Illumination Models and Surface Rendering Methods

Realistic displays of a scene are obtained by perspective projection and applying natural light effects to the visible surfaces an illumination model (lighting model) and sometimes called shading model, is used to calculate the intensity of light that we should see at a given point on the surface of an object.

A surface rendering algorithm uses the intensity calculations from an illumination model to determine the light intensity calculation from an illumination model.

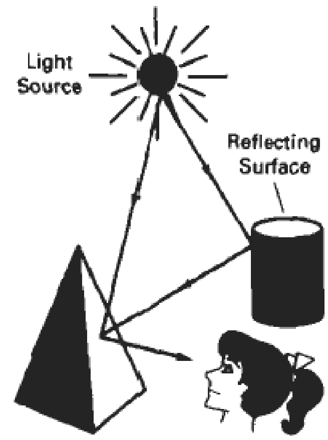
Light sources

Point source: tungsten filament bulb image can be seen

Distributed light source: fluorescent light

When light is incident on an opaque surface part reflected part
absorbed. Surface that are rough or grainy tend to scatter reflected light in all direction is called diffuse reflection

Light sources create highlights or bright spots called specular-reflection.



Ambient light surface directly not exposed directly but visible if nearby objects are illuminated

Combination of light reflections from various surfaces to produce a uniform illumination called the ambient light or background light(no shadow's produced)

It has no spatial or direction characteristics and amount on each object is a constant for all surfaces and over all directions

Diffuse reflection

Ambient light is an approximation of global diffuse, light effects .

Diffuse reflections are constant over each surface in a scene independent of viewing direction

k_d or diffuse reflection coefficient or diffuse reflectivity (0 to 1)

k_d is nearly 1 for highly reflective surface and k_d is 0 where light absorbs (black surfaces)

Diffuse reflection intensity at any point on the surface as

$$I_{ambDiff} = k_d \,.\, I_d$$

Where $I_{ambDiff}$ is ambient light due to diffusion and Id is light due to diffusion assuming diffuse reflections from the surface are scattered with equal intensity in all directions independent of the

Viewing direction (called "ideal diffuse reflectors") also called Lambertian reflectors and governed by Lambert's Cosine Law.

If "angle of incidence" between incoming light direction and surface normal is 0

$$I_{LDiff} = k_d \,.\, I_L \cos\theta$$

where I_{LDiff} is light due to diffusion

If N is unit normal vector to a surface and L is unit direction vector to the point light source then

$$I_{LDiff} = k_d \,.\, I_L (N \,.\, L)$$

In addition many graphics packages introduce an ambient reflection coefficient k_d to modify ambient light intensity k_d then

$$I_{Diff(i.e.\ total)} = k_a \,.\, I_a + k_d \,.\, I_L (N \,.\, L)$$

Assigning Intensity Levels (not in course)

To display n+1 successive intensity levels with equal perceived brightness the intensity levels on the monitor should be spaced so that ratio of successive intensities is constant.

$$I_1 / I_0 = I_2 / I_1 = \text{-----------------------------} = I_n / I_{n-1} = r \quad (0 < \text{intensity} < 1)$$

I_0 = lowest intensity level and I_n = highest intensity level

any intermediate intensity in term of I_0 $\quad I_k = r^k I_0$ to calculate r substituting k = n and $I_k = I_n = 1$

$$r = (1/I_0)^{1/n}$$

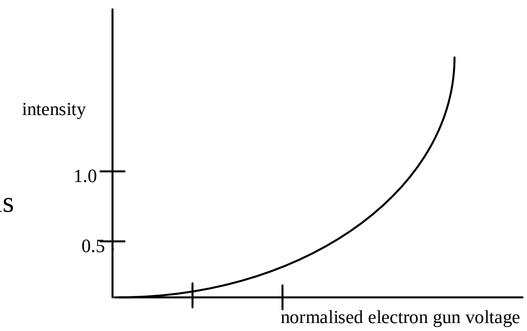
e.g. if $I_0 = ⅛$ and n = 3, r = 2 four intensities are ⅛ ¼ ½ and 1

Lowest intensity value I_0 depends on the characteristics of the monitor typically from 0.005 to 0.025

For B.W. monitor with 8 bits per pixel (n = 255) and $I_0 = 0.01$ r = 1.0182 and approximate values for the 256 intensities on the system are 0.01, 0.0102, 0.0104,………., 0.98211, and 1.00.

