Maharaja Agrasen Institute of Technology
ETCS 211
Computer Graphics & Multimedia
UNIT 3
Shading

Objective

Why Shade?

illumination Vs. Shading

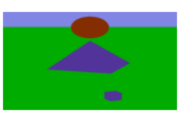
Global Illumination

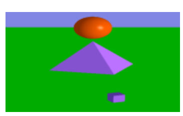
Local illumination

Q & A

Why Shade?

Human vision uses shading as a cue to form, position, and depth
- Total handling of light is very expensive
- Shading models can give us a good approximation of what would “really” happen, much less expensively
- Average and approximate





illumination Vs. Shading

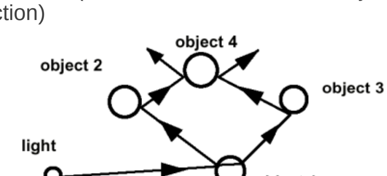
- Illumination (lighting) model: determine the color of a surface point by simulating some light attributes.
- Shading model: applies the illumination models at a set of points and colors the whole image.

Illumination (Lighting) Model

To model the interaction of light with surfaces to determine the final color & brightness of the surface
- Global illumination
- Local illumination

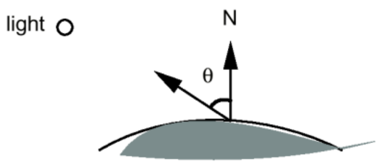
Global Illumination

Global Illumination models: take into account the interaction of light from all the surfaces in the scene. (will cover under the Radiosity section)



Local illumination

Only consider the light, the observer position, and the object material properties



Basic Illumination Model

Simple and fast method for calculating surface intensity at a given point

Lighting calculation are based on:

- The background lighting conditions
- The light source specification: color, position
- Optical properties of surfaces:
  - Glossy OR matte
  - Opaque OR transparent (control refection and absorption)

Ambient light (background light)

The light that is the result from the light reflecting off other surfaces in the environment

A general level of brightness for a scene that is independent of the light positions or surface directions -> ambient light

Has no direction

Each light source has an ambient light contribution, Ia

For a given surface, we can specify how much ambient light the surface can reflect using an ambient reflection coefficient : Ka (0 < Ka < 1)

Ambient Light

So the amount of light that the surface reflect is therefore

Iamb = Ka * Ia

Diffuse Light

The illumination that a surface receives from a light source and reflects equally in all directions

This type of reflection is called Lambertian Reflection (thus, Lambertian surfaces)

The brightness of the surface is indepenent of the observer position (since the light is reflected in all direction equally)

Lambert's Law

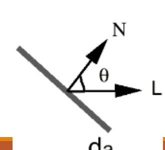
How much light the surface receives from a light source depends on the angle between its angle and the vector from the surface point to the light (light vector)

Lambert's law: the radiant energy '$\mathbf{I_d}$' from a small surface $\mathbf{d_a}$ for a given light source is:

$I_d = I_L * \cos(\theta)$

I_L : the intensity of the light source

θ is the angle between the surface normal (N) and light vector (L)



The Diffuse Component

Surface's material property: assuming that the surface can reflect K_d ($0<K_d<1$), diffuse reflection coefficient) amount of diffuse light:

$I_{diff} = K_d * I_L * \cos(\theta)$

If N and L are normalized, $\cos(\theta) = N*L$

$I_{diff} = K_d * I_L * (N*L)$

The total diffuse reflection = ambient + diffuse

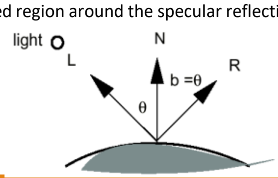
$I_{diff} = K_a * I_a + K_d * I_L * (N*L)$

Examples

Sphere diffusely lighted from various angles !

