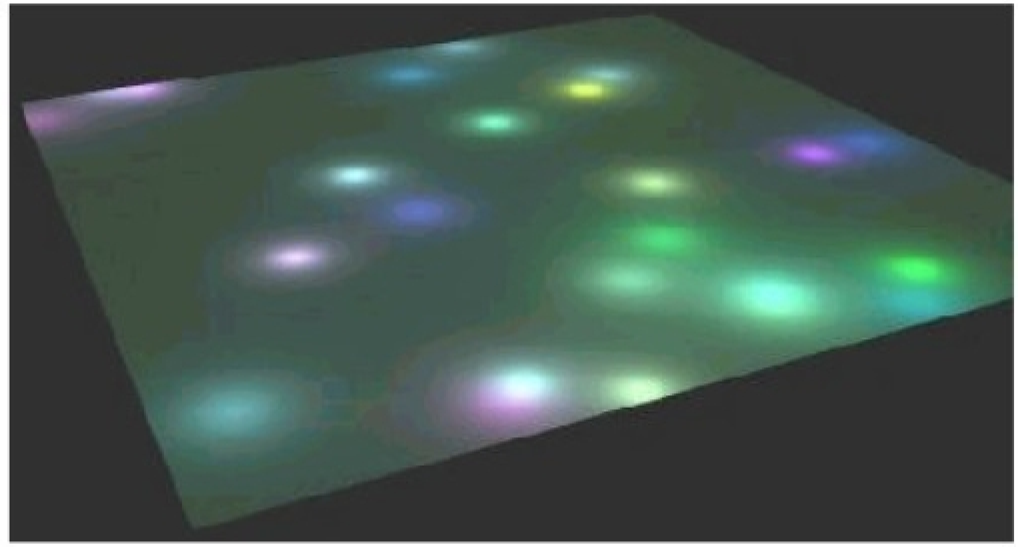
Flat shaded Utah Teapot

Phong shaded Utah Teapot

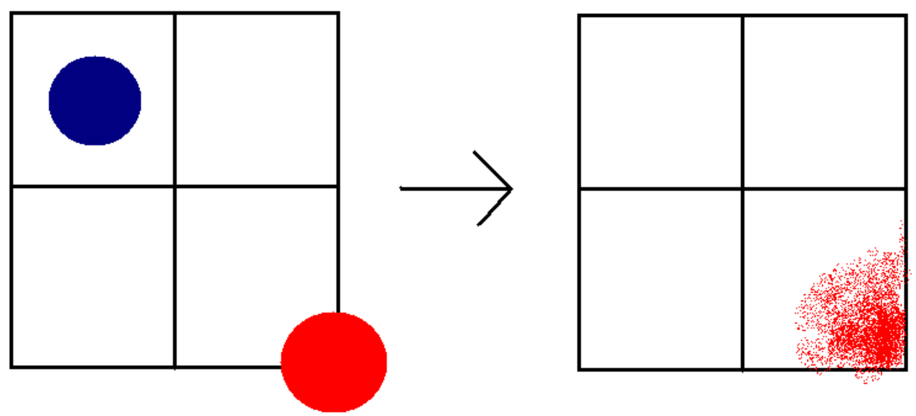
- Gouraud Shaded Floor



Phong Shaded Floor



- Gouraud shading is not good when the polygon count is low



Application

Phong reflection model is often used together with Phong shading to shade surfaces in 3D computer graphics software. Apart from this, it may also be used for other purposes.

For example, it has been used to model the reflection of thermal radiation from the Pioneer probes in an attempt to explain the Pioneer anomaly.

Scope of Research

Inverse Phong reflection model

The Phong reflection model in combination with Phong shading is an approximation of shading of objects in real life. This means that the Phong equation can relate the shading seen in a photograph with the surface normals of the visible object. Inverse refers to the wish to estimate the surface normals given a rendered image, natural or computer-made.