COSC 414/519I: Computer Graphics

2023W2

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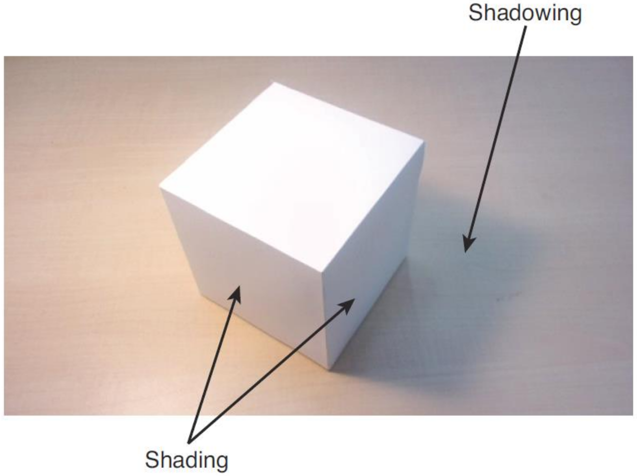
Lighting and Shading 3D Objects

- In the real world, two important phenomena occur when light hits an object:
  - Depending on the light source and direction, surface color is shaded.
  - Depending on the light source and direction, objects "cast" shadows on the ground or the floor.



Lighting and Shading

- Without lighting and shading, the rendered images may look flat and fail to illustrate 3D nature of a model.
- The orthogonal projection of a sphere is a uniformly colored circle, and a cube is a flat hexagon.
- If we look at a photograph of a lit sphere, we see not a uniformly colored circle but a circular shape with many gradations or shades of color.

Lighting and Shading

- It is these gradations that give 2D images the appearance of being 3D.
- What we have left out is the interaction between light and the surfaces in our models.
- We only consider local lighting models which allow us to compute the shade to assign to a point on a surface, independent of any other surfaces in the scene.

Lighting and Shading

- The calculations depend only on the material properties assigned to the surface, the local geometry of the surface, and the locations and properties of the light sources.

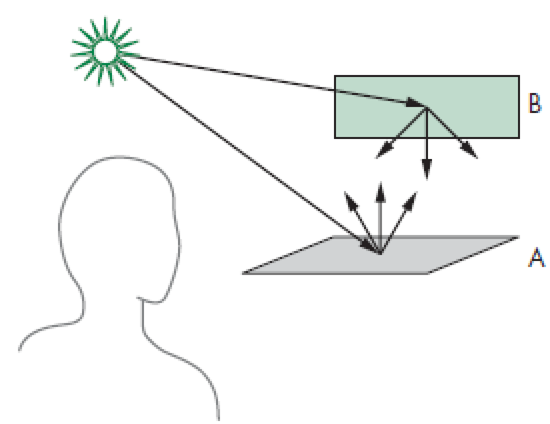
Lighting and Matter

- Perhaps the most general approach to rendering is based on physics, where we use principles such as conservation of energy to derive equations that describe how light is reflected from surface.
- From a physical perspective, a surface can either emit light by self-emission or reflect light from other surfaces that illuminate it.

Lighting and Matter

- Some surfaces may both reflect light and emit light from internal physical processes.
- When we look at a point on an object, the color that we see is determined by multiple interactions among light sources and reflective surfaces.
- These interactions can be

viewed as a recursive process.

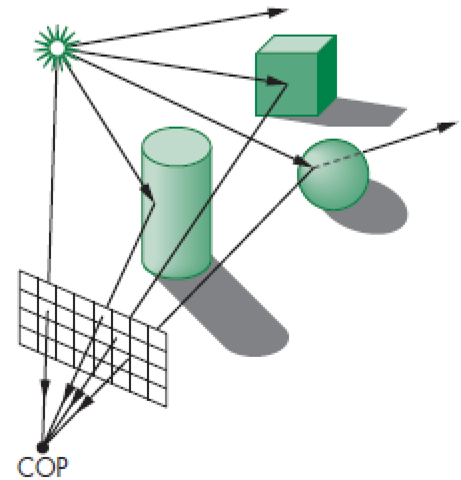


Reflecting surfaces.

