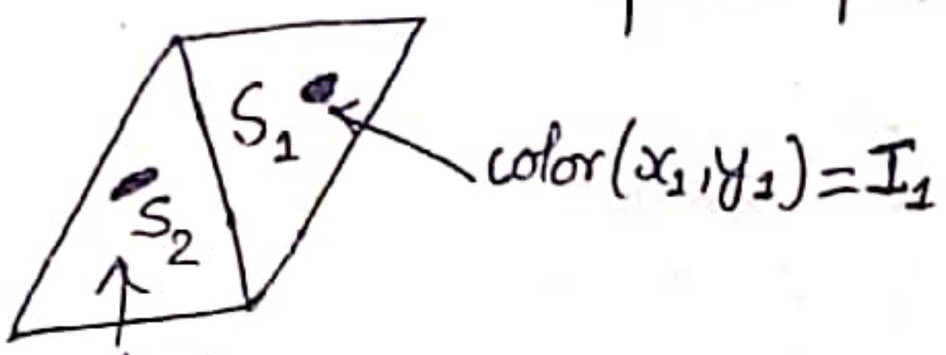
Unit-8

Illumination Models and Surface Rendering Techniques:

Illumination models are mathematical model to determine color calculation or intensity calculation of a single pixel within a particular surface. It is sometimes also refered as shading model. The colour seen on particular point of the surface depends on various optical parameters as below:-



1) Light source Type → There are two lighting models in CG.

a) Point light source → Light rays radially diverge from a light source and there is a point of a origin of light rays. Light intensity appears equal in all directions
e.g. Bulb, Sun.

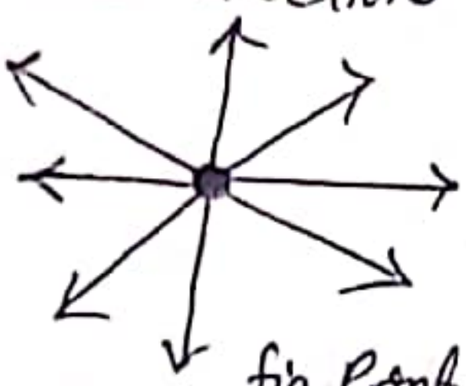
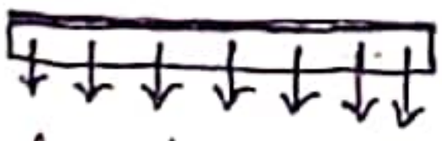


fig. Point light source

b) Distributed light source → There is no point origin and light rays are parallel to each other. Light rays are focused to particular direction. E.g. Lazer light, Torch, etc.



2) Surface Characteristics → It determines type of reflection from a particular surface. Surface can be rough, shiny, transparent and can produce specular reflection or diffuse reflection. Illumination model are necessary in CG for producing realastic displays.

⊛ Types of Illumination Models:

1) Ambient Light: Objects that are not in direct control with light source can still be visible if nearby objects are illuminated this is called ambient light. It is constant in all directions irrespective of viewing direction.

