Imatge Sintètica

Ray Tracing for Realistic Image Synthesis

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Lecture 3 - Direct Illumination

2017/2018

Class Outline

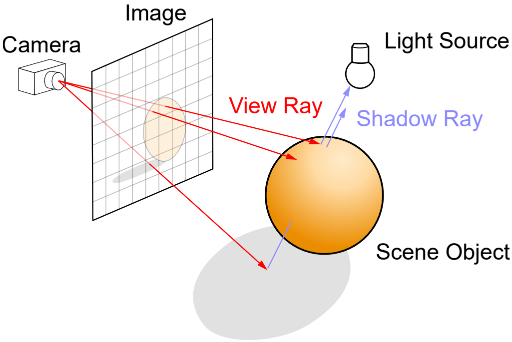
Lecture 3 - Direct Illumination

Last Class Summary

- We have seen basic ray tracing concepts such as:
  - Commonly used coordinate spaces
    - World space, object space, camera space
    - Image space, NDC
  - How to define a ray
  - The orthographic and perspective camera models
  - How to generate camera rays using these camera models
  - How to compute ray-sphere intersections
- Used this knowledge to generate our first ray tracing image in Assignment 2

Recall: The Ray Tracing Principle

- Use rays to compute the light that enters the virtual camera
  - Simulate the light propagation from light sources
  - Model the light interaction with the scene materials

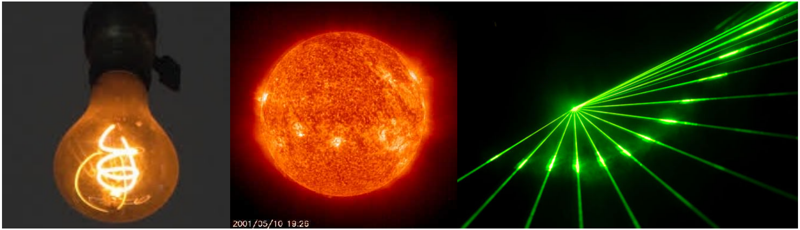


Section 2

Light Sources & Lighting Effects

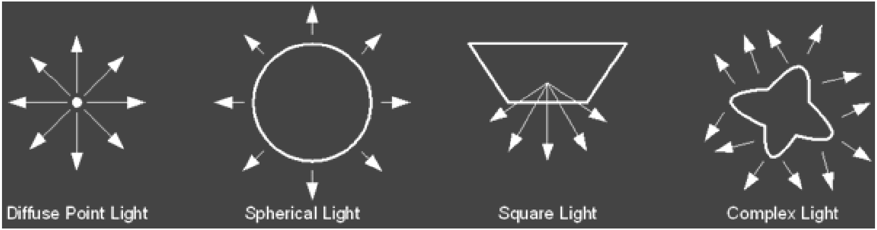
Light Sources

- A light source emits light
- Examples of light sources



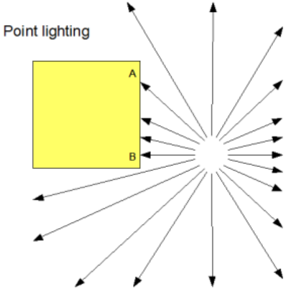
Light Sources

- There are different types of light sources
  - Different areas and shapes
  - Different power, different color
  - Can emit light differently in different directions

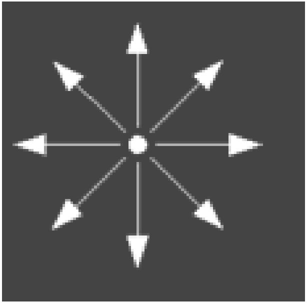


Diffuse Point Light Sources

- Precise characterization of light sources is too advanced for this course (requires radiometric notions!)
- We will only consider **diffuse point light sources**



[Image from learningWebGl.com]



