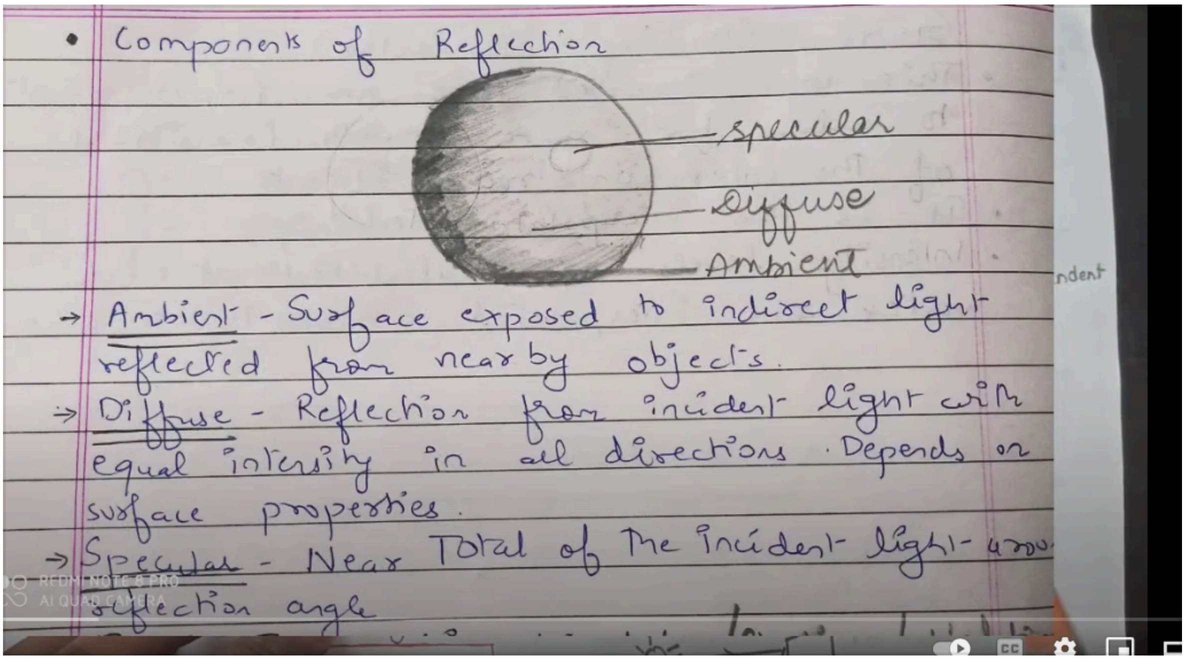
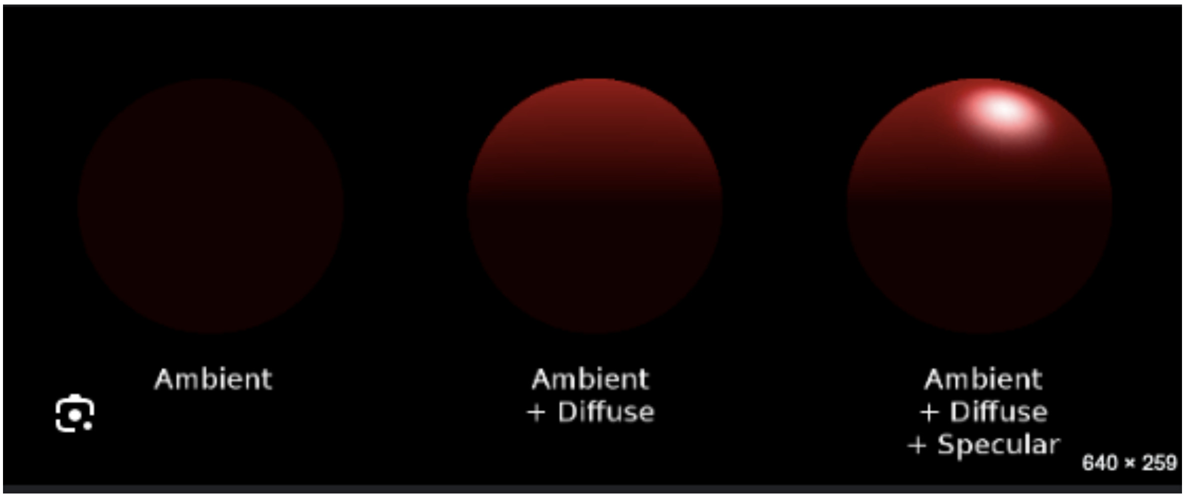
Unit - 3 Shading & Illumination Model

