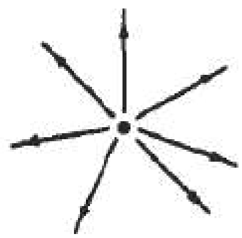
Unit-7: Illumination Model and Surface Rendering

- Illumination model is used to calculate the intensity of light reflected from a point on a surface.
- Surface rendering uses the intensity calculations from the illumination model to determine the light intensity at all pixels in the image, by possibly, considering light propagation between surfaces in the scene.

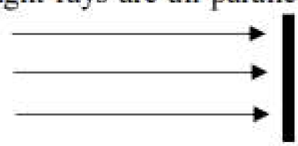
Light sources

Light sources are referred as light emitting object and light reflectors.

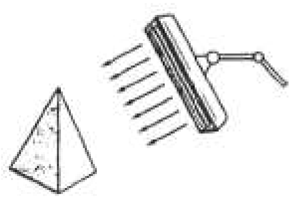
i. ***Point source:*** A point light source emits light equally in all directions from a single point.



ii. ***Parallel source:*** Light rays are all parallel. May be modeled as a point source at infinity (the sun).

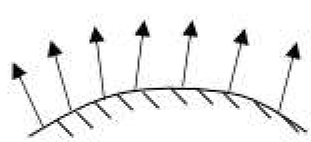


iii. ***Distributed source:*** All light rays orginate at a finite area in space. A nearby sources such as fluorescent light.



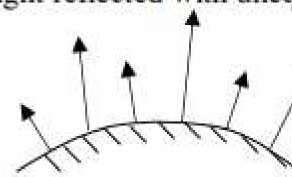
Types of Reflection

i. ***Diffuse Reflections:*** Surfaces appear equally bright from all viewing angles since they reflect light with equal intensity in all directions. E.g. rough surfaces



- Position of viewer is not important.

ii. ***Specular reflection:*** Light reflected with unequal intensity. E.g. shiny surface.



- Position of viewer is important.

<u>Illumination model / Lighting model / Shading model</u>

An illumination model is a formula in variables associated to the surface properties and light conditions to calculate the intensity of light reflected from a point on a surface.

Based on standard lighting conditions in a scene, some illumination models are:

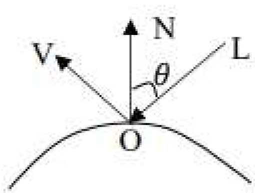
i. ***<u>Ambient light:</u>***
Surface getting light from various reflected source i.e. light not coming directly from a light source but coming after getting reflected from other surface.

- Ambient light has no spatial or directional characteristics and amount on each object is a constant for all surfaces and all directions.
The reflected intensity I due to ambient light of any point on the surface is:

$$I = I_a K_a$$

Where, I_a= intensity of ambient light.
K_a= ambient reflection coefficient, $0 \leq K_a \leq 1$.

ii. ***<u>Diffuse reflection:</u>***
Light reflected with equal intensity in all direction. Amount of light seen by viewer is independent of viewer direction. Brightness depends only on the angle θ between light direction and the surface normal.



L=light source

N=normal to surface

V=viewer direction

θ=angle bet^n S & N

The reflected intensity I of any point on surface is

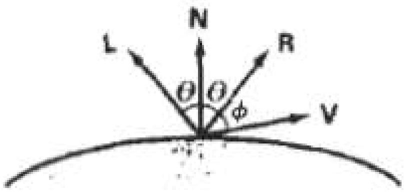
$$I = I_l K_a \vec{N} . \vec{L} = I_l K_d cos\theta$$

Where, K_d= coefficient of diffuse reflection

Net diffuse reflection= Diffuse reflection due to ambient light +Diffuse reflection due to light source = $I_{amb,\ diff} + I_{l,\ diff} = I_a K_a + I_l K_d cos\theta$

iii. ***<u>Specular reflection and Phong model</u>***

In shiny surface we see highlight or bright spot from certain viewing directions called specular reflection. (Light reflected with unequal intensity).



L=incident light

N=normal to surface

R=direction of ideal specular reflection

V=viewer

ϕ=angle bet^n R & V

$$I_{l,spec} = K_s I_l(\vec{V}.\vec{R})^{n_s}$$

Where, K_s= specular reflection coefficient

n_s= specular reflection parameter

Phong model:

$$\boxed{I_{l,spec} = K_s I_l cos^{n_s}\phi}$$

Polygon Rendering Method

a) Constant intensity shading method
b) Gouraud shading method (Intensity Interpolation)
c) Phong shading mehod (Normal vector interpolation)

a) Constant Intensity Shading (Flat Shading)Method

- A fast and simple method for rendering an object with polygon surfaces is constant intensity shading.
- In this method, a single intensity is calculated for each polygon and the intensity is applied to all the points of surface of polygon. Hence, all the points over the surface of the polygon are displayed with same intensity value.
- Constant shading is useful for quickly displaying the general appearance of a curved surfaces. This approach is valid if:
  a. Light source is at infinity ($\vec{N}.\vec{L}$ is constant on polygon).
  b. Viewer is at infinity ($\vec{V}.\vec{R}$ is constant on polygon).
  c. Object is polyhedron and is not an approximation of an object with a curved surface.