Lighting and Matter

- The limit of this recursive process can be described using an integral equation, the rendering equation, which in principle we could use to find the shading of all surfaces in a scene.
- Approximate approaches: radiosity and ray tracing.

Lighting and Matter



Light, surfaces, and computer imaging.

- We follow rays of light from light-emitting surfaces that we call light sources.
- We then model what happens to these rays as they interact with reflecting surfaces in the scene.
- We need to model the light sources in the scene and build a reflection model that deals with the interactions between materials and light.

Lighting and Matter

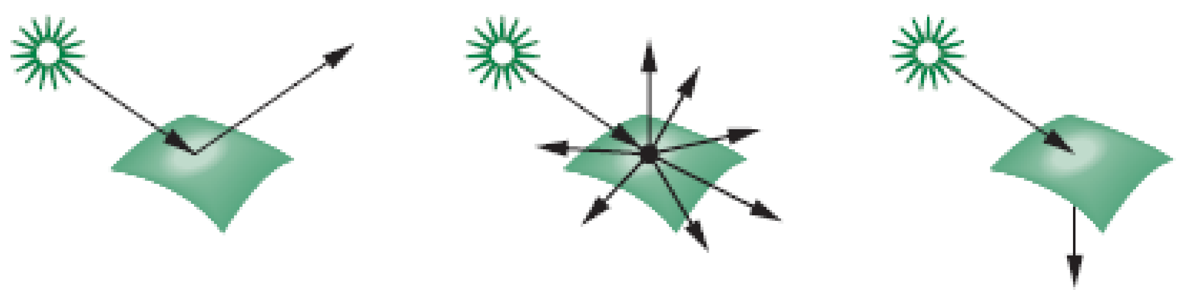
- The color of the light source and of the surfaces determines the color of one or more pixels in the framebuffer.
- When light strikes a surface, some of it is absorbed and some of it is reflected. If the surface is opaque, reflection and absorption account for all the light striking the surface. If the surface is translucent, some of the light is transmitted through the material and emerges to interact with other objects.

Lighting and Matter

- An object illuminated by white light appears red is because it absorbs most of the incident light but reflects light in the red range of frequencies.

Lighting and Matter

- The interactions between light and materials can be classified into the three groups:
  (a) Specular surfaces
  (b) Diffuse surfaces
  (c) Translucent surfaces



(a) (b) (c)

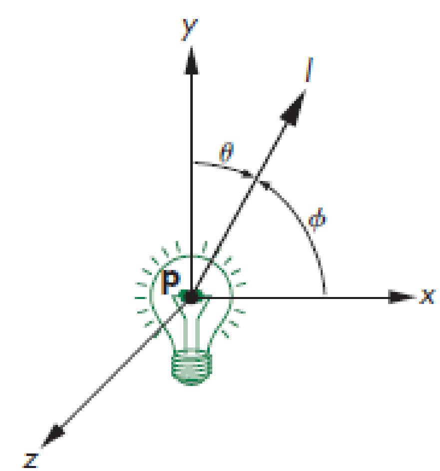
Light–material interactions. (a) Specular surface. (b) Diffuse surface. (c) Translucent surface.

