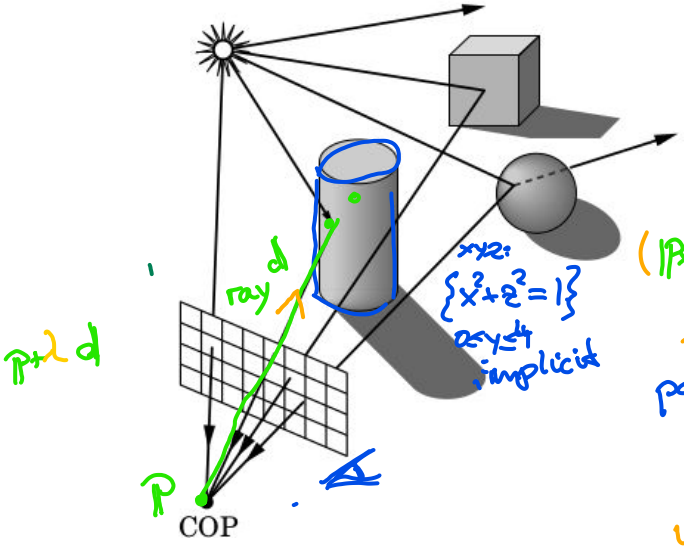
Illumination & Lighting

Ray Tracing: not supported by openGL
Path from light source to object to observer



Ray-object intersection reduces to root finding

find λ:

$x^2 + z^2 = 1$

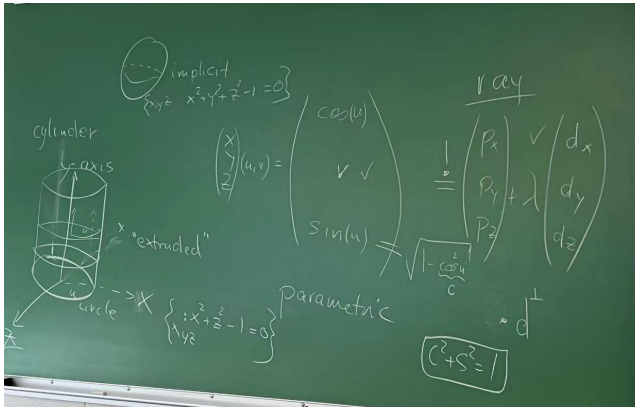
$(P_x+\lambda d_x)^2 + (P_z+\lambda d_z)^2 = 1$

$\lambda = \frac{\cdots \pm \sqrt{\cdots}}{\cdots}$

parametric

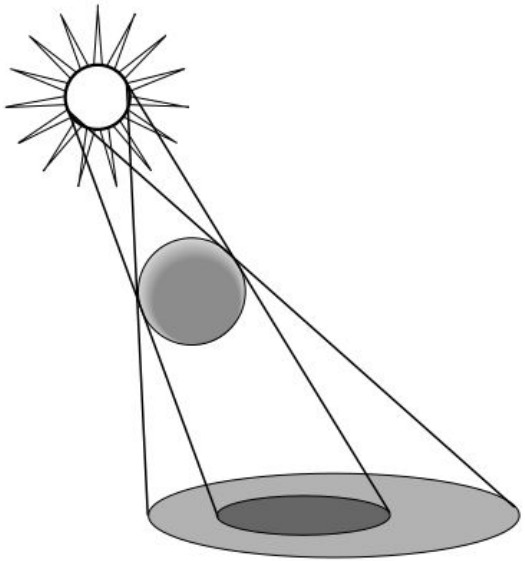
$\begin{pmatrix} \cos(u) \\ v \\ \sin(u) \end{pmatrix} = \begin{pmatrix} P \end{pmatrix} + \lambda \begin{pmatrix} d \end{pmatrix}$