Basic Illumination Models
Illumination model, also known as Shading model or Lighting model, is used to calculate the intensity of light that is reflected at a given point on surface. There are three factors on which lighting effect depends on:



1. **Light Source :** Light source is the light emitting source. There are three types of light sources: Their position, electromagnetic spectrum and shape determine the lighting effect.
    1. **Point Sources –** The source that emit rays in all directions (A bulb in a room).
    2. **Parallel Sources –** Can be considered as a point source which is far from the surface (The sun).
    3. **Distributed Sources –** Rays originate from a finite area (A tubelight).
2. **Surface :** When light falls on a surface part of it is reflected and part of it is absorbed. Now the surface structure decides the amount of reflection and absorption of light. The position of the surface and positions of all the nearby surfaces also determine the lighting effect.
3. **Observer :** The observer's position and sensor spectrum sensitivities also affect the lighting effect



1. Ambient Illumination
-> Constant amount of light

Assume you are standing on a road, facing a building with glass exterior and sun rays are falling on that building reflecting back from it and the falling on the object under observation. This would be **Ambient Illumination,**In simple words, Ambient Illumination is the one where source of light is indirect.

The reflected intensity I_{amb} of any point on the surface is:

$$I_{amb} = K_a I_a$$

Where, I_a : ambient light intensity
K_a : surface ambient reflectivity, value of K_a varies from 0 to 1

2. Diffuse Reflection
Diffuse reflection occurs on the surfaces which are rough or grainy. In this reflection the brightness of a point depends upon the angle made by the light source and the surface.

The reflected intensity I_{diff} of a point on the surface is:

$$I_{diff} = K_d \, I_p \cos(\theta) = K_d \, I_p (N \cdot L)$$

Where, I_p : the point light intensity
K_d : the surface diffuse reflectivity, value of K_d varies from 0 to 1
N : the surface normal
L : the light direction

3. Specular Reflection
When light falls on any shiny or glossy surface most of it is reflected back, such reflection is known as Specular Reflection. **Phong Model** is an empirical model for Specular Reflection which provides us with the formula for calculation the reflected intensity I_{spec}.

$$I_{spec} = W(\theta) \, I_l \cos^n(\Phi)$$

where, $W(\theta)$: K_s
L : direction of light source
N : normal to the surface
R : direction of reflected ray
V : direction of observer
Θ : Angle between L and R
Φ : angle between R and V

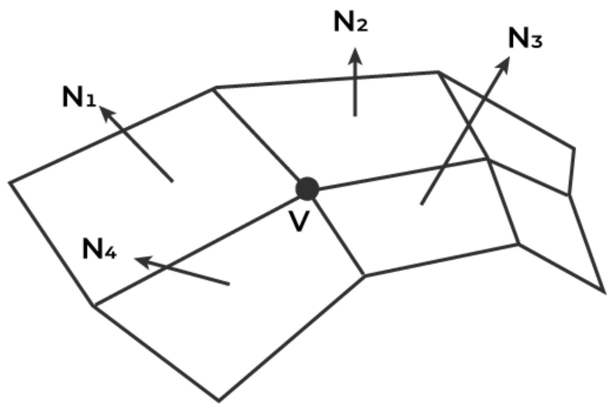
Gouraud Shading in Computer Graphics

Gouraud shading is a method used in computer graphics to simulate the differing effect of light and color across the surface of an object. Intensity- interpolation is used to develop Gouraud shading. By intensity interpolation, the intensity of each and every pixel is calculated. Gouraud shading shades a polygon by linearly interpolating intensity values across the surface. By this, if we know the intensities of two points then we can able to find the intensity of any point in between them.

By Gouraud shading, we can overcome the discontinue intensity values for each polygon that are matched with the values of adjacent polygons along the common edges.

Each polygon surface is rendered with Gouraud shading by performing the following calculations.

- The first step is to determine the average normal vector as add a polygon vertex. Determining the average unit normal vertex at each polygon vertex.

