AN OVERVIEW OF THE LIGHTING MODELS OF GRAPHIC OBJECTS

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Abstract

During shading process it is vary important to chose the right illumination model. In present paper are described the most often used illumination model, which can be applied for realistic image creation.

The incoherent components are modeled by bi-directional densities in the Hall equation, but they are difficult to derive for real materials [1]. Thus, we describe these bi-directional densities by some simple functions containing a few free parameters instead. These free parameters can be used to tune the surface properties to provide an appearance similar to that of real objects.

First of all, consider diffuse - optically very rough - surfaces reflecting portion of the incoming light with radiant intensity uniformly distributed in all directions. The constant radiant intensity (I_d) of the diffuse surface lit by a collimated beam from the angle ϕ_{in} (fig.1) in can be calculated thus:

$$I_d = \int^{2\pi} I_{in}(\vec{L}) \cos\phi_{in} R^*\left(\vec{L},\vec{V}\right) d\omega_{in}$$

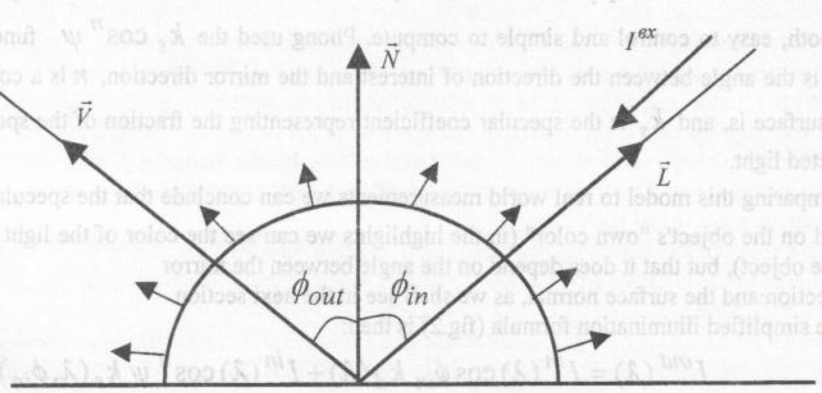

Figure. 1. Diffuse reflection

The collimated beam is expressed as a directional delta function, $I^{in}\delta(\vec{L})$ simplifying the integral as:

$$I_d = I^{in} \cos\phi_{in} R^*(\vec{L},\vec{V}).$$

Since I_d does not depend on $\vec{V}$ or ϕ_{out}, the last term is constant and is called the diffuse reflection coefficient k_d:

$$k_d = R^*(\vec{L},\vec{V}) = \frac{R(\vec{L},\vec{V})}{\cos\phi_{out}}.$$

The radiant intensity of a diffuse surface is:

$$I_d(\lambda) = I^{in}(\lambda) \cos\phi_{in}\, k_d.$$

This is Lambert's law of diffuse reection [1]. The term $\cos\phi_{in}$ can be calculated as the dot product of unit vectors $\vec{N}$ and $\vec{L}$. Should $\vec{N}\cdot\vec{L}$ be negative, the light is incident to the back of the surface, meaning it is blocked by the object. This can be formulated by the following rule:

$$I_d(\lambda) = I^{in}(\lambda)\, k_d \max\left\{\left(\vec{N}\cdot\vec{L}\right), 0\right\}.$$

Since diffuse surfaces cannot generate mirror images, they present their own color" if they are lit by white light. Thus, the spectral dependence of the diffuse coefficient k_d, or the relation of k_d^{red}, k_d^{green}, k_d^{blue} in the simplified case, is primarily responsible for the surface's "own color" even in the case of surfaces which also provide non-diffuse reflections.

A more complex approximation of the incoherent reflection has been proposed by Phong [2]. The model is important in that it also covers shiny surfaces. Shiny surfaces do not radiate the incident light by uniforminten-sity, but tend to distribute most of their reflected energy around the direction defined by the reflection law of geometric optics.

