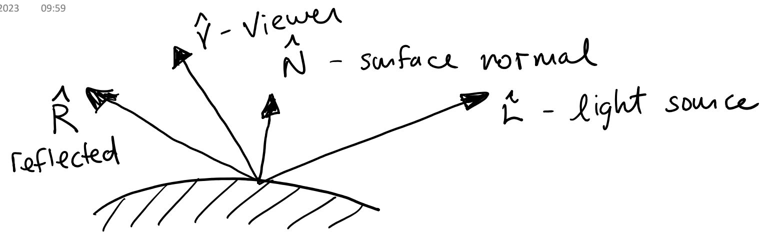
Ray Tracing - Material Properties

Monday, 27 February 2023 09:59



if $(\hat{L} \cdot \hat{N})$ large : Bright diffuse lighting

if $(\hat{R} \cdot \hat{V})$ large : Bright specular reflection

if "metalic" then specular color = light source color

else specular color $\cong$ material color

Light $\underline{I}_m = (R, G, B)$ intensity of infalling light

$\underline{A} = (R, G, B)$ intensity of the ambient light

Note $\underline{C}\,\underline{I} = \{C_r I_r, C_g I_g, C_b I_b\}$

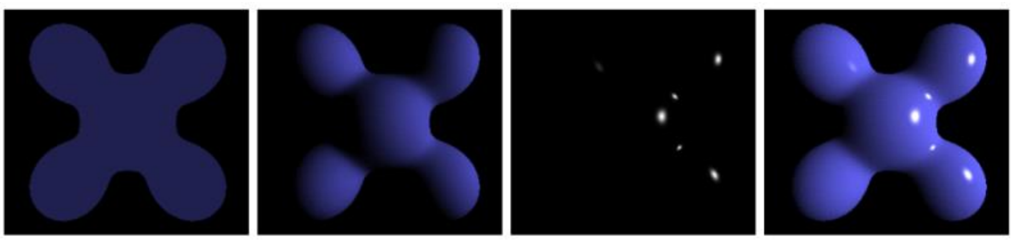
component-wise multiplication

Object $\underline{C} = (R, G, B)$ is the color of the object

$\underline{S}$ is the specular highlight color, which is linearly interpolated according to m_{sm}

Geometry + Material

Material
- m_a, m_d, m_s (ambient, diffuse, specular)
- η - for transparent objects
- m_{sp} — Phong exponent
- m_{sm} is the "metalness" parameter of the material (0 → very metalic)
- $\underline{C}$ color of the material



Ambient + Diffuse + Specular = Phong Reflection

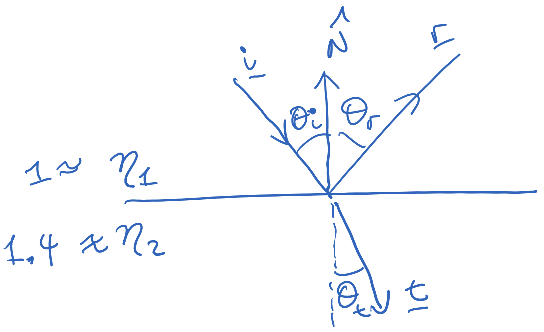
$$\rho = m_a \underline{C}\,\underline{A} + \sum_{m \in \text{Lights}} \Big[m_d \underline{C}\,\underline{I}_m \max(\hat{\underline{L}}_m \cdot \hat{N}, 0) + m_s \underline{S}\,\underline{I}_m \max(\hat{R}_m \cdot \hat{V}, 0)^{m_{sp}} \Big]$$

$$\underline{S} = m_{sm}\underline{C} + (1-m_{sm})(1,1,1)$$

$$\hat{R}_m = 2(\hat{L}_m \cdot \hat{N})\hat{N} - \hat{L}_m$$

Reflection and Refraction

$$\theta_i = \theta_r$$



$$n_1 \sin\theta_i = n_2 \sin\theta_t$$

(Snell's Law)

$$\sin\theta_t = \frac{n_1}{n_2}\sin\theta_i$$

$$\sin\theta_i > \frac{n_2}{n_1} \Rightarrow \text{TIR}$$

total internal reflection

$$\underline{t} = \underline{t}_\parallel + \underline{t}_\perp$$

FRESNEL EQUATIONS

$$T + R = 1$$

$$\boxed{\begin{aligned} R_\perp(\theta_i) &= \left(\frac{n_1\cos\theta_i - n_2\cos\theta_t}{n_1\cos\theta_i + n_2\cos\theta_t}\right)^2 \\ R_\parallel(\theta_i) &= \left(\frac{n_2\cos\theta_i - n_1\cos\theta_t}{n_2\cos\theta_i + n_1\cos\theta_t}\right)^2 \end{aligned}}$$