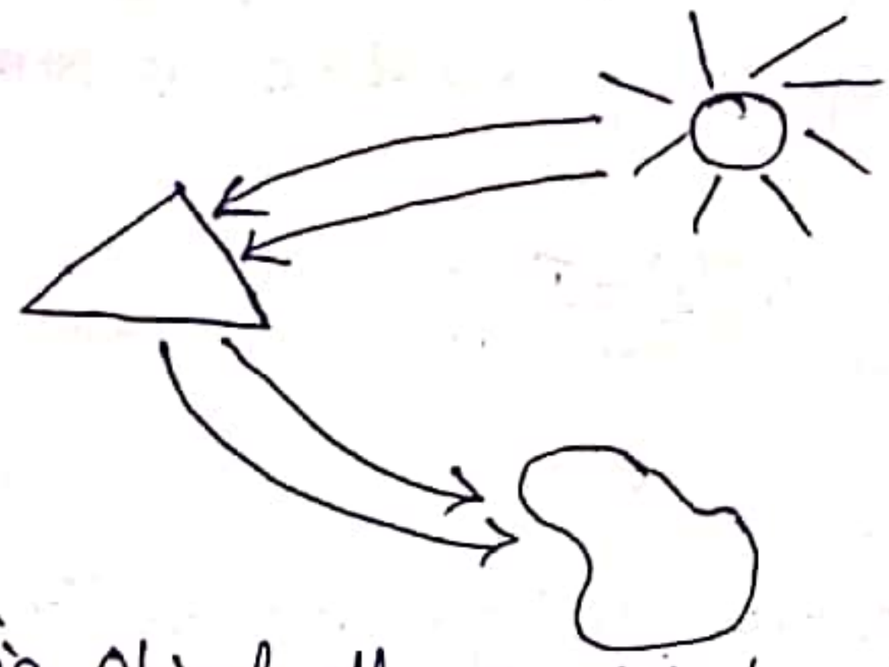


fig. Object illuminated due to ambient light

If a surface is exposed only to ambient light, then the intensity of the diffuse reflection at any point on surface is; $I = K_a I_a$.

where, I_a is the intensity of ambient light
& K_a is the ambient coefficient reflection.

2) Diffuse reflection: It is a reflection due to rough regular surfaces. Reflection of light is equal in all directions. It is the background light reflected from walls, floor and ceilings.

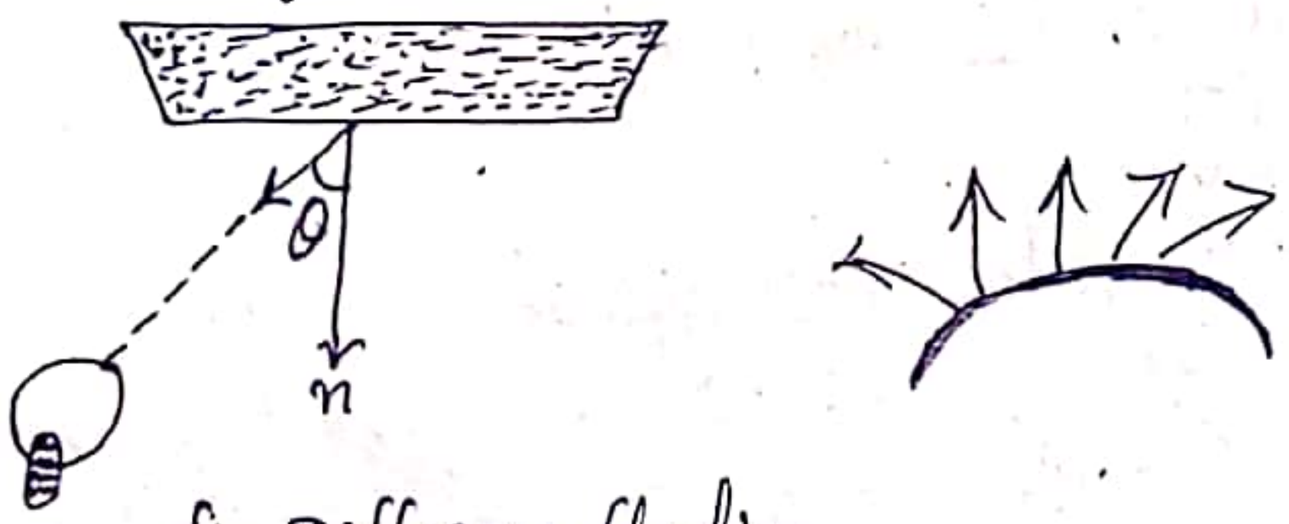


fig. Diffuse reflection

This effect of light reflection for purely dull surfaces can be computed according to Lambert's cosine law by illumination equation;

$$I = I_l \cdot K_d \cdot \cos\theta$$

where, I_l is intensity of light hitting surface, $0 \le K_d \le 1$ is the reflection coefficient of surface and θ angle between normal vector n to surface.