u, v, λ $\qquad c^2+s^2=1$



Illumination & Lighting

Interreflection: soft shadows, color bleeding, umbra, penumbra, shadows



Global Illumination

energy preservation

bi-directional reflectance distribution function

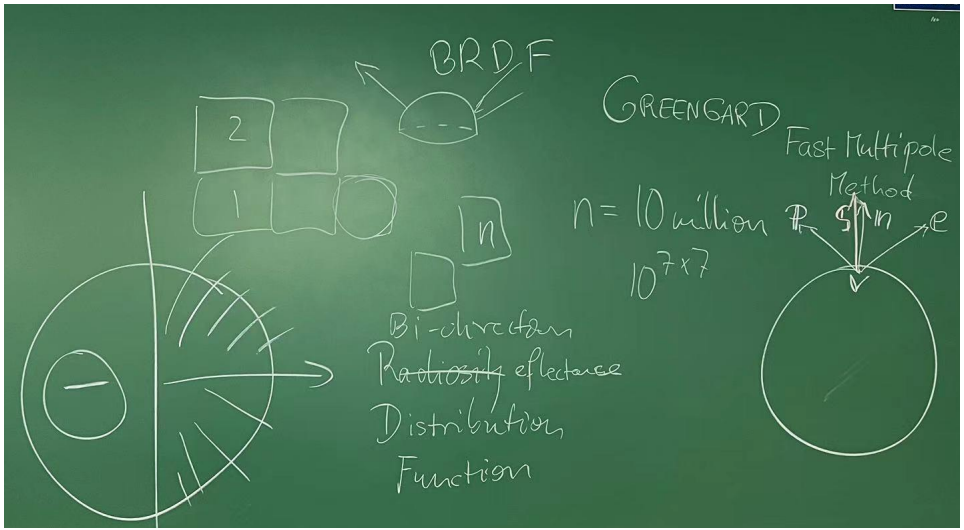
$f(\varphi, \theta, \lambda) = \iint \text{-brdf } d\omega d\nu$

n panels (elements) in scene...

n^2 interactions...

⇓ too slow Hierarchical hierarchy

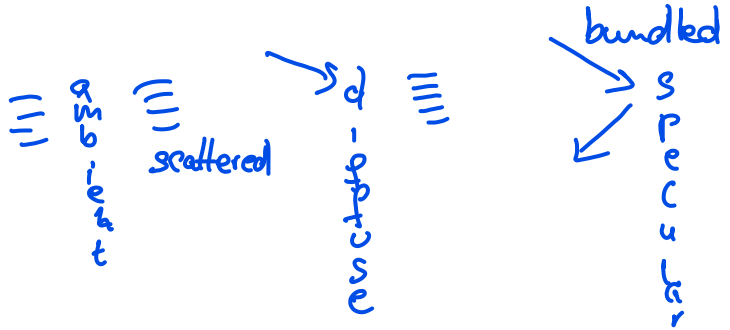
hierarchical interaction until steady state



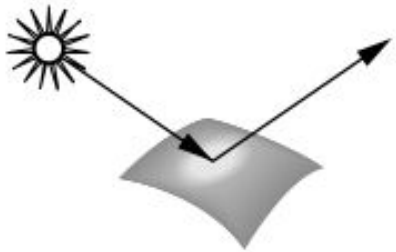
OpenGL's approximation of global illumination and ray tracing

Spectrum→ RGB (no refraction, incadescence)
Radiosity in→ sum over light sources
(no soft shadows,color bleed)
BRDF→ ambient,diffuse,specular
Radience→ intensity

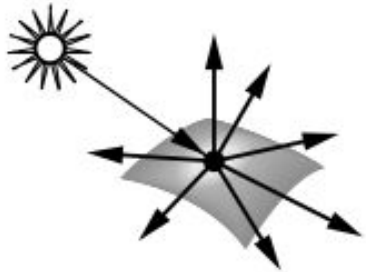
accumulation buffer



OpenGL's approximation of global illumination and ray tracing



Specular (Phong)
laser beam, mirror



Diffuse (Lambertian)
nature, equal scattering
(but still directional light source)

Ambient (global energy)
background glow,
equal scattering

OpenGL lighting model

$$\text{intensity} := \text{emission}_m + \text{ambient}_l \cdot \text{ambient}_m + \sum_{\text{lights}} \frac{1}{k_0 + k_1 d + k_2 d^2} \cdot \text{spot}_\ell \cdot \ldots$$

$$\left(\text{ambient}_\ell \cdot \text{ambient}_m + \max\{\frac{\mathbf{p}-\mathbf{v}}{d} \star \mathbf{n}, 0\}\text{diffuse}_\ell \cdot \text{diffuse}_m \ldots\right.$$

$$\left. + \quad \max\{\mathbf{s} \star \mathbf{n}, 0\}^{\text{shininess}}\text{specular}_\ell \cdot \text{specular}_m\right)$$

where

m	=material	ℓ	=light source	l	=lighting model
$\mathbf{v}$	=vertex	$\mathbf{n}$	=normal	$\mathbf{p}$	=light position
$\mathbf{e}$	=eye position	d	$:= \|\mathbf{p}-\mathbf{v}\|$	$\mathbf{s} := \frac{\mathbf{s}'}{\|\mathbf{s}'\|}$	$\mathbf{s}' := \frac{\mathbf{p}-\mathbf{v}}{\|\mathbf{p}-\mathbf{v}\|} + \frac{\mathbf{e}-\mathbf{v}}{\|\mathbf{e}-\mathbf{v}\|}$

Here specular_ℓ, specular_m etc. are scalars.