$$\sin^2\theta_t = \left(\frac{n_1}{n_2}\right)^2\sin^2\theta_i = \left(\frac{n_1}{n_2}\right)^2(1-\cos^2\theta_i)$$

$$\cos\theta_t = \sqrt{1-\sin^2\theta_t}$$

$$R(\theta_i) = \begin{cases} R_\perp(\theta_i) + R_\parallel(\theta_i) & \text{for !TIR} \\ 1 & \text{for TIR} \end{cases}$$

$$T(\theta_i) = 1 - R(\theta_i)$$

Schlick's Approx (optimization)

$$R_{Sch}(\theta_i) = R_0 + (1-R_0)(1-\cos\theta_i)^5$$

where $R_0 = \left(\dfrac{n_1 - n_2}{n_1 + n_2}\right)^2$

careful : $n_1 > n_2$

use $\cos\Theta_t$ instead of $\cos\Theta_i$

$$R_{SH}(\Theta_i) = \begin{cases} R_0 + (1-R_0)(1-\cos\Theta_i)^5 & n_1 < n_2 \\ R_0 + (1-R_0)(1-\cos\Theta_t)^5 & n_2 > n_1 \text{ and no TIR!} \\ 1 & \text{TIR} \end{cases}$$

$$\max(\hat{R}_m \cdot \hat{V}^{\alpha}, 0) = \max\left((1-\lambda)^{\beta\gamma}, 0\right) = \max\left(((1-\lambda)^{\beta}, 0)^{\gamma}\right)$$

where $\lambda = 1 - \hat{R}_m \cdot \hat{V}$ and $\beta = \frac{\alpha}{\gamma}$ small

$$\approx \max(1-\beta\lambda, 0)^{\gamma}$$

If we choose γ to be an integer power of 2, i.e., $\gamma = 2^n$

$(1-\beta\lambda)^{\gamma} \rightarrow$ square $(1-\beta\lambda)$ n-times

$$(1-\beta\lambda)^{\gamma} = (1-\beta\lambda)^{2^n} = (1-\beta\lambda)^{2\cdot2\cdot2\cdot2\cdots} = (\cdots((1-\beta\lambda)^2)^2\cdots)^2$$

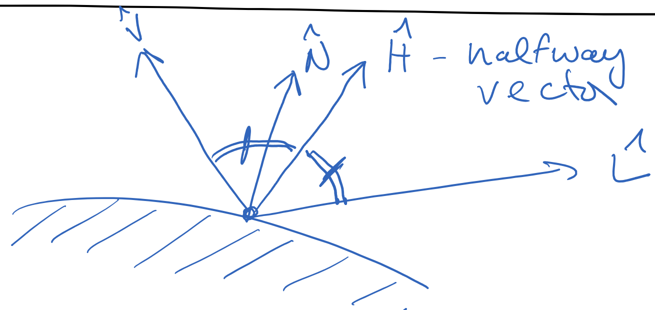
holds for sufficiently large γ (4 or 8)

$$\lambda = (\hat{R}_m - \hat{V}) \cdot (\hat{R}_m - \hat{V})/2$$

or

$$= (\hat{R}_m \times \hat{V}) \cdot (\hat{R}_m \times \hat{V})/2$$

Blinn-Phong Model



$$(\hat{R}_m \cdot \hat{V})^{\alpha} \longmapsto (\hat{N} \cdot \hat{H})^{\alpha'} \quad \alpha' > \alpha$$

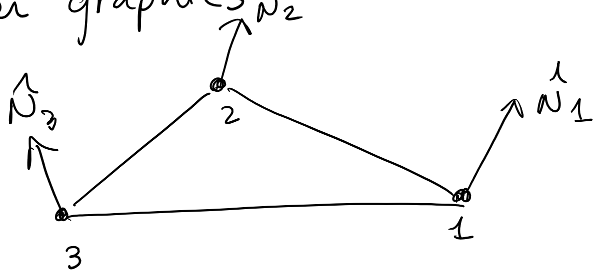
For a front lit surface $\alpha' = 4\alpha$

$\hat{H}$ is independent of position if $L \to$ "∞"

$\hat{H}$ is independent of position if $L \to$ "∞"
$V \to$ "∞"

$\hookrightarrow$ calculate this once.

Raster graphics



(Gouraud)
Shading