3) Specular Reflection:-

Specular light is the white highlight reflection seen on smooth, shiny objects. Specular reflection is a reflection due to shiny surfaces. This phenomena occurs due to total internal reflection of a incident light. In this phenomena maximum intensity appears in particular direction.

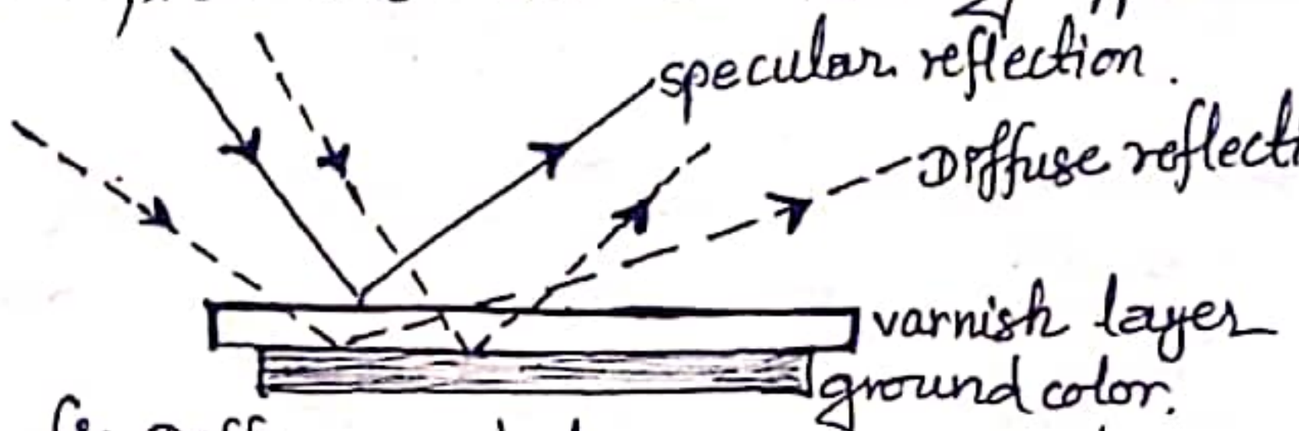


fig. Differences between diffuse and specular reflections.

It is calculated using Phong model. The Phong specular reflection model is described by the relation,

$$I = I_L \cdot w(\theta) \cdot \cos(\alpha)^n$$

where, I_L is intensity of light. The value $0 \leq w(\theta) \leq 1$ is the fraction of light which is directly reflected at the shiny surface.

⊛ **Intensity Attenuation:-** The rate of decrease in intensity w.r.t. distance between light source and objects is called intensity attenuation. If point light source is used the intensity attenuation is given by $\frac{1}{d^2}$. But if distributed light is used then intensity attenuation factor is given by a function $f(d) = \frac{1}{a_0 + a_1 d + a_2 d^2}$

where a_0, a_1 & a_2 are surface parameter and d is distance betn object and distributed light source.

⊛ **Color Consideration:-** Most of graphics displays of realistic scenes are in colour. But the illumination model discussed so far considers only ~~mono~~chro monochromatic ~~from each other~~. lighting effects. To incorporate color, we need to write the intensity equation as a function of the colour properties of the light sources and object surfaces.

⊛. Transparency:- Transparent surfaces reflect light but objects behind them can also be seen. A typical transparent object is coloured glass plane. Transparency means that only a fraction of light can pass behind through the transparent surface.

⊛ Shadows:- Shadow can help to create realism (means like as real). Shadows contribute a lot to the visual effect of the scene. Through shadows humans distinguish more clearly movement and depth of objects. There are number of techniques that can be used to create shadows for the objects.

