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

For each channel, we'll approximate the color at the intersection point as the sum of five terms:
- emission
- ambient reflection
- diffuse reflection
- specular reflection
- specular transmission

We'll describe the terms for the red channel.

Red emission term

*mer* the material red emission

Note: terms shown in red are input parameters
ambient light

uniform from every direction in scene

red ambient term

the red ambient term is \( ar \cdot mar \) where
- \( ar \) is the red intensity of the ambient light
- \( mar \) is the response of the surface to red ambient light

color

for each channel we’ll approximate the color \( e \) at the intersection point as the sum of five terms
- emission
- ambient reflection
- diffuse reflection
- specular reflection
- specular transmission

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 \( \sum R_{L,D} \) 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

\( R_{L,D} \)

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

Note: terms in green are explained in subsequent slides
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

\[ R_{L,D} = \begin{cases} 0 & \text{if } L \text{ is occluded} \\ \text{otherwise} \\ \frac{mdr \cdot lr \cdot \max(0, (n \cdot -ld))}{m} & \end{cases} \]

- 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

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

\[ R_{L,D} = \begin{cases} 0 & \text{if } L \text{ is occluded} \\ \text{otherwise} \\ A \cdot mdr \cdot lr \cdot \max(0, n \cdot -ld)) & \end{cases} \]

- mdr, lr, and n are as previously defined
- ld is the unit vector from the light position P_L to the intersection point
- \( A = 1/(ca + la \cdot d + qa \cdot d^2) \) 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

**RL,D for spot light L**

\[ R_{L,D} = 0 \text{ if } L \text{ is occluded} \]

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

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 \( CO \)
  - \( SP = \max(0, ld \cdot lo)^{\text{drop off exponent DO}} \) otherwise

**Diffuse reflection term for each light L**

\[ R_{L,D} = 0 \text{ if } L \text{ is occluded} \]

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

**color**

for each channel we’ll approximate the color at the intersection point as the sum of five terms
- emission
- ambient reflection
- diffuse reflection
- specular reflection
- specular transmission

**specular reflections**

specular reflections provide highlights
red specular

the red specular reflection term is 
\[(1-k_{\text{trans}}) \sum R_{L,S} \]
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)

vector of reflection
\[dr = (-ld \cdot n) \text{ since } n \text{ is a unit vector} \]
\[\theta = \theta \]

directional light

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

vector of reflection
\[dr \text{ given } n \text{ and } ld \]
(all unit vectors)

\(R_{L,S}\) for directional light \(L\)

\[R_{L,S} = 0 \text{ if light is occluded} \]
\[R_{L,S} = msr \cdot lr \cdot \max(0,(-v \cdot dr)) \cdot 128 \cdot k_{\text{spec}} \]
on 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
- \(k_{\text{spec}}\) is the shininess constant

\(R_{L,S}\) depends on
- type of light
- geometry of scene
- material properties of surface
The vector of reflection is given by:

$$dr = -ld + 2((-ld \cdot n + ld) \cdot n + ld)$$

For point light $L$, the illumination $R_{LS}$ is:

$$R_{LS} = \begin{cases} 0 & \text{if light is occluded} \\ A \cdot m \cdot r \cdot \max(0, (-v \cdot dr))^{128} \cdot k_{spec} & \text{otherwise} \end{cases}$$

where all terms are as previously defined.

For spot light, the illumination is:

$$R_{LS} = \begin{cases} \text{light emanates in a cone} & \\ \text{specifications} & \\ \text{- location in world coordinates} & \\ \text{- red, green, and blue intensity} & \\ \text{- how the light drops off with distance} & \\ \text{- how light drops with angle from center} & \\ \end{cases}$$
Specular reflection term for each light L

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

Spot light effect

Positional/spot light attenuation

R\_L\_S for spot light L

- $R_{LS} = 0$ if L is occluded
- $R_{LS} = A \cdot \text{SP} \cdot msr \cdot lr \cdot \max(0, (-v \cdot dr))^{128 \cdot k_{spec}}$
  otherwise

All terms are as previously described

Color

For each channel, we'll approximate the color at the intersection point as the sum of five terms:
- Emission
- Ambient reflection
- Diffuse reflection
- Specular reflection
- Specular transmission

Thin surface for now