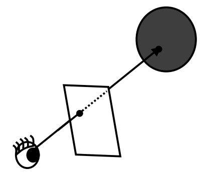
cs155 – z sweedyk

ray tracing

ray casting



- cast ray through pixel into scene
- find intersection point (if any) that is closest to eye
- **compute color at intersection**

color

the color of a point on a surface depends on

- lights in scene
- material properties of surface
- geometry of scene

color

for each channel we'll **approximate** the color at the intersection point as the sum of four terms

- emission
- ambient reflection
- diffuse reflection
- specular reflection

We'll describe the terms for the red channel.

color

for each channel we'll approximate the color at the intersection point as the sum of four terms

- **emission**
- ambient reflection
- diffuse reflection
- specular reflection

red emission term

mer the material red emission

NOTE: terms shown in red are input parameters

red

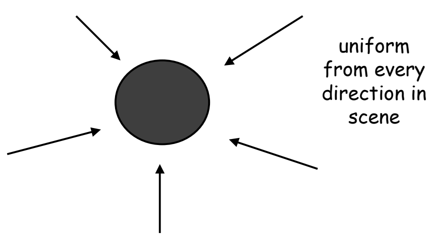
red = *mer* + ...

color

for each channel we'll approximate the color at the intersection point as the sum of four terms

- emission
- **ambient reflection**
- diffuse reflection
- specular reflection

ambient light



red ambient term

the red ambient term is *ar* * *mar* where

- *ar* is the red intensity of the ambient light
- *mar* is the response of the surface to red ambient light

red

red = *mer* + *ar* * *mar* + ...

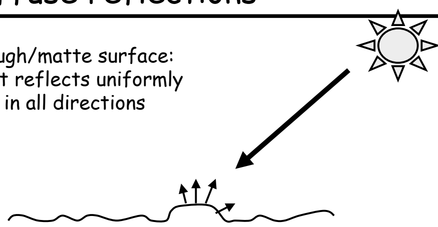
color

for each channel we'll approximate the color e at the intersection point as the sum of four terms

- emission
- ambient reflection
- **diffuse reflection**
- specular reflection

diffuse reflections

rough/matte surface:
light reflects uniformly
in all directions



diffuse reflections provide the surface "color"

red diffuse term

the red diffuse reflection term is $\Sigma R_{L,D}$ where

- the summation is taken over all lights L
- $R_{L,D}$ is the intensity of the red, diffuse reflection of light L at the intersection point

Note: terms in green are explained in subsequent slides

$R_{L,D}$

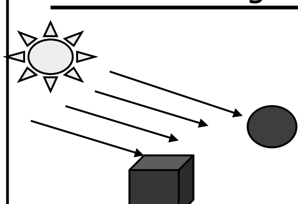
depends on

- type of light
- geometry of scene
- material properties of surface

types of lights

- directional light
- point light
- spot light

directional light



- light positioned at "infinity"; intensity and incident angle are constant for all points in scene
- specification
  - direction
  - red, green, and blue intensity

$R_{L,D}$ for directional light L

$R_{L,D}$ = 0 if L is occluded

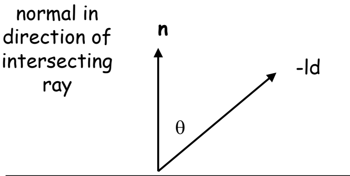
$R_{L,D} = mdr \cdot lr \cdot \max(0,(\mathbf{n} \bullet -\mathbf{ld}))$ otherwise

- *mdr* is the diffuse response of the surface material to red light
- *lr* is the red intensity of light L
- **n** is the unit normal of the surface at the point of intersection
- **ld** is a unit vector in direction the light falls

Note: you need to compute terms in blue

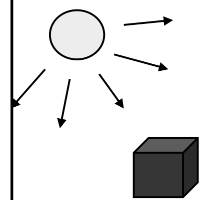
normal

normal in direction of intersecting ray



reflection decreases as θ increases. if $|\theta| > 90°$ the light falls on the other side of the surface and is not reflected

point light



- light emanates uniformly in all directions
- specification
  - location in world coordinates
  - red, green, and blue intensity
  - how the light drops off with distance

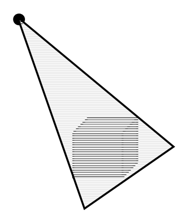
$R_{L,D}$ for point light L

$R_{L,D}$ = 0 if L is occluded

$R_{L,D} = A \cdot mdr \cdot lr \cdot \max(0, \mathbf{n} \bullet -\mathbf{ld})$ otherwise