Specular Light

- These are the bright spots on objects (such as polished metal, apple ...)
- Light reflected from the surface unequally to all directions.
- The result of near total reflection of the incident light in a concentrated region around the specular reflection angle



Phong's Model for Specular

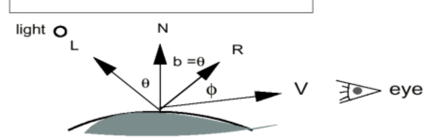
How much reflection light you can see depends on where you are

Specular light :

specular reflection coefficient

specular light

Phong's model $I_s = K_s * I_s * \cos^n(\phi)$

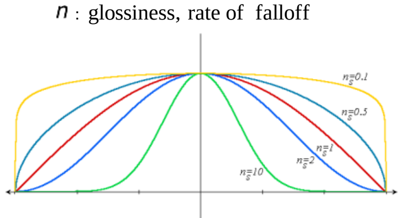


Phong Illumination Curves

Specular exponents are much larger than 1;

Values of 100 are not uncommon.

n : glossiness, rate of falloff



Specular Highlights

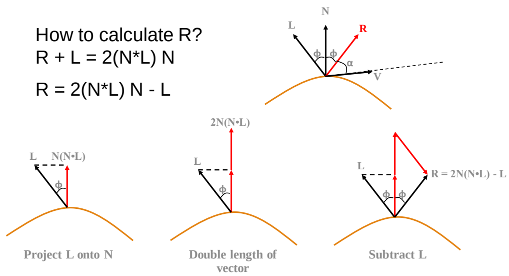
- Shiny surfaces change appearance when viewpoint is changed
- Specularities are caused by microscopically smooth surfaces.
- A mirror is a perfect specular reflector

Reflected Ray

How to calculate R?

R + L = 2(N*L) N

R = 2(N*L) N - L

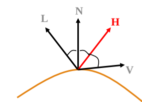


Half Vector

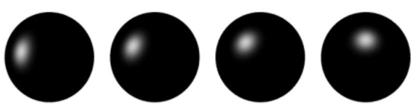
An alternative way of computing phong lighting is: $I_s = k_s * I_s * (N*H)^n$

H (halfway vector): halfway between V and L: (V+L)/2

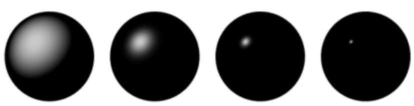
Fuzzier highlight



Phong Illumination



Moving Light



Change n

Putting It All Together

Single Light (white light source)

$$I = \text{Ambient} + \text{Diffuse} + \text{Specular} =$$

$$Ka * Ia + Kd * \underbrace{I_L * (N.L)}_{Id} + Ks * \underbrace{I_L * (R.V)^n}_{Is}$$

Multiple Light Source

I_L: light intensity

$$I = Ka * Ia + \sum_i (Kd * I_L * (N.L) + Ks * I_L * (R.V)^n)$$

For multiple light sources
- Repeat the diffuse and specular calculations for each light source
- Add the components from all light sources
- The ambient term contributes only once

The different reflectance coefficients can differ.
- Simple "metal": k_s and k_d share material color,
- Simple plastic: k_s is white

Remember, when cosine is negative lighting term is zero!

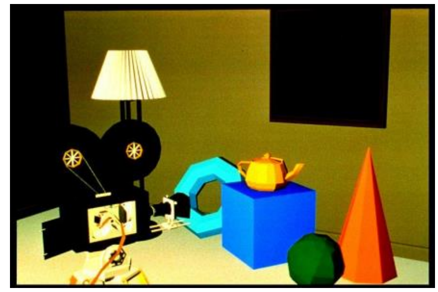
Constant Shading

Compute illumination only at one point on the surface

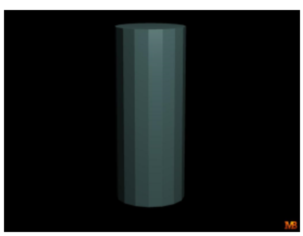
Okay to use if all of the following are true
- The object is not a curved (smooth) surface (e.g. a polyhedron object)
- The light source is very far away (so N.L does not change much across a polygon)
- The eye is very far away (so V.R does not change much across a polygon)
- The surface is quite small (close to pixel size)

Un-lit

Flat Shading



Mach Band ?



