Unit 3

Illumination Models & Surface Rendering Method

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Illumination Model

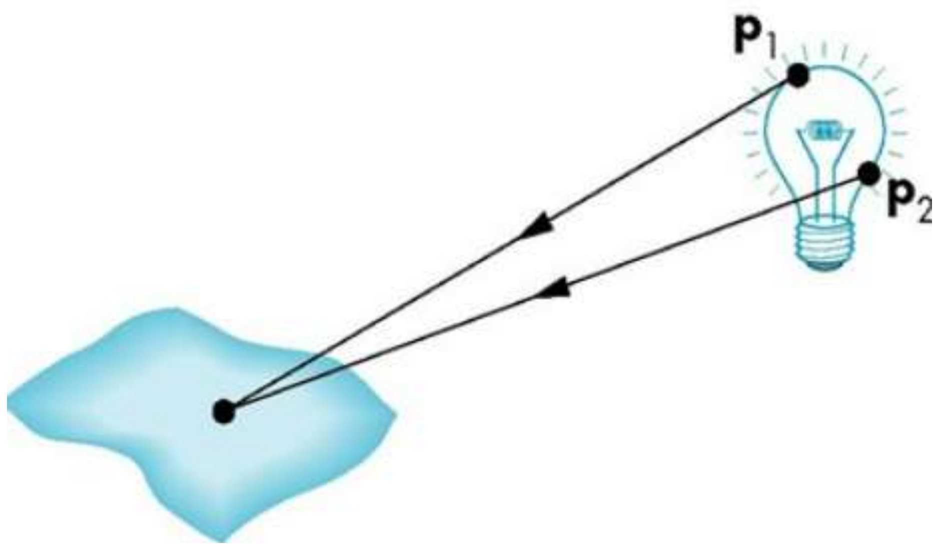
- **Illumination model**, also known as Shading model or Lightning model, is used to calculate the intensity of light that is reflected at a given point on surface.
- Rendering method uses intensity calculations from the illumination model to determine the light intensity at all pixels in the image

Light Material Interaction

- Light that strikes an object is partially absorbed & partially reflected.
- Shiny materials reflect more of the incident light and dull surfaces absorb more of the incident light.
- The amount reflected determines the color and brightness of the object
- The reflected light is scattered in a manner that depends on the orientation of the surface

Light sources

- Generally light sources are difficult to work with because we must integrate light coming from all points on the source

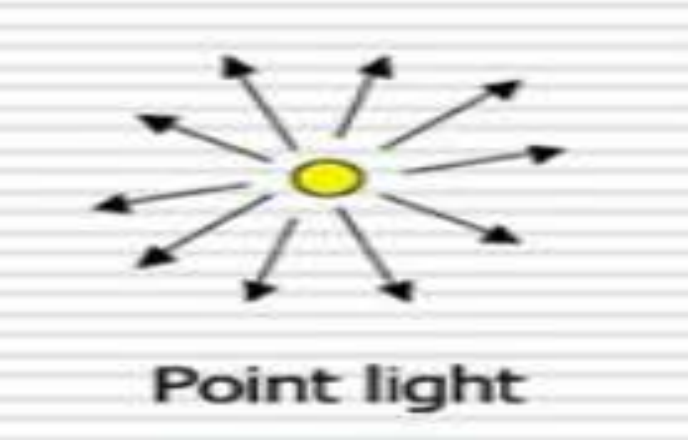


Light source is the light emitting source.
There are following types of light sources

- **Point Light**
- **Spot Light**
- **Directional Light**
- **Area Light**

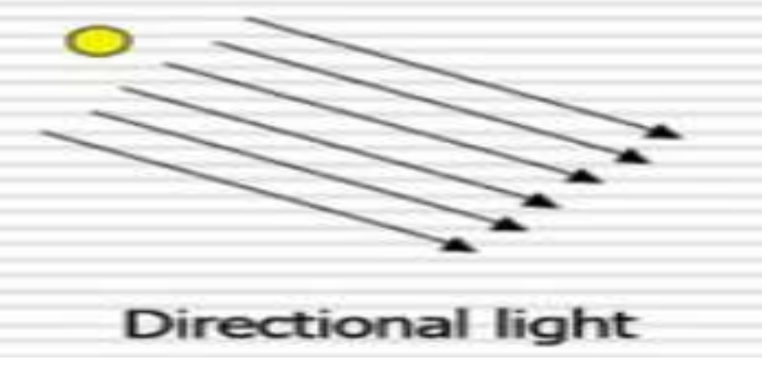
- **Point Light**

  Point sources emit light from a single point in all directions, with the intensity of the light decreasing with distance. An example of a point source is a standalone light bulb