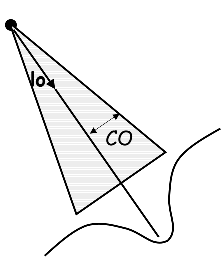
- *mdr* , *lr* , and **n** are as previously defined
- **ld** is the unit vector **from** the light position P_L to the intersection point
- $A = 1/(ca + la * d + qa * d^2)$ is the attenuation term, d is the distance between the light and the surface point

spot light



- light emanates in a cone
- specifications
  - location in world coordinates
  - red, green, and blue intensity
  - how the light drops off with distance
  - **how light drops with angle from center**

spot light



- light emanates in a cone
- specifications
  - location in world coordinates
  - red, green, and blue intensity
  - how the light drops off with distance
  - **how light drops with angle from center**
    - light orientation vector **lo**
    - cutoff angle *CO*
    - drop off exponent DO

$R_{L,D}$ for spot light L

$R_{L,D}$ = 0 if L is occluded

$R_{L,D} = A \cdot SP \cdot mdr \cdot lr \cdot \max(0,(\mathbf{n} \bullet -\mathbf{ld}))$ where

- A, *mdr, lr*, and **ld** are as previously defined
- SP is the “spot light effect”
  - SP=0 if angle between lo and ld is greater than *CO*
  - SP = $\max(0, ld \bullet lo)^{128*DO}$ otherwise

where does the 128 come from? what should you do about it?

Diffuse reflection term for each light L

$R_{L,D}$ = 0 if L is occluded

$R_{L,D} = A \cdot SP \cdot mdr \cdot lr \cdot \max(0,(\mathbf{n} \bullet -\mathbf{ld}))$

spot light effect (SP=1 for directional and point lights)

positional/spot light attenuation (A=1 for directional light)

red

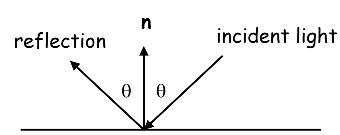
red = $mer + ar * mar + \Sigma_L R_{L,D} + \ldots$

color

for each channel we'll approximate the color at the intersection point as the sum of four terms

- emission
- ambient reflection
- diffuse reflection
- **specular reflection**

specular reflections



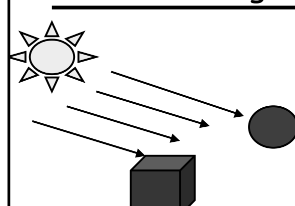
specular reflections provide highlights

red specular

the red specular reflection term is $\Sigma_L R_{L,S}$ where

- the summation is taken over all lights L
- $R_{L,S}$ is the intensity of the red, specular reflection of light L at the intersection point (details to follow shortly)

directional light



light positioned at infinity; intensity and incident angle are constant for all surface points in scene

$R_{L,S}$ for directional light L

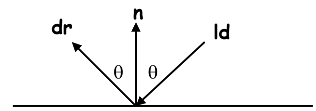
$R_{L,S} = 0$ if light is occluded

$R_{L,S} = msr \cdot lr \cdot \max(0,(-v \bullet \mathbf{dr}))^{128 * k_{spec}}$ otherwise

- *msr* is the specular response of the surface material to red light
- *lr is* as previously defined
- v is the direction of the incoming ray
- **dr** is a unit vector in the direction of reflection
- k_{spec} is the shininess constant

where does the 128 come from? what should you do about it?

vector of reflection



compute **dr** given **n** and **ld**

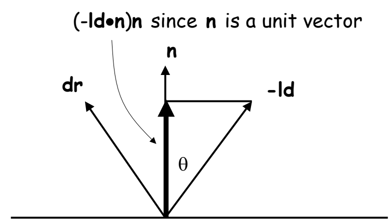
(all unit vectors)