Smooth Shading

Need to have per-vertex normals

Gouraud Shading
- Interpolate color across triangles
- Fast, supported by most of the graphics accelerator cards

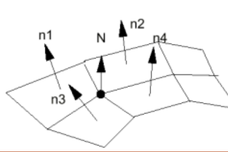
Phong Shading
- Interpolate normals across triangles
- More accurate, but slow. Not widely supported by hardware

Gouraud Shading

Normals are computed at the polygon vertices

If we only have per-face normals, the normal at each vertex is the average of the normals of its adjacent faces

Intensity interpolation: linearly interpolate the pixel intensity (color) across a polygon surface



N = (n1+n2+n3+n4) / 4

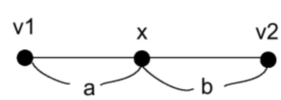
Linear Interpolation

Calculate the value of a point based on

the distances to the point's two neighbor points

If v1 and v2 are known, then

x = b/(a+b) * v1 + a/(a+b) * v2



Linear Interpolation in a Triangle

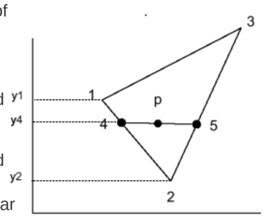
To determine the intensity (color) of point P in the triangle,

we will do:

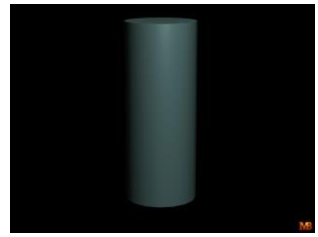
determine the intensity of 4 by linearly interpolating between 1 and 2

determine the intensity of 5 by linearly interpolating between 2 and 3

determine the intensity of P by linear interpolating between 4 and 5



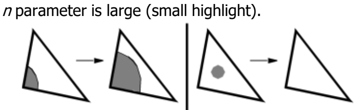
Mach Band ?



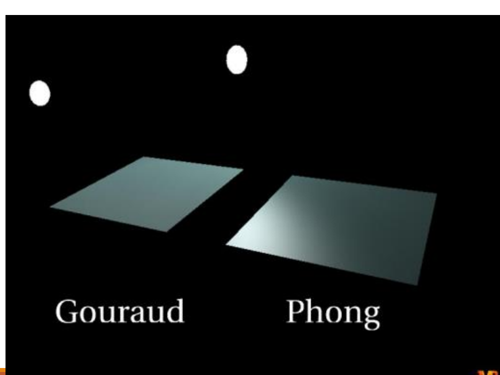
Image

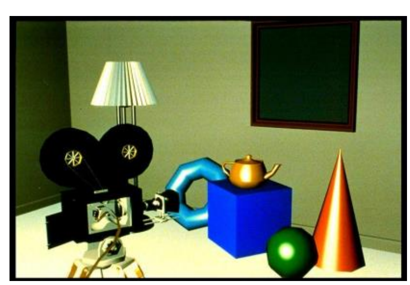
Phong Shading Model

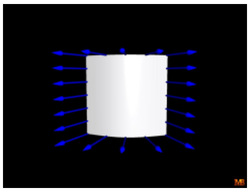
- Gouraud shading does not properly handle specular highlights, specially when the *n* parameter is large (small highlight).

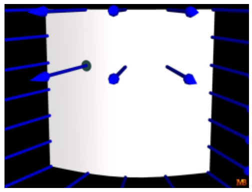


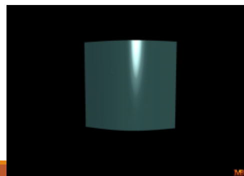
- **Reason:** colors are interpolated.
- **Solution:** (Phong Shading Model)
  - 1. Compute averaged normal at vertices.
  - 2. Interpolate *normals* along edges and scan-lines. (component by component)
  - 3. Compute *per-pixel* illumination.