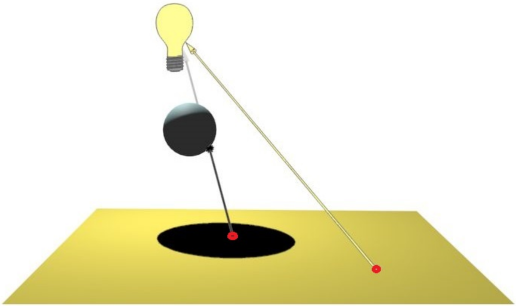
[Image from wikidot.com]

Diffuse Point Light Sources

- Called **diffuse** because they emit light with the same *intensity* I_L in all directions
- Called **point light** because they have no mass (infinitely small)
- Do not exist in reality
- Simple to implement and very efficient to sample

Diffuse Point Light Sources

- Visibility of a point light source can be determined using a single ray



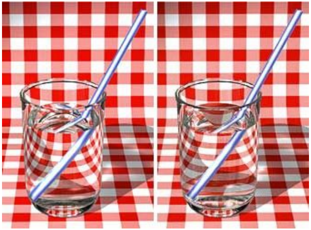
[Image from gamasutra.com]

- The direct light $L_i(\mathbf{p})$ arriving at a point $\mathbf{p}$ from a point light source with position $\mathbf{p}_L$ is decreases with the distance d between $\mathbf{p}$ and $\mathbf{p}_L$:

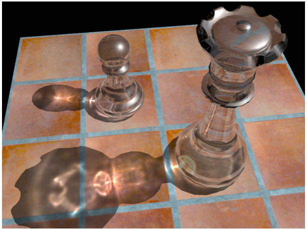
$$L_i(\mathbf{p}) = I_L/d^2, \quad \text{where} \quad d = \|\mathbf{p} - \mathbf{p}_L\|$$

Lighting Effects

- There are different types of light/matter interaction
  - Reflections at the surface
  - Refraction (when light changes propagation medium)
  - Caustics
  - Subsurface scattering, etc...



(a) Refraction

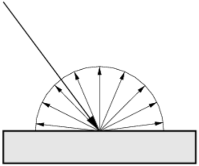


(b) Caustics

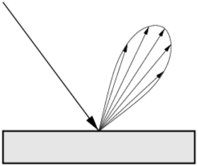
(b) Subsurface Scattering

Reflections at the Surface

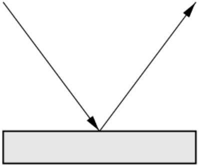
- For now, will only consider *reflections* at the surface:



(a) Perfect diffuse reflection

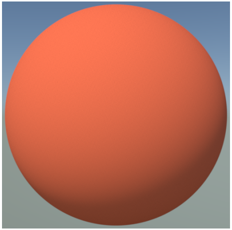


(b) Glossy specular reflection

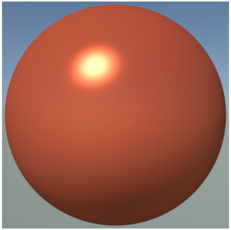


(c) Perfect specular reflection

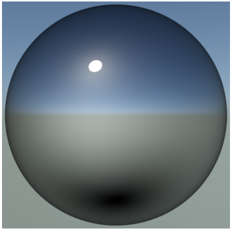
- Examples of materials



(a) Perfect diffuse material



(b) Glossy specular material



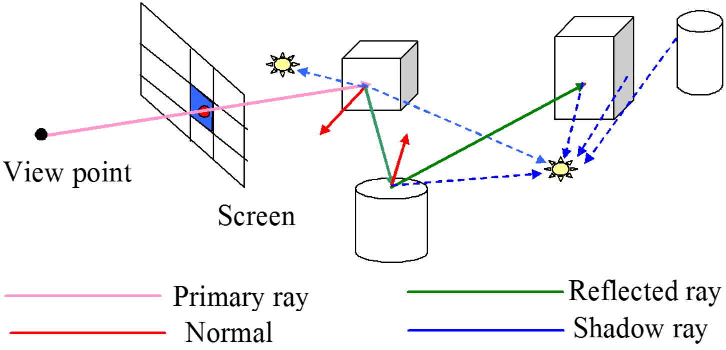
(c) Perfect specular material

Section 3

Direct Illumination With Surface Reflections

Direct (Local) VS Global Illumination

- *Direct Illumination*: only the light arriving directly from the light sources to the shading points is taken into account
- *Global Illumination*: account also for light reflected once or more times on other scene objects