b) Gouraud shading method

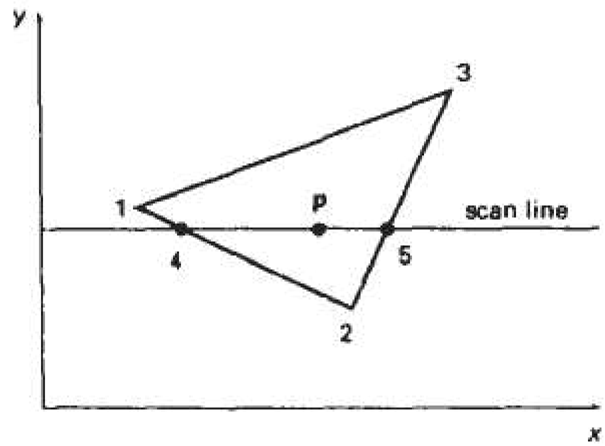
- Developed by Henri Gouraud.
- It renders the polygon surface by linearly interpolating intensity values across the surface.
- Intensity values for each polygon are matched with the values of adjacent polygon along the common edge, thus eliminating the intensity discontinuities that occur in flat shading.

Steps:

1. Determine the average unit normal vector at each vertex of polygon.

$$\vec{N}_{avg} = \frac{\sum_{i=1}^{n}\vec{N}_i}{|\sum_{i=1}^{n}\vec{N}_i|}$$

2. Apply illumination model at each vertex to calculate the vertex intensity.
3. Linearly interpolate the vertex intensities over the projected area of polygon.



$$I_4 = \frac{y_4 - y_2}{y_1 - y_2} I_1 + \frac{y_1 - y_4}{y_1 - y_2} I_2$$

$$I_5 = \frac{y_5 - y_2}{y_3 - y_2} I_3 + \frac{y_3 - y_5}{y_3 - y_2} I_2$$

$$I_p = \frac{x_5 - x_p}{x_5 - x_4} I_4 + \frac{x_p - x_4}{x_5 - x_4} I_5$$

Advantages:

- It removes the intensity discontinuity which exists in constant shading model.
- It can be combined with hidden surface algorithm to fill in the visible polygon along each scan line.

Disadvantages:

- Causes bright or dark intensity streak called mach bands.

c) ***Phong shading method***

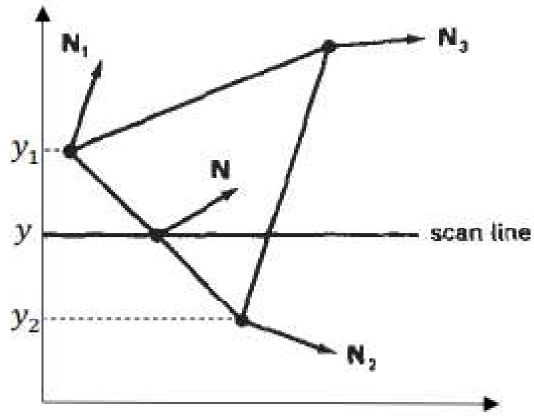
- Developed by Phong Bui Tuong.
- It renders the polygon surface by linearly interpolating normal vector across the surface.

Steps:

1. Determine the average unit normal vector at each vertex of polygon.

$$\vec{N}_{avg} = \frac{\sum_{i=1}^{n} \vec{N}_i}{|\sum_{i=1}^{n} \vec{N}_i|}$$

2. Linearly interpolate the vertex normal over the projected area of the polygon.
3. Apply illumination model at position along each scan line to calculate pixel intensities using interpolated normal vectors.



$$\vec{N} = \frac{y - y_2}{y_1 - y_2}\vec{N}_1 + \frac{y_1 - y}{y_1 - y_1}\vec{N}_2$$

Advantages:

- It displays more realistic highlights on a surface.
- It greatly reduces the Mach band effect.
- It gives more accurate results.

Disadvantages:

- It requires more calculation and greatly increases the cost of shading steeply.

Comparison of polygon rendering method

Flat shading	Gouraud shading	Phong shading
Computes illumination once per polygon and apply it to whole polygon.	Computes illumination at vertices and interpolates.	Applies illumination at every point of polygon surface.
Creates discontinuous in color.	Interpolates colors along edges and scan line.	Interpolates normal instead of colors.
Problems of Mach bands.	Handles Mach bands problem found in flat shading.	Removes Mach bands completely.
Low cost.	Not so expensive.	More expensive than gouraud shading.
Requires very less processing and is fast in time.	Required moderate processing time.	Requires complex processing and is slower but is more efficient as compared to other shading methods.
Lighting equation used once per polygon.	Lighting equation used at each vertex.	Lighting equation used at each pixel.