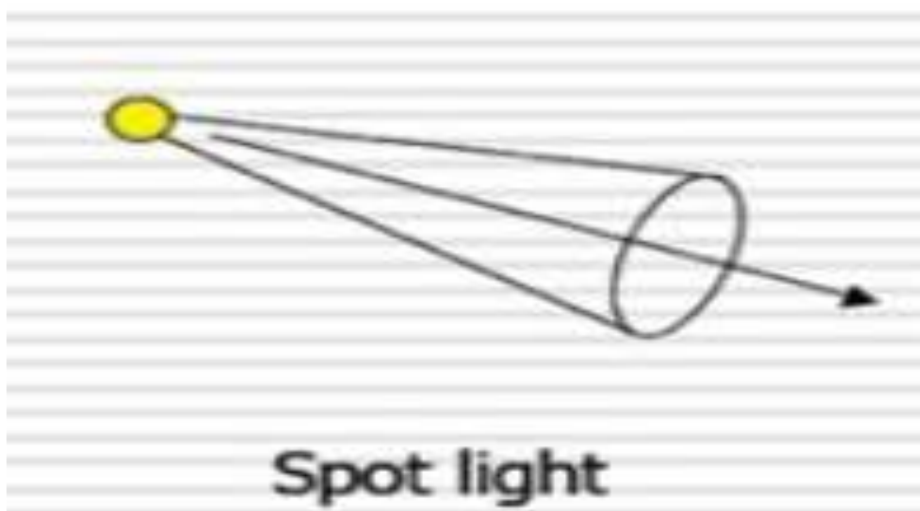
- **Directional Light**

  A directional source (or distant source) uniformly lights a scene from one direction. Unlike a point source, the intensity of light produced by a directional source does not change with distance over the scale of the scene, as the directional source is treated as though it is extremely far away. An example of a directional source is sunlight on Earth.



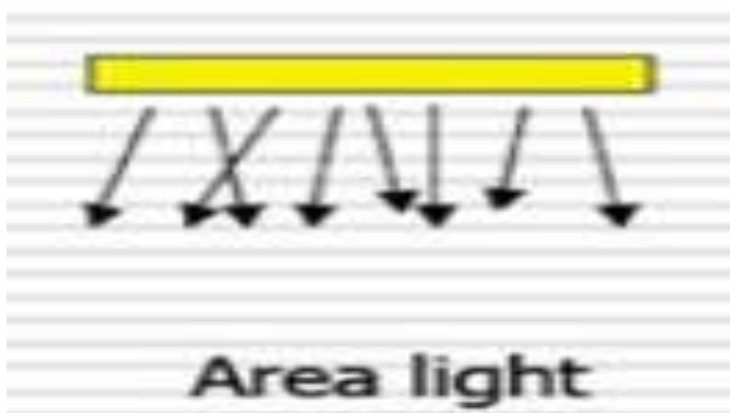
- **Spot Light**

  A spotlight produces a directed cone of light. The light becomes more intense as the viewer gets closer to the spotlight source and to the center of the light cone. An example of a spotlight is a flashlight.



- **Area Light**

  Area lights are 3D objects which emit light. Whereas point lights and spot lights sources are considered infinitesimally small points, area lights are treated as physical shapes. Area light produce softer shadows and more realistic lighting than point lights and spot lights.

