Chapter 9

Chapter 9. Lighting and shading

9.1 Introduction

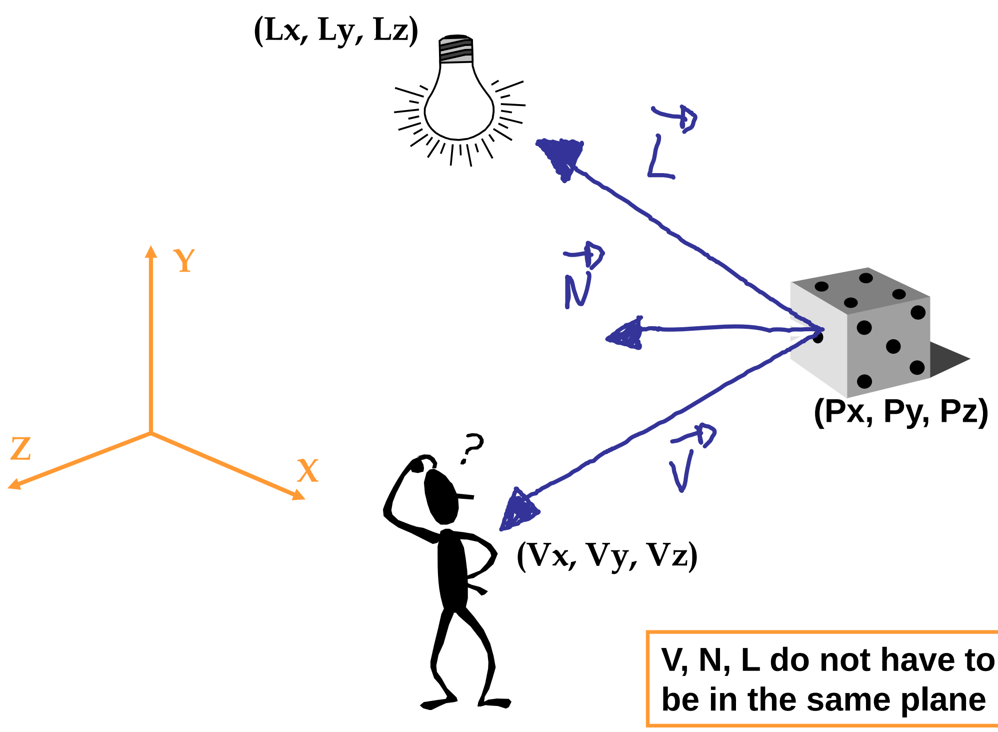
OBJECTIVES

- To know the visual effects of light over objects and the problems we have when considering lights over the represented image.
- To learn how to model these effects through an easy mathematic function.
- To understand the relationship between light source, object sufrace and the observer.
- To understand the meaning of the mathematical lighting model and the consequences of the variation of its parameters over the represented image.
- To be ready to learn more complex lighting models.

9.1 Introduction

- Models of object geometry
  - The scene to be represented is composed by geometrically well-defined objects.
  - There is a geometrical model able to be prompted about position and orientation characteristics of the objects.
  - In every point of the object, the exterior normal is defined.
  - The surface of the object is smooth and plain.
- Models of visual object attributes.
  - It is known the color of the objects.
- Viewer model.
  - It is known the viewer position or the projection direction in the object space.
  - It is known which object parts are visible from this position.

9.1 Introduction



V, N, L do not have to be in the same plane

9.1 Introduction

- Light sources:
  - Position: localized or at infinite.
  - Intensity: source color.
  - Quantity: integration of effects.
  - Light distribution: uniform, focalized, directional, etc.
  - Geometry: punctual, spherical, linear, etc.
- Objects:
  - Distances: to the viewer and the source light.
  - Material: polished, metallic, rough, etc.
  - Optic properties: transparency, refraction, etc.
  - Chromaticity: Superficial color of the object.
  - Light interaction with other objects of the scene.
- Viewer:
  - Viewing direction: intensity calculation.