It would seem convenient to break down the reflected light and the bidirectional reflection into two terms; a) the diffuse term that satisfies Lambert's law and b) the specular term that is responsible for the glossy reflection concentrated around the mirror direction:

$$R(\vec{L},\vec{V}) = R_d(\vec{L},\vec{V}) + R_s(\vec{L},\vec{V}),$$

$$I^{out} = I_d + I_s = I^{in}(\lambda)\cos\phi_{in}\, k_d + I^{in}(\lambda)\cos\phi_{in}\frac{R_s(\vec{L},\vec{V})}{\cos\theta}$$

Since $R_s(\vec{L},\vec{V})$ is relevant only when $\vec{V}$ is close to the mirror direction of $\vec{L}$:

$$R_s(\vec{L},\vec{V}) \approx \cos\phi_{in}\cdot\frac{R_s(\vec{L},\vec{V})}{\cos\theta}.$$

To describe the intensity peak mathematically, a bi-directional function had to be proposed, which is relatively smooth, easy to control and simple to compute. Phong used the $k_s\cos^n\psi$ function for this purpose, where ψ is the angle between the direction of interest and the mirror direction, n is a constant describing how shiny the surface is, and k_s is the specular coefficient representing the fraction of the specular reflection in the total reflected light.

Comparing this model to real world measurements we can conclude that the specular coefficient k_s does not depend on the object's "own color" (in the highlights we can see the color of the light source rather than the color of the object), but that it does depend on the angle between the mirror direction and the surface normal, as we shall see in the next section.

The simplified illumination formula (fig.2) is then:

$$I^{out}(\lambda) = I^{in}(\lambda)\cos\phi_{in}\, k_d(\lambda) + I^{in}(\lambda)\cos^n\psi\, k_s(\lambda,\phi_{in}).$$

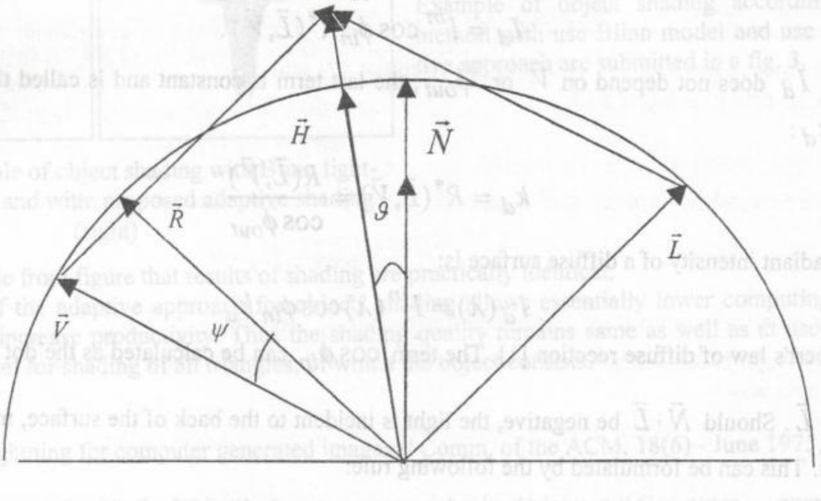

Figure 2. Phong and Blinn illumination models

$$f_{r,Блін}(N,H) = k_{дз}(\lambda)\cdot\cos^n\vartheta = k_{дз}(\lambda)\cdot(N\cdot H)^n,$$

$\vec{H}$ - halfway unit vector and can be calculated in the next way (fig.2):

$$\vec{H} = \frac{\vec{L} + \vec{V}}{\left|\vec{L} + \vec{V}\right|}.$$

According to Blinn model the color intensity can be calculated in

$$I^{out}(\lambda) = I^{in}(\lambda)\cos\phi_{in}\, k_d(\lambda) + I^{in}(\lambda)\, k_s(\lambda, \phi_{in})(\vec{N} \cdot \vec{H})^n.$$

The using of Lambert model is good for the mat surfaces or for the objects, which are produced only diffuse reflection. If the objects produced not only a diffuse reflection but and specular it is necessary to use Phong or Blinn models.

References:

[1] Foley, Van Dam, Feiner, and Hughes Computer Graphics // Principles and Practice. Addison Wesley. – Ch. 16. - 1996. - pp. 800-870.

[2] Phong B.T. Illumination for computer generated images // Comm. of the ACM. - 18(6). - June 1975. - pp. 311-317.

[3] Blinn J. F. Models of light reflection for computer synthesized pictures// Computer Graphics. - Vol. 11. - 1977. - pp. 192-198.