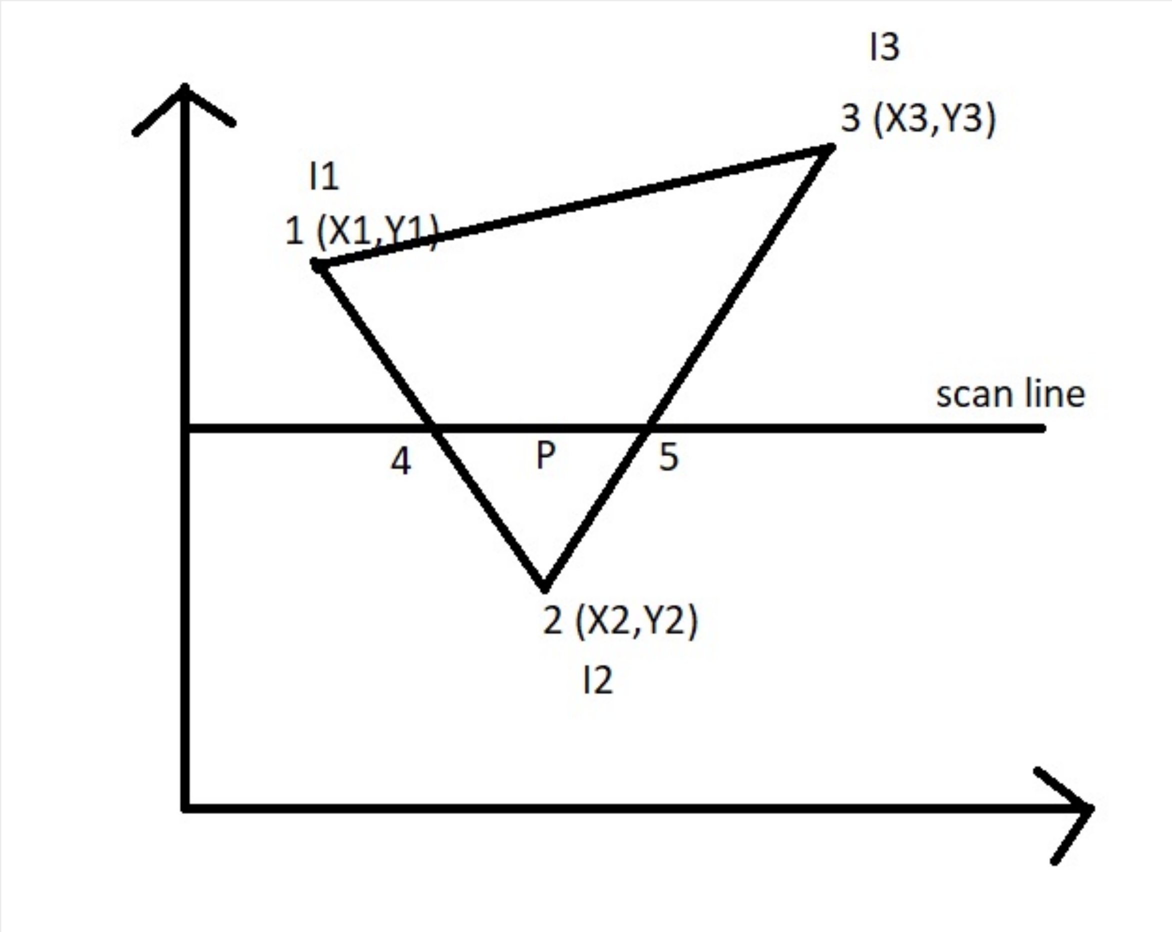


The Normal Vector at Vertex V is Calculated as the Average of the Surface Normal for each Polygon Sharing that Vertex