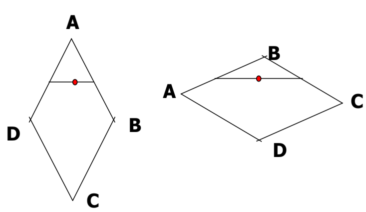


Interpolated Shading - Problems

- Polygonal silhouette – edge is always polygonal. Solution ?
- Perspective distortion – interpolation is in screen space and hence for-shortening takes place. Solution ?
- In both cases finer polygons can help !

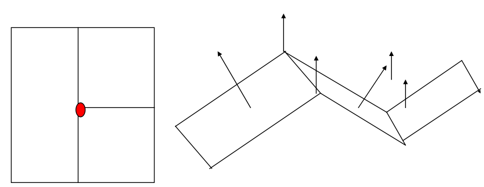
Interpolated Shading - Problems

- Orientation dependence - small rotations cause problems



Interpolated Shading - Problems

- Problems at shared vertices – shared by right polygons and not by one on left and hence discontinuity
- Incorrect Vertex normals – no variation in shade



Light Sources

Point light source

Directional light source: e.g. sun light

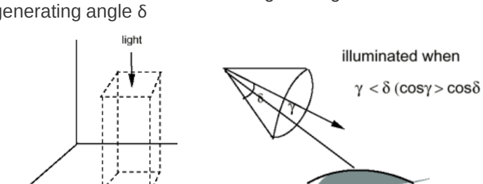
Spot light

Spot Light

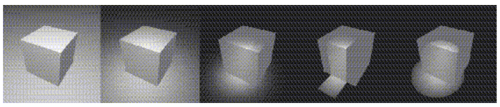
To restrict a light's effects to a limited area of the scene

Flap: confine the effects of the light to a designed range in x, y, and z world coordinate

Cone: restrict the effects of the light using a cone with a generating angle δ



Example



Light Source Attenuation

Takes into account the distance of the light from the surface

$I'_L = I_L$ * fatt (d)

I'_L: the received light after attenuation

I_L: the original light strength

fatt: the attenuation factor

d: the distance between the light source and the surface point

fatt = max (1/(c1 + c2*d + c3*d^2) , 1)

C1, C2, C3 are user defined constants associated with each light source

More on Homogeneous Coordinates

To 4D: (x,y,z) -> (x,y,z,1)

Back to 3D: (x,y,z,w) -> (x/w, y/w, z/w)

A point is on a plane if the point satisfies 0 == A*x + B*y + C*z + D

Point **P**: (x,y,z,1).

Representing a plane **N** = (A,B,C,D). Point **P** is on the plane, if **P** dot **N** == 0

Q & A

Q1. A surface rendering algorithm
a) is used to calculate the intensity of light that we should see at a given point on the surface of an object
b) uses the intensity calculations to determine the light intensity
c) scattered light from a rough surface
d) light source creating highlights on bright spots

Q2. Diffuse reflection is
a) is used to calculate the intensity of light that we should see at a given point on the surface of an object
b) uses the intensity calculations to determine the light intensity
c) scattered light from a rough surface
d) light source creating highlights on bright spots

Q & A

Q3 A shading Model
a) is used to calculate the intensity of light that we should see at a given point on the surface of an object
b) uses the intensity calculations to determine the light intensity
c) scattered light from a rough surface
d) light source creating highlights on bright spots

Q4. In the Clip Art task pane, the standard extension of an "event" sound such as a door closing sound is ________________.
a) .mp3
b) .wav
c) .midi
d) .ram

Q & A

Q5. Wave front is
a) intermediate frames between the key frame
b) positioning of objects + lt soures
c) layout of motion paths for the object and camera
d) an animation package