9.2 Simple lighting model

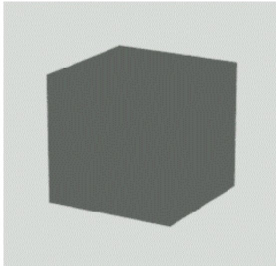
- A lighting model is defined as:

  $$I = f(p, PV, \{O\}, \{F\})$$

  - p: point where the lighting calculation is carried out.
  - PV: point of view position.
  - {O}: geometric model and material of the objects.
  - {F}: geometric model and intensity of light sources.
  - I: intensity light viewed at p.
- The light models we are about to see are empirical, i.e., they are not based on physics but observing its behavior.
- Applied simplifications:
  - Punctual sources.
  - Non-transparent objects.
  - *Local lighting model.*

9.2 Simple lighting model. Environmental light

- The simplest lighting model shows each object using a kind of internal light
- The light equation of this model is:



$$I = k_i$$

where

– I is the resulting intensity

– k_i is the intrinsic intensity [0..1]

- Environmental light: A non-directional light is considered, as a product of multiple light reflections from many lights that are present in the environment.
- The environment light affects equally in all the surfaces in all directions and its equation is:

$$I=I_a \cdot k_a$$

where

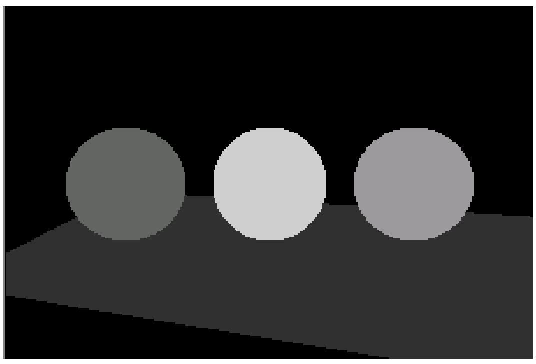
– I_a is the intensity of the environment light

– k_a is the environment reflection quocient

Simple lighting model. Environmental ligth

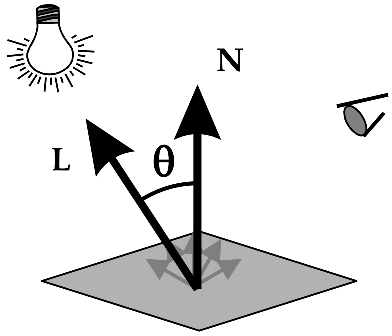
- Light characteristics:
  – Ia = 1
- Material characteristics:

	Ka
Left	0.4
Center	0.8
Right	0.6



9.2 Simple lighting model. Diffuse reflection

- Diffuse reflection: a part of the reflected light of a surface is reflected in a non-directional way (same intensity in any direction)
- The intensity of the reflected light at a point is independent of the viewer position.
- Lambert law: "the diffuse component of the reflected light by a surface is proportional to the cosine of the incidence angle"
- It is characteristic of matt surfaces: (chalk, walls, fabrics,...).



9.2 Simple lighting model. Diffuse reflection

- El brillo depende únicamente del ángulo θ entre la dirección de L y de N (ángulo de incidencia).

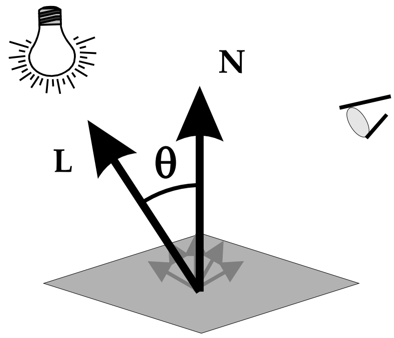
$$I = I_L \cdot k_d \cdot \cos(\theta)$$

- La ecuación de reflexión difusa:

$$I = I_a \cdot k_a + I_L \cdot k_d \cdot \cos(\theta) = I_a \cdot k_a + I_L \cdot k_d \cdot (\vec{N} \cdot \vec{L})$$

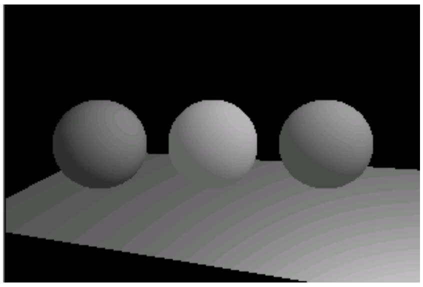
en donde:

