MODELING LIGHT INTENSITIES
(Section 14-1 in Computer Graphics)

- Light Source
- Diffuse Reflection
- Specular Reflection
- Transmitted or Refracted Light
- Texture and Surface Pattern
- Shadows

DISPLAYING LIGHT INTENSITIES
(Section 14-2 in Computer Graphics)

- Halftoning
- Dithering
Introduction

- achieving realistic views
  - generate perspective projections
  - remove hidden surfaces
  - apply light intensities to present shading and color patterns

- calculate light intensities using a shading model based on optical properties of surfaces
  - opaque
  - transparent
  - shiny or matte
  - relative positions of surfaces
  - orientations of surfaces with respect to light sources
  - types of light sources
light sources

- light-emitting sources
  - point sources: the dimensions of the light source are small compared to the dimensions of the object
  - distributed sources: the dimensions of the light source are significant

- light-reflecting sources
  - illuminated surfaces
  - multiple reflections combine to produce ambient light or background light

- light-transmitting sources
  - transparent and translucent objects
reflections

- diffuse reflection
  - scattered light from point light sources and ambient light sources
  - a matte surface produces primarily diffuse reflection

![Diffuse Reflections From a Surface](image)

- specular reflection
  - highlights or bright spots
  - more pronounced on shiny surfaces

![Specular Reflection Superimposed on Diffuse Reflections](image)
diffuse reflection

- effects of ambient light
  - uniform intensity in all directions
  - surfaces range from highly reflective to highly absorptive
  - \( I = k_d I_a \), where
    - \( I \) is the intensity at any point on the surface
    - \( k_d \) is the coefficient of reflection or reflectivity
    - \( I_a \) is the intensity of the ambient light

- effects of point source light
  - the intensity of reflected light depends on the angle of illumination (Lambert's law)
  - perpendicular incident light produces a brighter surface than does oblique incident light

- for simplification, light sources are treated as being far enough away to produce parallel rays
diffuse reflection, cont.

\[ I = \frac{k_d I_p}{d + d_0}(N \cdot L) \]

- \( I \) is the intensity of any point on the surface
- \( k_d \) is the coefficient of reflection or reflectivity
- \( I_p \) is the intensity of the point source
- \( d \) is the distance from the point source to a point on the surface
- \( d_0 \) is a constant which prevents the denominator from approaching zero
- \( N \) is the surface normal
- \( L \) is the unit vector to the point source
ambient light and diffuse reflection

\[ I = k_d I_a + \frac{k_d I_p}{d + d_0} (N \cdot L) \]

when color is modeled, there is one component of this form for each color
specular reflection

- at certain angles, shiny surfaces reflect all incident light
- a specular reflection is a spot of reflected light that is the same color as the incident light
- for an ideal reflector, the angle of incidence is equal to the angle of specular reflection

- shiny surfaces have a narrow reflection range

- dull surfaces have a wider reflection range

- diffuse reflection and specular reflection are modeled with simplifications to increase efficiency
specular reflection, continued

\[ I = \frac{I_p}{d + d_0} (W(\Theta) \cos^n \phi) \]

- \( W(\Theta) \) depends on the surface material and is determined empirically
- \( \phi \) is the angle between the \( R \) (the angle of specular reflection) and \( V \) (the unit vector to the viewer)
- \( n \) is high for shiny surfaces
complete reflection model

diffuse component due to point source light

\[ I = k_d I_a + \frac{I_p}{d + d_0} \left[ k_d (N \cdot L) + \psi(\theta) \cos^n \phi \right] \]

ambient component   specular component
transmitted or refracted light

- usually from light-reflecting surfaces
  - see figure 14-10 on page 281

- diffuse refraction from translucent, light-scattering surfaces
  - implemented by diminishing the intensity
    spreading it over a finite area
  - costly to implement

- specular refraction
  - light incident on a transparent surface has a reflected component and a refracted component
transmitted or refracted light, continued

- commonly modeled by shifting the path
  of the incident light or by ignoring path shifts
  altogether

![Diagram of light transmission through glass]

- implemented by modifying the intensity
- \((l_t)\) of the transparent object according to the
  intensity \((l_b)\) of the background object and the
  refraction coefficient \((r)\)
  \[ I = rl_t + (1 - r)l_b \]
- easily accommodated by the depth-sort
  hidden-surface method
- see figure 14-14 on page 283
texture and surface patterns

- texture distinguishes
  - orange peel from orange plastic of the same color
  - glazed brick from china of the same color

- surface patterns permit
  - china with designs
  - Persian carpets
  - highways and runways with dividing lines and skid marks
texture and surface patterns, continued

- achieving texture
  - alter the surface normal (as a function of position over the surface)
  - alter the reflection coefficient
  - alter both
  - use texture mapping methods (similar to pattern fill)

- achieving surface patterns
  - the surface pattern is defined as an array
  - the array is mapped onto the object at a designated position
  - patterns can be wrapped around three-dimensional objects
shadows

- use hidden surface methods with the light source at the view position
  - use shadow polyhedra to identify surface sections which cannot be "seen" by the light source
  - compute the shade of each shadow area without a contribution from the light source that produced the shadow

- alternatively, apply surface patterns to shadow areas
  - see figure 14-17 on page 285

- shadow patterns are valid for any viewing position, as long as the light sources remain stationary
Displaying Light Intensities

- some graphics systems can display several intensity levels
  - a four-level system provides minimal shading capability
  - high quality shading patterns require 32 to 256 levels of intensity
  - intensity information may be stored as
    - an intensity level ($I_k$)
    - a level number ($k$)
    - a value proportional to the control grid voltage
halftoning

- other graphics systems can display only "on" and "off"
- pixels are treated as being 2-by-2 or 3-by-3 or larger
- 2-by-2 pixels have 5 different intensity levels

- n-by-n pixels have $n^2 + 1$ different intensity levels
- color variations can be obtained by halftoning (see figure 14-20 on page 287)
- resolution diminishes
halftoning, continued

- avoid introducing patterns

- equivalent combinations can be selected randomly

- patterns can be avoided by successively higher grid patterns with the same pixels set
halftoning, continued

- halftoning can be combined with systems that have multiple levels of intensity

- natural when the resolution of the scene is less than the resolution of the output device
dithering techniques

- used with halftoning methods to smooth edges and improve overall appearance
- a dither intensity or dither noise is added to the calculated intensity
- dither noise can be calculated randomly or based on position
- alternatively, intensity is compared to a dither value (thresholding)
  - the pixel is turned on if the intensity exceeds the dither value
  - again, dither values can be generated randomly or based on position
  - example
    - \( i = x \mod 2 \)
    - \( j = y \mod 2 \)
    - if \( I > D(i, j) \)
      then turn on pixel at \((x, y)\)
    - where \( D \) is a 2-by-2 matrix containing the integers 0 through 3

\[
D = \begin{bmatrix}
3 & 1 \\
0 & 2
\end{bmatrix}
\]
MODELING LIGHT INTENSITIES

- light source
- diffuse reflection
- specular reflection
- transmitted or refracted light
- texture and surface pattern
- shadows

DISPLAYING LIGHT INTENSITIES

- halftoning
- dithering