⊛. Polygon (Surface) Rendering Method / Surface Shading:-

Polygon rendering is the process of calculating intensity and color considerations for a polygon surface.

Scene description + Illumination Model + Rendering Technique = Image.

There are two ways of polygon rendering:

- Rendering each polygon surface with single intensity
- Calculate intensity at each point of the surface using interpolation scheme.

There are three approaches for surface rendering as below:

1) Constant Intensity shading / Flat shading:-

In this method illumination model is applied by selecting arbitary pixel inside the surface and calculated intensity is applied to all other pixels inside the surface. It requires less computations but can not produce realistic images. It is the simplest model for shading a polygon.

Algorithm:-

→ Calculate surface normal vector for each surface.
→ Apply illumination model to particular interior pixel to determine intensity value.
→ Assign calculated intensity value to all other pixels on the surface.

2) Gouraud Shading / Intensity Interpolation Method:-

In this method, firstly the average surface normal vector at each vertex is determined as;

$$\vec{N_V} = \frac{\vec{N_1} + \vec{N_2} + \ldots + \vec{N_n}}{|\vec{N_1} + \vec{N_2} + \ldots + \vec{N_n}|}$$

where, $\vec{N_V}$ is the average surface normal vertex at vertex V, and $\vec{N_1}, \vec{N_2}, \ldots, \vec{N_n}$ are surface normal vectors on surfaces $S_1, S_2, \ldots, S_n$. Here, vertex V is shared by all n surfaces.

- Then illumination model are applied to each vertex to determine intensity value at that vertex.
- These calculated intensities are interpolated to determine intensity value of all other pixels.
- → It provides more realistic graphics than flat shading but suffered by Mach-Band Effect (i.e, Appearance of dark and bright spots at the corner of the objects surface).

Algorithm:-

1. Calculate average surface normal vector at each vertex.
2. Apply illumination model of vertices to calculate intensity value.
3. Apply interpolation to vertex intensities by using vertex coordinates and intensity at that vertex to determine intensities for all other pixel.

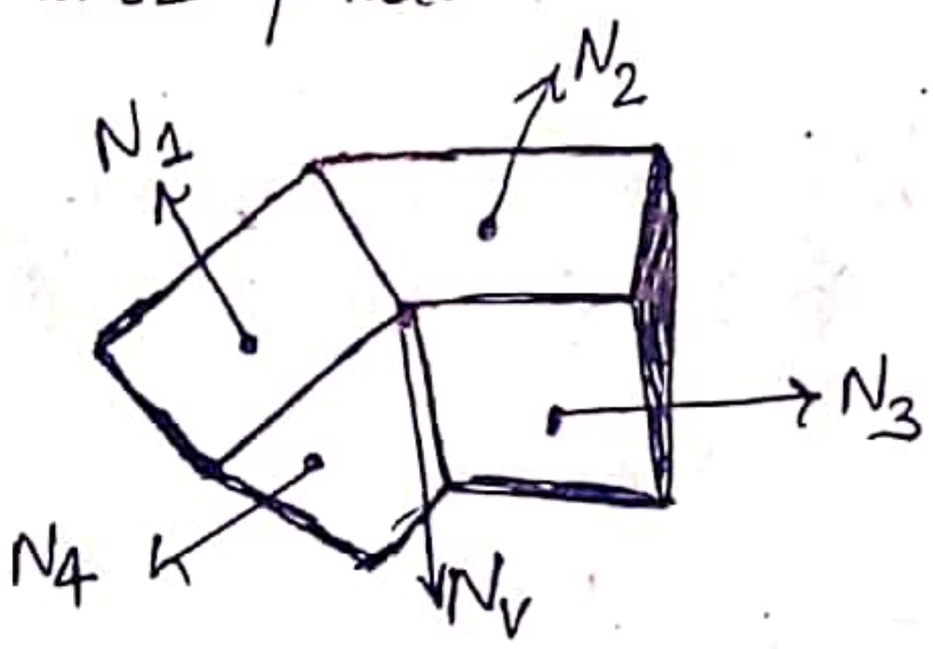


fig. Gouraud Shading

3) Phong Shading / Normal Vector Interpolation:-

An improvement of Gouraud Shading suggested by Phong Bui Toung that interpolates average surface normal vector to calculate color of the surface. It is the most effcient shading method but requires large number of computation.