Light Sources

- We consider a light source as an object with a surface.
- Each point (x, y, z) on the surface can emit light that is characterized by the direction of emission $(\theta, \emptyset)$, and the intensity of energy emitted at each wavelength λ.
- Thus, a general light source can be characterized by a six-variable

illumination function,

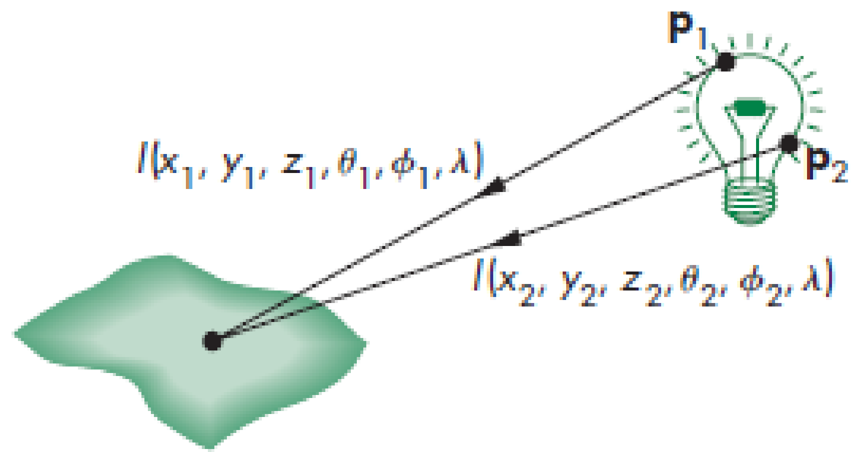
$I(x, y, z, \theta, \emptyset, \lambda)$.



Light source.

Light Sources

- From the perspective of a surface illuminated by this source, we can obtain the total contribution of the source by integrating over its surface.



Adding the contribution from a source.

- We consider four basic types of sources: ambient lighting, point sources, spotlights and distant light.

Light Sources

- Color Sources
  - Our model of the human visual system is based on three-color theory that tells us we perceive three tristimulus values, rather than a full-color distribution.
  - We can model light sources as having three components – red, green, and blue.
  - We describe a source through a three-component intensity or luminance function $I = \begin{bmatrix} I_r \\ I_g \\ I_b \end{bmatrix}$.