$R_{L,S}$

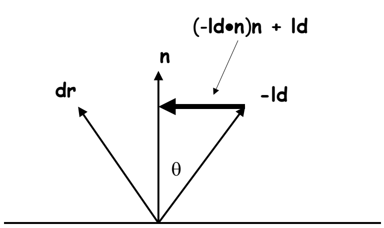
depends on

- type of light
- geometry of scene
- material properties of surface

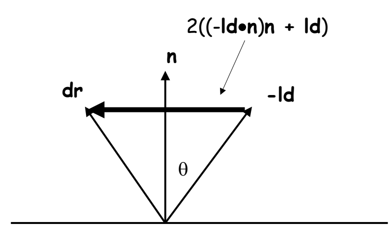
vector of reflection



vector of reflection

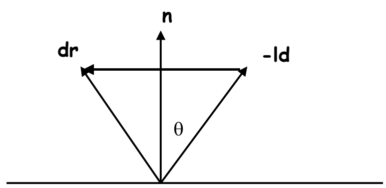


vector of reflection

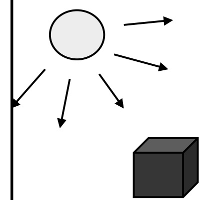


vector of reflection

$\mathbf{dr} = -\mathbf{ld} + 2((-\mathbf{ld} \bullet \mathbf{n})\mathbf{n} + \mathbf{ld}) = \mathbf{ld} + 2(-\mathbf{ld} \bullet \mathbf{n})\mathbf{n}$



point light



- light emanates uniformly in all directions
- specification
  - location in world coordinates
  - red, green, and blue intensity
  - how the light drops off with distance

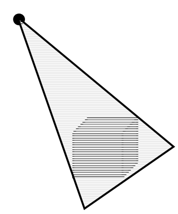
$R_{L,S}$ for point light L

$R_{L,S}$ = 0 if light is occluded

$R_{L,S} = A \cdot msr \cdot lr \cdot \max(0,(-\mathbf{v} \bullet \mathbf{dr}))^{128*k_{spec}}$
otherwise

all terms are as previously defined

spot light



- light emanates in a cone
- specifications
  - location in world coordinates
  - red, green, and blue intensity
  - how the light drops off with distance
  - how light drops with angle from center

Specular reflection term for each light L

$R_{L,S}$ = 0 if L is occluded
$R_{L,S} = A \cdot SP \cdot msr \cdot lr \cdot \max(0,(-\mathbf{v} \bullet \mathbf{dr}))^{128*k_{spec}}$

spot light effect (SP=1 for directional and point lights)

positional/spot light attenuation (A=1 for directional lights)

$R_{L,S}$ for spot light L

$R_{L,S}$ = 0 if L is occluded

$R_{L,S} = A \cdot SP \cdot msr \cdot lr \max(0,(-\mathbf{v} \bullet \mathbf{dr}))^{128*k_{spec}}$
otherwise

all terms are as previously described

red

red = $mer + ar * mar + \Sigma_L (R_{L,D} + R_{L,S})$

occlusion

what about occlusions? (i.e. shadows)

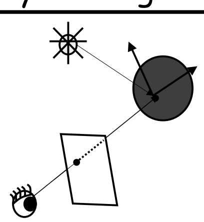
ray tracing

- simple ray casting
- **recursive ray tracing**
- cheap tricks
- optimizations

global effects

- shadows
- indirect specular reflection
- indirect specular transmission

ray tracing



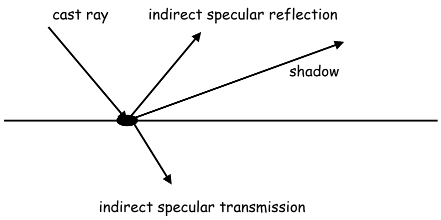
- cast ray through pixel into scene
- find closest intersection (if any)
- compute luminance at intersection
  - direct illumination (**no occlusions**)
  - **indirect reflection and occlusions**

color: ray tracing

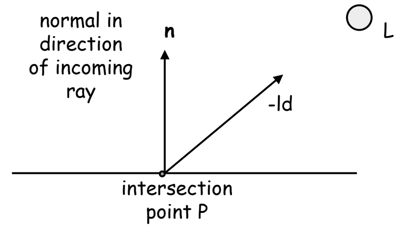
for each channel we'll approximate the color at the intersection point as the sum of five terms

- emission
- ambient reflection
- diffuse reflection **(check for occlusion)**
- specular reflection **(check for occlusion)**
- **recursive term**

recursive rays

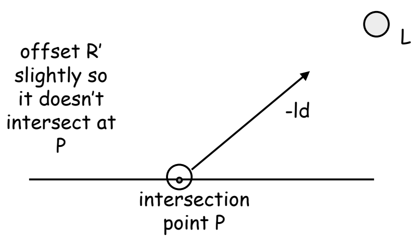


occlusion (shadows)



light L is occluded if the ray R'=(P,-ld) intersects some object in the scene

occlusion: implementation



L is occluded if the ray (P,-ld) intersects some object in the scene

global effects

- shadows
- indirect specular reflection
- indirect specular transmission

next time