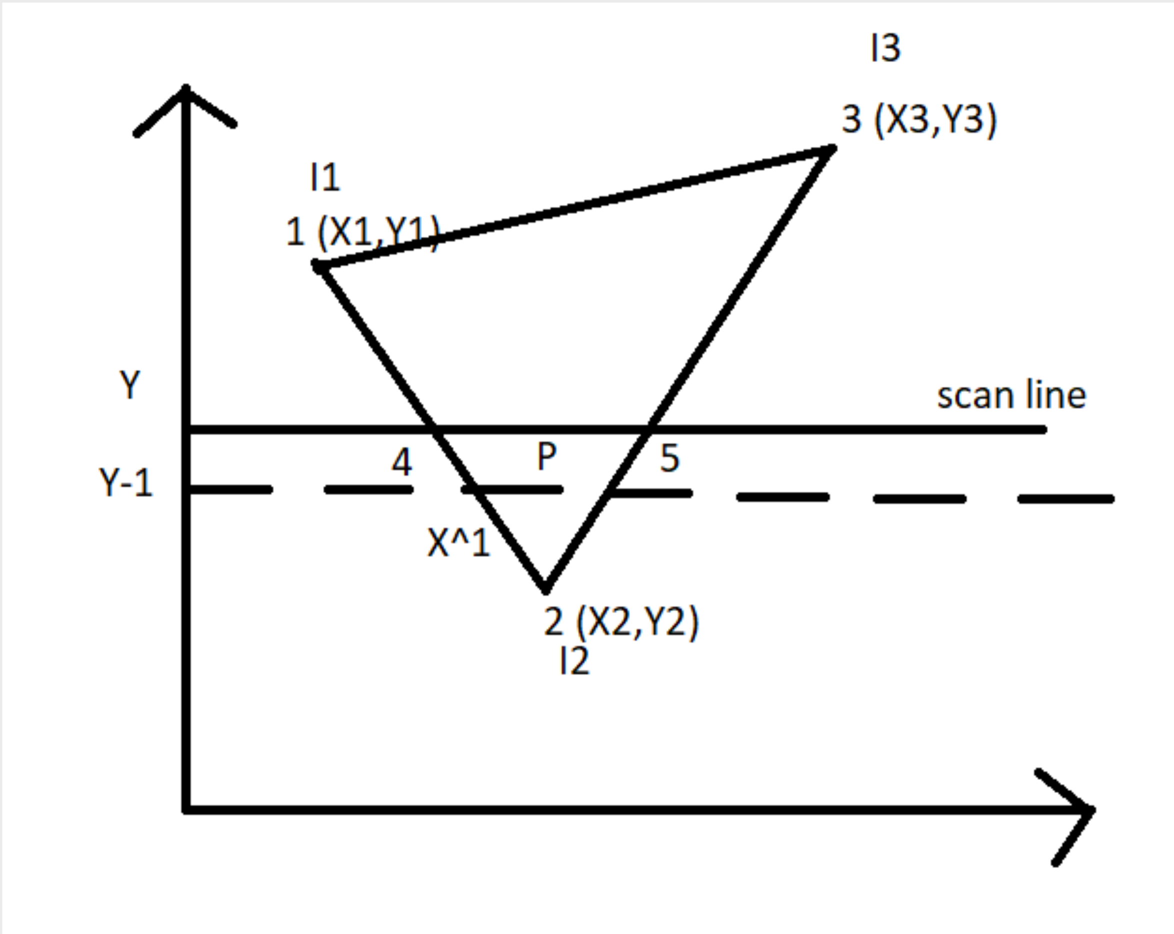
Calculating the average unit normal vector at point p. Point p is attached with four polygons.
So, the average unit normal vector = N1+N2+N3+N4/|N1+N2+N3+N4|

for n polygons —-> summation of k Nk / | summation of k Nk |
(where k is initialized from 1 to N)

- Applying an illumination model at each vertex to calculate vertex intensity.
- In computer graphics, we use an illumination model to calculate vertex intensity at each vertex.
- Linearly interpolated the vertex intensities over the surface of the polygon for each scanline the intensity at the intersection with a polygon edge is linearly interpolated.



In the above example, the vertex values and intensities of 1,2,3 are given. By linear interpolating, we can find the intensity at point 4 (by points 1 and 2) and at point 5 (by points 3 and 2)
I1 intensity at vertex 1
I2 intensity at vertex 2
I3 intensity at vertex 3
I4 intensity at vertex 4
I5 intensity at vertex 5
Now we can able to find the intensity at point p (by points 4 and 5)
And now we are taking y-1 as our next scanline.



Similar calculations are used to obtain intensities at successive horizontal pixel positions along each scan line. Incremental interpolation of intensity value along a polygon edge for successive scan line:
When the surfaces are to be rendered in color, the intensities of each color component are calculated at the vertices. Gouraud can be connected with a hidden surface algorithm to fill in the visible polygons along each scan line.
Advantages :

- Gouraud shading discards the intensity discontinuities associated with the constant shading model.
- Linear intensity interpolation can cause bright or dark intensity streaks, called match bands, to appear on the surface.
- The match band effect can decrease by dividing the surface into a higher no of polygon faces or by using other methods such as Phong shading which requires more calculations .

Disadvantages :

- Highlights on the surface are sometimes displayed with anomalous shapes.

- The linear intensity interpolation can result bright or dark intensity streaks to appear on the surface. These bright or dark intensity streaks, are called Mach bands. The mach band effect can be reduced by breaking the surface into a greater number of smaller polygons.
- Sharp drop of intensity values on the polygon surface can not be displayed.