Types of Light Source

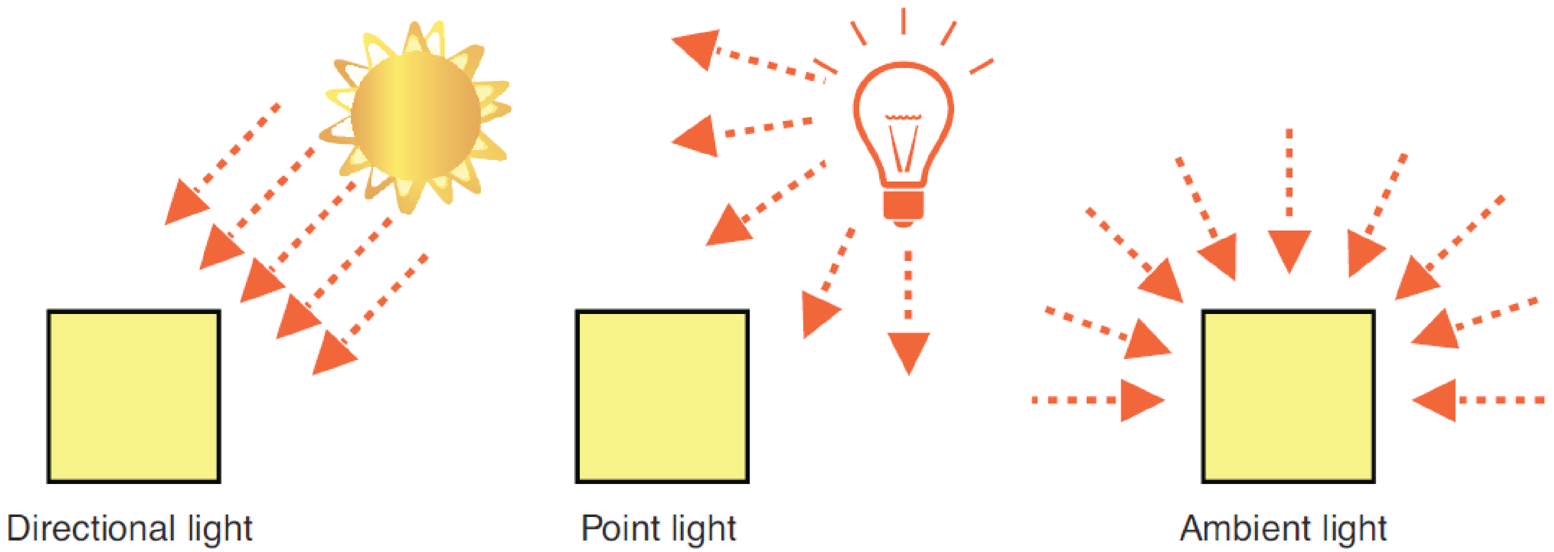


Figure 8.2 Directional light, point light, and ambient light

Light Sources

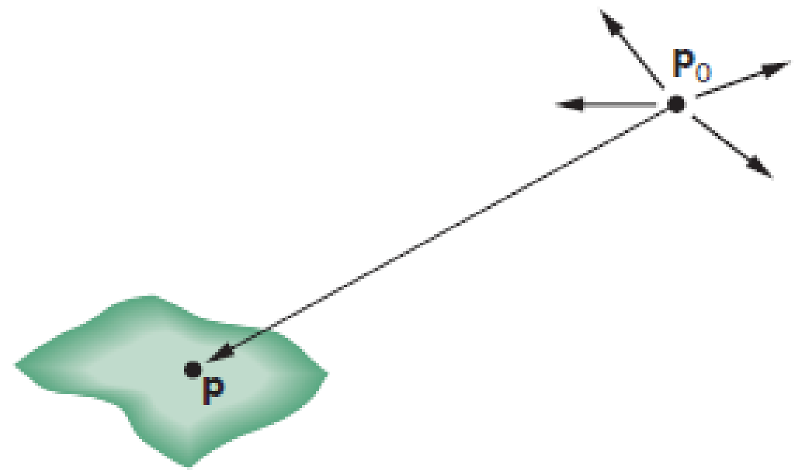
- Ambient Light
  - Provide uniform illumination throughout the room.
  - Often such illumination is achieved through large sources that have diffusers whose purpose is to scatter light in all directions.
  - We could create an accurate simulation of such illumination, at least in principle, by modeling all the distributed sources and then integrating the illumination from these sources at each point on a reflecting surface.

Light Sources

- Ambient Light
  - Alternatively, we can look at the desired effect of the sources: to achieve a uniform light level in the room.
  - This uniform lighting is called ambient light.
  - The ambient illumination is characterized by an intensity I_a that is identical at every point in the scene.
  - Although every point in our scene receives the same illumination from I_a, each surface can reflect this light differently.

Light Sources

- Point Sources
  - An ideal point source emits light equally in all directions.
  - The intensity of illumination received from a point source is proportional to the inverse square of the distance between the source and surface.

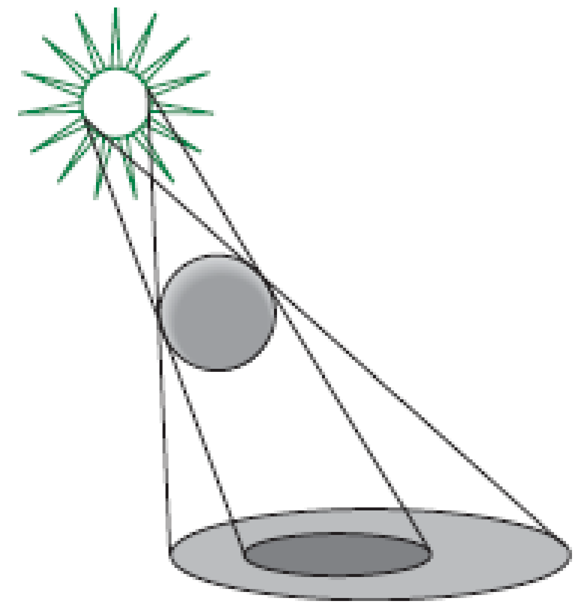


Point source illuminating a surface.

$$i(p, p_0) = \frac{1}{|p - p_0|^2} I(p_0)$$

Light Sources

- Point Sources
  - Scene rendered with only point sources tend to have high contrast; objects appear either bright or dark.
  - We can mitigate the high-contrast effect from point-source illumination by adding ambient light to a scene.