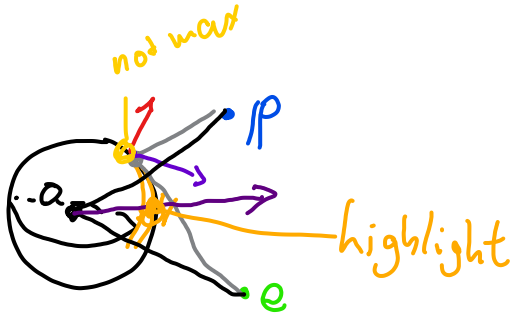
Formula applies separately to RGB

Lights are objects affected by model-view transformations.

OpenGL Lighting

Given a unit sphere, where is the highlight (= point of highest intensity)?
Compute this for some choice of e and p. (Reduce to plane through 0, e, p since n lies in that plane.)

screenshot?

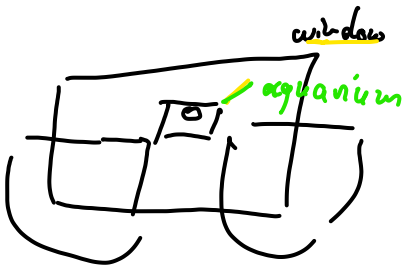


Translucency

If vertex v_j has
opaqueness value α_j and intensity i_j
is drawn before v_{j+1} then the intensity is

$$\alpha_0 \mathbf{i}_0 + (1-\alpha_0)(\alpha_1 \mathbf{i}_1 + (1-\alpha_1)(\ldots))$$

0.3 rgb 0.7 0.1 0.9



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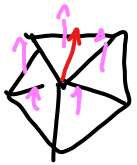


Computing Normals

Surface in *implicit* representation $p(\mathbf{x}) = p(x, y, z) = 0$.

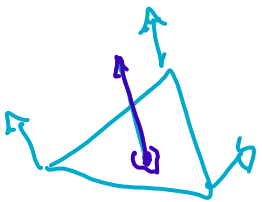
The normal direction is the (normalized) gradient $\nabla p = \begin{bmatrix} \frac{\partial}{\partial x} p \\ \frac{\partial}{\partial y} p \\ \frac{\partial}{\partial z} p \end{bmatrix}$

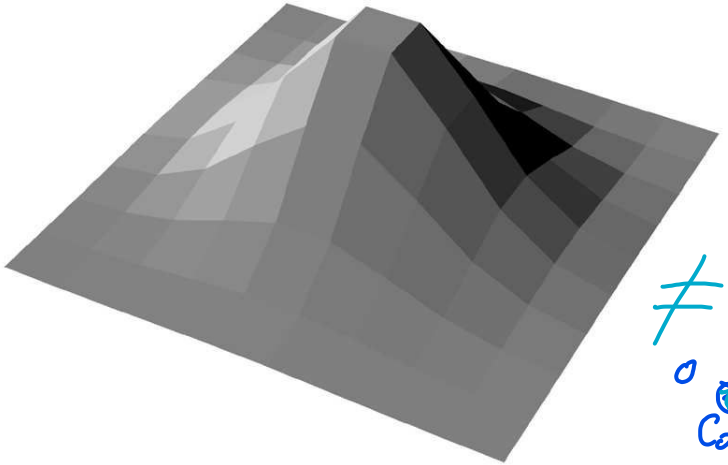
Surface in *parametric* representation $\mathbf{x}(u, v) = \begin{bmatrix} x(u, v) \\ y(u, v) \\ z(u, v) \end{bmatrix}$.

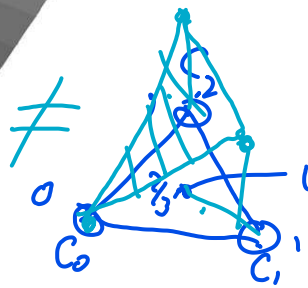
The normal direction is $\frac{\partial \mathbf{x}}{\partial u} \times \frac{\partial \mathbf{x}}{\partial v}$. To obtain the normal, normalize the normal direction to length 1.

Blackboard Examples: $p(\mathbf{x}) = x^2 + y^2 + z^2 - 1$, $\mathbf{x}(u, v) = \begin{bmatrix} \cos(u)\cos(v) \\ \cos(u)\sin(v) \\ \sin(u) \end{bmatrix}$

Polygon Shading







Flat

Gouraud : averaged vertex color using barycentric weights.

Phong: averaged vertex normal (and other lighting factors)

Dithering, fog, blur