Algorithm:-

→ Calculate average surface normal vector at each vertex.

→ Apply interpolation to determine average normal vector for all other points. by using average normal vector at vertices.

$$N = \frac{y - y_2}{y_1 - y_2} N_1 + \frac{y_1 - y}{y_1 - y_2} N_2$$

This is general form for interpolating normal vectors.

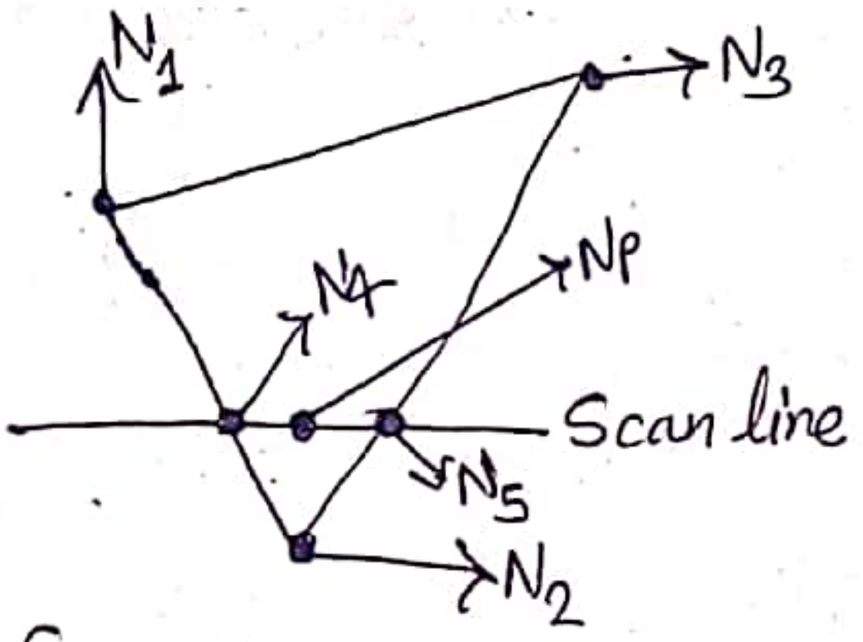


fig. Phong shading

$$\begin{cases} N_4 = \frac{y_4 - y_2}{y_1 - y_2} N_1 + \frac{y_1 - y_4}{y_1 - y_2} N_2 \\ N_5 = \frac{y_5 - y_2}{y_3 - y_2} N_3 + \frac{y_3 - y_5}{y_3 - y_2} N_2 \\ N_p = \frac{y_p - y_5}{y_4 - y_5} N_4 + \frac{y_4 - y_p}{y_4 - y_5} N_5 \end{cases}$$

Advantages:

→ It displays more realistic highlights on a surface.
→ It reduces the mach band effect.
→ It gives more accurate result.

Disadvantages:

→ It requires more calculations
→ It greatly increases thecost of shading steeply.

⊛. Differences between Gouraud Shading and Phong Shading:-

S.No	Gouraud Shading	Phong Shading
1.	Gouraud shading is named after Henri Gouraud.	Phong Shading model is named after Bui Tuong Phong.
2.	Computes illumination at border vertices and interpolates	Illumination at every point of polygon surface.
3.	Interpolates colors along edges and scan line.	Interpolates normal instead of colors.
4.	Not so expensive.	More expensive than Gouraud shading.
5.	Lighting equation is used at each vertex.	Lighting equation is used at each pixel.
6.	Requires moderate processing and time.	Required complex processing and it is slower but produces good quality.