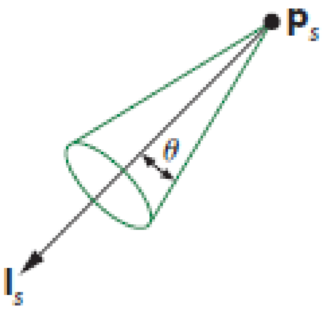
Shadows created by finite-size light source.

Light Sources

- Point Sources
  - In practice, the distance term is replaced by a term of the form $(a + bd + cd^2)^{-1}$, where *d* is the distance between p and p_0. The constants *a*, *b*, and *c* can be chosen to soften the lighting.
  - If the light source is far from the surfaces in the scene, the intensity of the light from the source is sufficiently uniform that the distance term is constant over each surface.

Light Sources

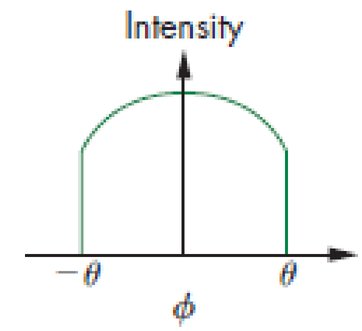
- Spotlights
  - Spotlights are characterized by a narrow range of angles through which light is emitted.
  - We can construct a spotlight from a point source by limiting the angles at which light from the source can be seen.
  - We can use a cone to represent it.



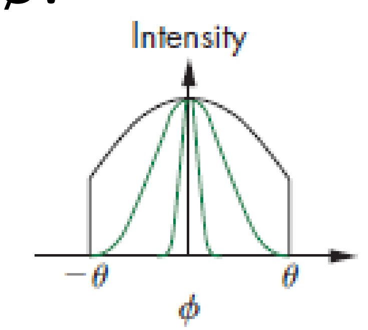
Spotlight.

Light Sources

- Spotlights
  - The intensity is a function of the angle Ø between the direction of the source and a vector *s* to a point on the surface.
  - The function is usually defined by $cos^e Ø$.
  - The exponent *e* determines how rapidly the light intensity drops off.



Attenuation of a spotlight.



Spotlight expo-nent.

Light Sources

- Spotlights
  - Cosines are convenient functions for lighting calculations. If *u* and *v* are any unit-length vectors, we can compute the cosine of the angle between them with the dot product

$$cos\theta = u \cdot v$$

a calculation that requires only three multiplications and two additions.

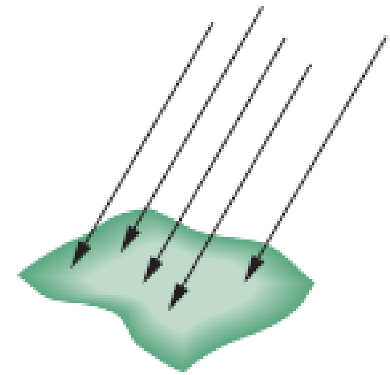
Light Sources

- Distant Light Sources
  - Most shading calculations require the direction from the point on the surface to the light source position.
  - As we move across a surface, the intensity of each point may be different.
  - If the light source is far from the surface, the intensity is kind of similar.

Light Sources

- Distant Light Sources
  - A point light source at p_0 is represented by $p_0 = \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$.
  - In contrast, the distant light source is described by a direction vector whose representation in homogeneous coordinates is

$$p_0 = \begin{bmatrix} x \\ y \\ z \\ 0 \end{bmatrix}$$



Parallel light source.