For color, we setup intensity levels for each component of the color models

Blue component of RGB $\quad I_{Bk} = r_B^{\,k} I_{B0} \quad$ where $r_B = \left(\dfrac{1}{I_{B0}}\right)^{1/n}$



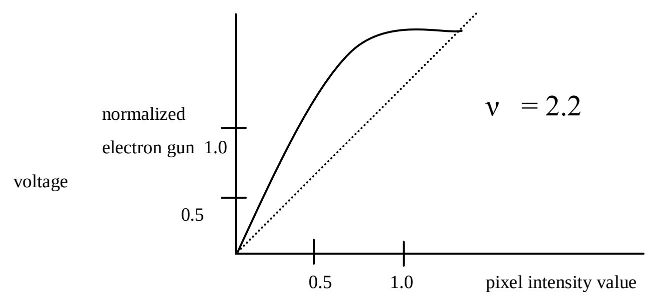
monitor response curve, showing display screen intensity as a function of normalized electron gun voltage

Gamma Correction and Video Look up Table **(not in course)**

Problem associated with the display of calculated intensities is the non linearity of display devices and illumination model produce a linear range of intensities.

Usually calculated intensities are stored in an image file as integer values (1 byte for each of three RGB components)

If we set the voltages for the electron gun to the linear pixel values the displayed intensities will be shifted according to the monitor response curve



video lookup correction curve

To correct for monitor nonlinearity graphics systems use a video lookup table that adjusts the linear pixel values

Monitor response curve is described by the exponential function

$I = a V^{\nu}$ $\quad$ and $\quad V = \left(\dfrac{I}{a}\right)^{\gamma}$ $\quad$ where, I = displayed Intensity, V = input parameter

a and ν depends on monitor characteristics

This calculation is referred to as "Gamma Correction of Intensity" , ν → 2 to 3 for NTSC ν = 2.2

We combine gamma correction with logarithmic intensity mapping to produce a lookup table that contains both conversions.

Intensity Attenuation (I A)

Intensity is attenuated by the factor $1/d^2$ (d – distance that light has traveled)

Graphics package have a general inverse quadratic attenuation function

$$F(d) = \frac{1}{a_0 + a_1 d^1 + a_2 d^2}$$

User can fiddle with a_0, a_1, a_2 to obtain a variety of lighting effects for a scene

Basic illumination model is modified as

$$I = k_a . I_a + \sum_{i=1}^{n} f(d_i)\ I_{Li}\ [\,k_d (N . L_i) + K_s (N . H_i)^{n_s}\,]$$

Color Considerations

Diffuse reflection coefficient vector for RGB component (K_{dR}, K_{dG}, K_{dB})

For blue reflectivity component ($K_{dR} = K_{dG} = 0$)

$$I_B = k_{aB} . I_{aB} + \sum_{i=1}^{n} f_i (d)\ I_{LB\,i}\ [\,k_{dB} (N . L_i) + K_{sB} (N . H_i)^{n_s}\,]$$

Another method diffuse and specular color vector

$$I_B = k_a S_{dB} . I_{aB} + \sum_{i=1}^{n} f_i (d)\ I_{LB\,i}\ [\,k_d S_{dB} (N . L_i) + K_s S_{sB} (N . H_i)^{n_s}\,]$$

Color specification with its spectral wavelength

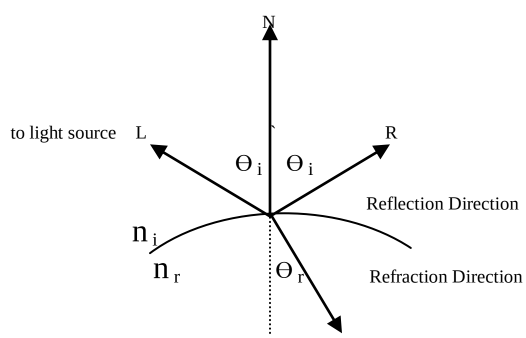
$$I = k_a S_d . I_a + \sum_{i=1}^{n} f_i (d)\ I_{L\,i}\ [\,k_d S_d (N . L_i) + K_s S_s (N . H_i)^{n_s}\,]$$

Transparency

A transparent surface in general produces both reflected and transmitted light

Θ_r = angle of refraction n_r - index of refraction

Θ_i = angle of incidence n_i - index of incidence



using Snell's law

$$\sin\Theta_r = \frac{n_r \sin\Theta_I}{n_i}$$

Also, $I = (1 - k_t) I_{reflect} + k_t I_{trans}$

Where, I_{trans} is transmitted intensity
I_{reflct} is reflected intensity
k_t transparency coefficient
$(1 - k_t)$ is the opacity factor

For highly transparent object k_t is near 1

For opaque objects k_t is near 0

Shadows

Hidden surface method can be used to locate area where light sources produce shadows

Once we have determined the shadow area for all light sources, the shadows could be treated as surface patterns and store in pattern arrays