- I_L: Intensidad fuente
- θ: Ángulo incidencia [0..90]
- k_d: Coeficiente reflexión difusa [0..1]
- N: Normal superficie (unitario)
- L: Vector iluminación (unitario)



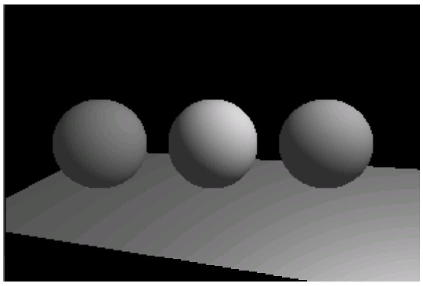
9.2 Simple lighting model. Diffuse reflection

- Características de la luz:
  - Ia = 0.5
  - I_L = 0.8
  - Pos = (2, 2, 2)



- Características del material:

	Color	Ka	Kd
Izq.	1	0.4	0.4
Cent.	1	0.8	0.4
Der.	1	0.6	0.4

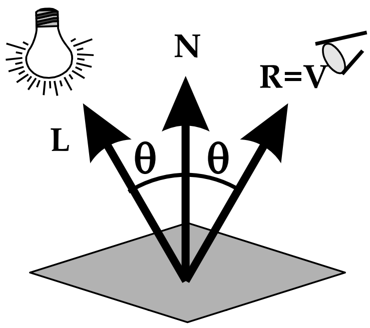


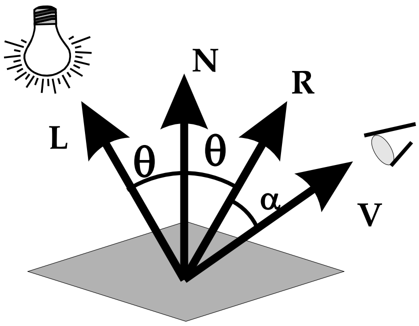
- Características del material:

	Color	Ka	Kd
Izq.	1	0.4	0.4
Cent.	1	0.4	0.8
Der.	1	0.4	0.6

9.2 Simple lighting model. Specular reflection

- The specular reflection is the light reflected component over a bright or polished surface in a priority direction, generating a brightness.
- Specular reflection depends on the viewer position.
- In a perfect mirror the direction from the reflection is seen is the prefect reflection direction R.
- In normal surfaces, the brightness decreases when the viewer moves further away from the reflection direction. This effect could be modeled taking into account the angle between R and V.
- It is also possible to observe that depending on the surface (degree of polish) the brightness is more or less centered to the point where R and V match.





L, N are R in the same plane, but V doesn't.

9.2 Simple lighting model. Specular reflection

Phong lighting model

- The model assumes that the maximum specular reflectance occurs when α is zero and decreases quickly as α increases.

- This decrement can be approached as $\cos^n(\alpha)$. Thus, the specular reflected intensity is:

$$I_s = I_L \cdot k_s \cdot \cos^n(\alpha) = I_L \cdot k_s \cdot (\vec{R} \cdot \vec{V})^n$$

where:

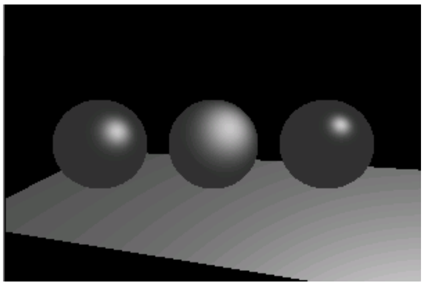
- k_S: specular reflection coefficient.
- α: angle between R and V.
- n: specular coefficient.