Direct and Indirect Light Components

Direct

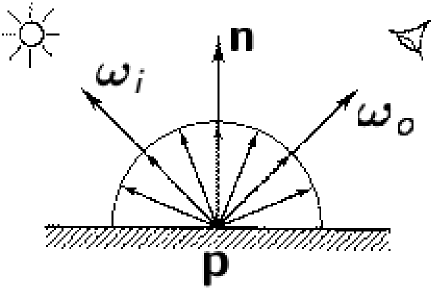
Indirect

Direct + Indirect

- **For now**, we will only deal with direct illumination

Appearance of a Shading Point due to Direct Illumination

- For a single light source, the *outgoing* light $L_o(\mathbf{p}, \omega_o)$ reflected at point $\mathbf{p}$ in the direction ω_o depends on:
  - The angle of incidence of light ω_i, given by the direction of the light source as seen from point $\mathbf{p}$
  - The amount of light arriving at the shading point $(L_i(\mathbf{p}))$
  - The *reflectance* of the material of the shading point $(r(\omega_i, \omega_o))$

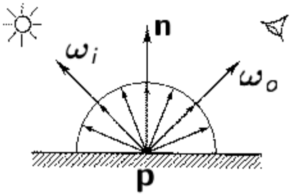


Appearance of a Shading Point due to Direct Illumination

- Assumption: the scene has a single light source L
- The outgoing light $L_o(\boldsymbol{\omega}_o)$ reflected at the shading point $\mathbf{p}$ in the direction $\boldsymbol{\omega}_o$ is then given by:

  $$L_o(\omega_o) = L_i(\mathbf{p})\, r(\omega_i, \omega_o)\, V(\mathbf{p})$$

  where $V(\mathbf{p})$ is called the *visibility term*
- If the light source is visible from $\mathbf{p}$, then $V(\mathbf{p}) = 1$, otherwise $V(\mathbf{p}) = 0$



Appearance of a Shading Point due to Direct Illumination

- If there are multiple light sources in the scene, *all of them* must be taken into account.

- The outgoing light $L_o(\boldsymbol{\omega}_o)$ reflected at the shading point $\mathbf{p}$ in the direction $\boldsymbol{\omega}_o$ is then given by:

$$L_o(\boldsymbol{\omega}_o) = \sum_{s=1}^{nL} L_i^s(\mathbf{p})\, r(\boldsymbol{\omega}_i^s, \boldsymbol{\omega}_o)\, V_i^s(\mathbf{p})$$

  where nL is the number of light sources

- **But**. . . we need to know the *reflectance* function $r(\boldsymbol{\omega}_i, \boldsymbol{\omega}_o)$

Section 4

Phong Reflection Model

Phong Model

- Empirical model of reflectance at a surface
  - Deals with diffuse and specular reflections

- Using the Phong model, the reflectance is given by:

$$r(\omega_i, \omega_o) = r_d(\omega_i, \omega_o) + r_s(\omega_i, \omega_o)$$

  where:

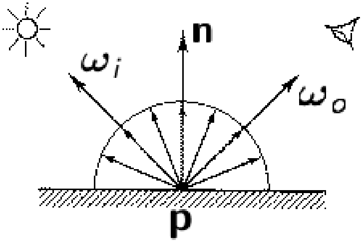
  - r_d: diffuse reflectance
  - r_s: specular reflectance

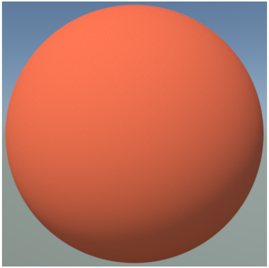
Diffuse Reflection (Lambert)