Phong Shading Computer Graphics

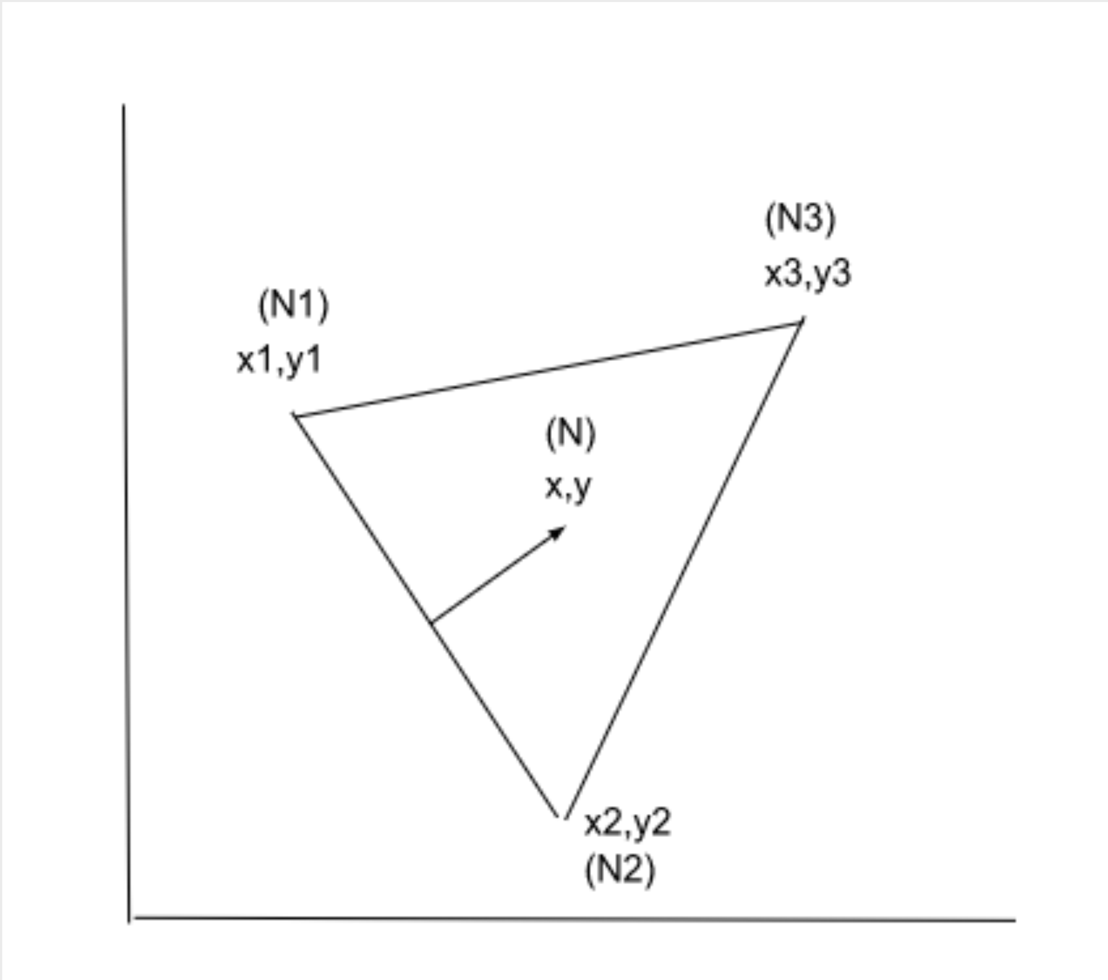
Phong shading is a more accurate interpolation-based approach that can be used for rendering a polygon. It was developed by Phong Bui Tuong.It improves upon the Gourand Shading and provides a better approximation of the shading of any smooth surface. It interpolates the normal vector instead of the intensity values.

Surface rendering is done with the help of Phong shading in the following manner:

- Determine the average unit normal vector at each polygon vertex.

So, for n polygons => summation of Ni/ | summation of Ni | (where i is initialized from 1 to N)

- Linearly interpolate the vertex normal over the surfaces of the polygon. N= (y-y2)/(y1-y2) N1 + (y1-y)/(y1-y2) N2



Interpolation of the surface normal

- By applying the illumination model along each scan we have to determine the projected pixel intensities of the surface points.

Advantages:

1. Some dark and bright intensity streaks known as mach bands appear on the surface due to the linear intensity interpolation, this method reduces the mach band effects and displays more realistic highlights.
2. It is more accurate as compared to the Gourand Shading.

Disadvantages:

1. It is slower as compared to the Gourand Shading.
2. It requires more calculation, hence it increases the cost of shading at each successive step.