- Intensity light equation in a point:

$$I = I_a \cdot k_a + f_{at} \cdot I_L \cdot (k_d \cdot (\vec{N} \cdot \vec{L}) + k_s \cdot (\vec{R} \cdot \vec{V})^n)$$

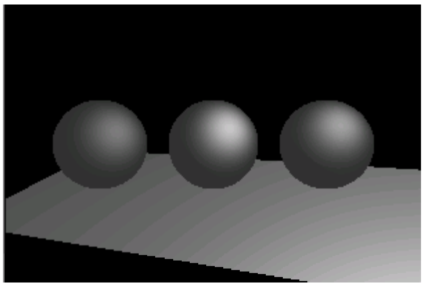
9.2 Simple lighting model. Specular reflection

- Light characteristics:
  - Ia = 0.5
  - I_L = 0.8
  - Pos = (2, 2, 2)



- Material characteristics:

	Color	Ka	Ks	n
Left	1	0.4	0.8	20
Center	1	0.4	0.8	5
Right	1	0.4	0.8	40

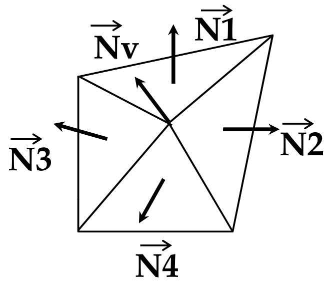


- Material characteristics:

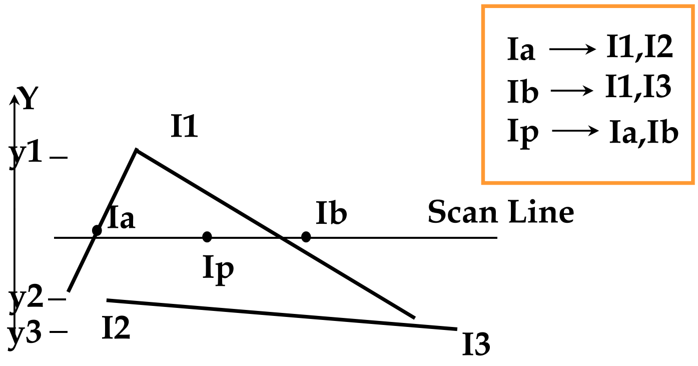
	Color	Ka	Ks	n
Left	1	0.4	0.4	5
Center	1	0.4	0.8	5
Right	1	0.4	0.6	5

9.5 Polygon shading

- Constant shading
  - The same intensity for all the polygon
- Gouraud interpolation
  - Calculate normal for every polygon
  - Calculate normal for every vertex
  - Calculate intensities for every vertex (applying a lighting model)
  - Polygon shading -> Scan-Line



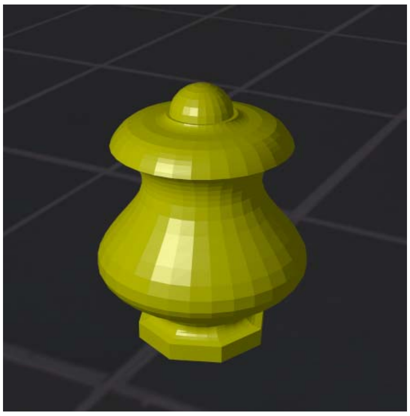
$\vec{Nv} = (\vec{N1}+\vec{N2}+\vec{N3}+\vec{N4})/4$



9.5 Polygon shading

- Phong interpolation
  - Calculate $\vec{N}$ for every polygon
  - Calculate $\vec{N}$ for every vertex
  - Polygon shading ⟶ Scan-Line
  - Characteristics
    - Interpolation of normals
    - Recalculates I for every pixel
    - Appropriate for specular reflection

9.5 Polygon shading



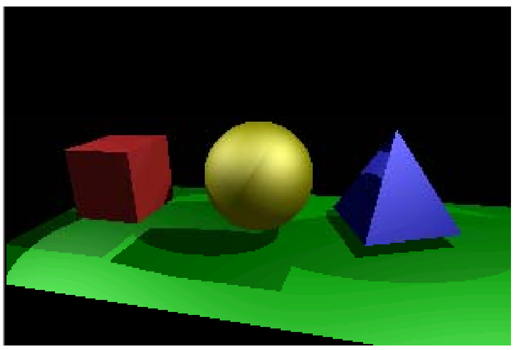
Flat

Gouraud

Phong

Advanced models

Shadows



Inter-reflection