- Part of the incident light is reflected with the same intensity in all the directions

$$r_d(\omega_i, \omega_o) = k_d \cos(\mathbf{n}, \omega_i)$$

- k_d is the diffuse object color
- $\mathbf{n}$ is the normal at $\mathbf{p}$
- ω_i is the incident light direction
- r_d does not depend on ω_o

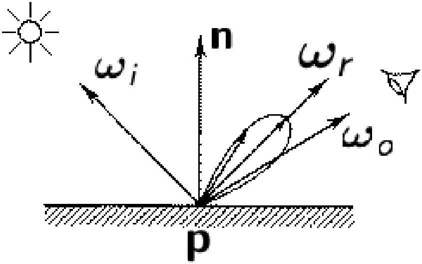


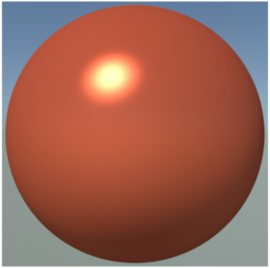


Specular Reflection

- Part of the incident light is reflected preferentially in one direction (ω_r, the ideal reflection direction)
  - ω_r depends on the incident light direction ω_i

$$\omega_r = 2\,(\mathbf{n} \cdot \omega_i)\,\mathbf{n} - \omega_i$$



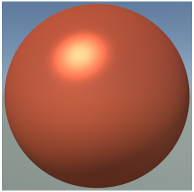


Specular Reflection

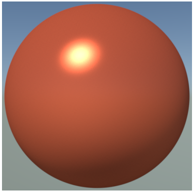
- Part of the incident light is reflected preferentially in one direction (ω_r, the ideal reflection direction)

$$r_s(\omega_i, \omega_o) = k_s \cos^n(\omega_o, \omega_r)$$

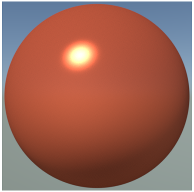
- k_s is the specular object color
- n is the shininess coefficient (or roughness)



(a) $n = 20$



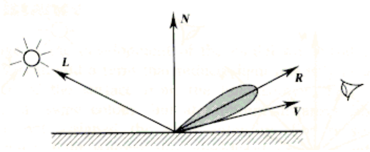
(b) $n = 50$



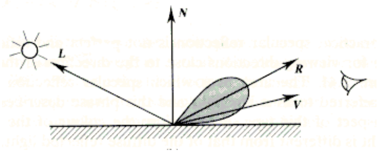
(c) $n = 80$

Specular Reflection

- The value of n determines the size of the cosine lobe ...
- ... which determines how large is the specular highlight



(a) $n = 50$



(b) $n = 20$

- In (a), the contribution of L to the light arriving at the viewer is smaller than in (b)

Putting it all together

- The outgoing light $L_o(\omega_o)$ reflected at point $\mathbf{p}$ in the direction ω_o is then given by:

$$L_o(\omega_o) = \sum_{s=1}^{nL} L_i^s(\mathbf{p})\, r(\omega_i^s, \omega_o)\, V_i^s(\mathbf{p})$$

- Using the Phong model, the reflectance is given by:

$$r(\omega_i, \omega_o) = r_d(\omega_i, \omega_o) + r_s(\omega_i, \omega_o)$$

where

$$r_d(\omega_i, \omega_o) = k_d \cos(\mathbf{n}, \omega_i)$$

and

$$r_s(\omega_i, \omega_o) = k_s \cos^n(\omega_o, \omega_r)$$

- So we can now compute direct illumination!

Lecture Summary

- Learned how to account for the contribution of point light sources to the illumination at a point
- Learned different lighting effects (light material interaction)
- Used the Phong reflection model (empirical) to model reflections at the surface (diffuse and glossy)

A Glance on the Next Classes

- Practicals and Seminars
  - Consolidate the concepts learned in Lecture 3 by implementing a direct illumination in RTIS
- Next Lecture
  - Learn how to intersect rays with other geometric primitives, such as an infinite plan and triangles
  - Learn how to simulate transmissions and perfect mirror reflections