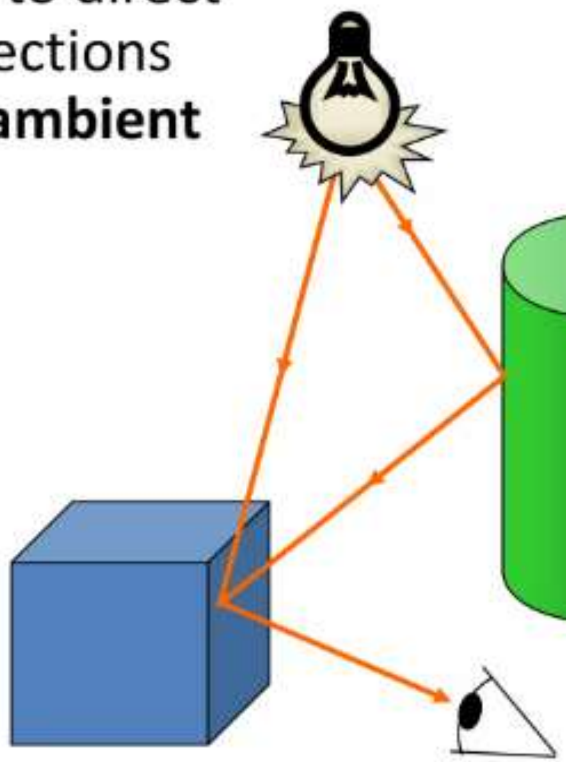


Types of Basic Illumination Models

- Ambient Light
- Diffuse Reflection
- Specular Reflection

Ambient Light

- A surface that is not exposed to direct light may still be lit up by reflections from other nearby objects – **ambient light.**

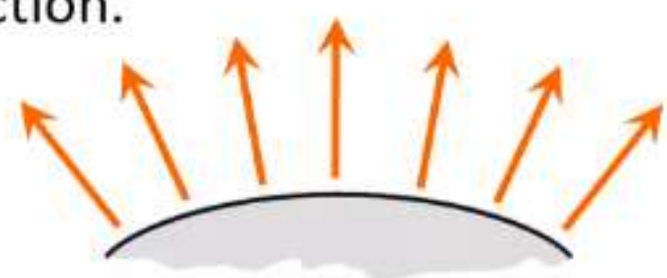


Surface Lighting Effects

- The amount of incident light reflected by a surface depends on the type of material.
- Shiny materials reflect more of the incident light and dull surfaces absorb more of the incident light.
- For transparent surfaces some of the light is also transmitted through the material.

Diffuse Reflection/Perfect Diffuse Reflection

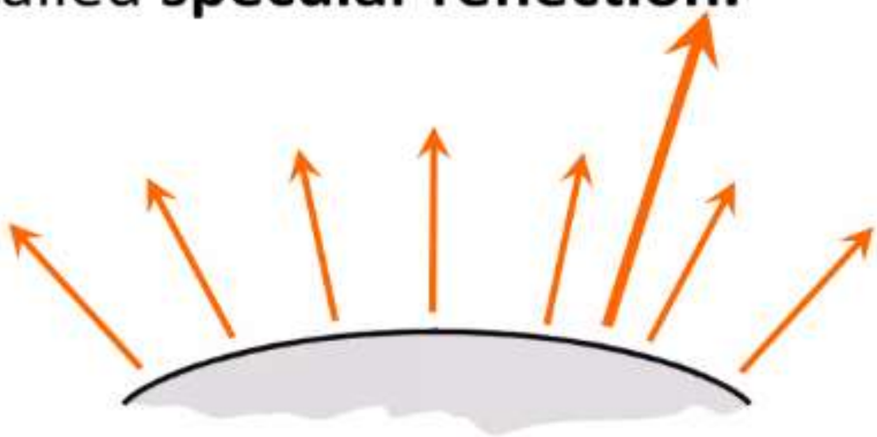
- Surfaces that are rough or grainy tend to reflect light in all directions.
- This scattered light is called **diffuse reflection.**
- Surfaces that reflect incident light with equal intensity in all directions. It is a case of perfect diffuse reflection.
- Such surfaces are referred to as **ideal diffuse reflectors.**
- **Example- snow, movie screen.**
- Lambertian surface appears equally bright from all the viewing directions. Because they reflect light with equal intensity in all direction.



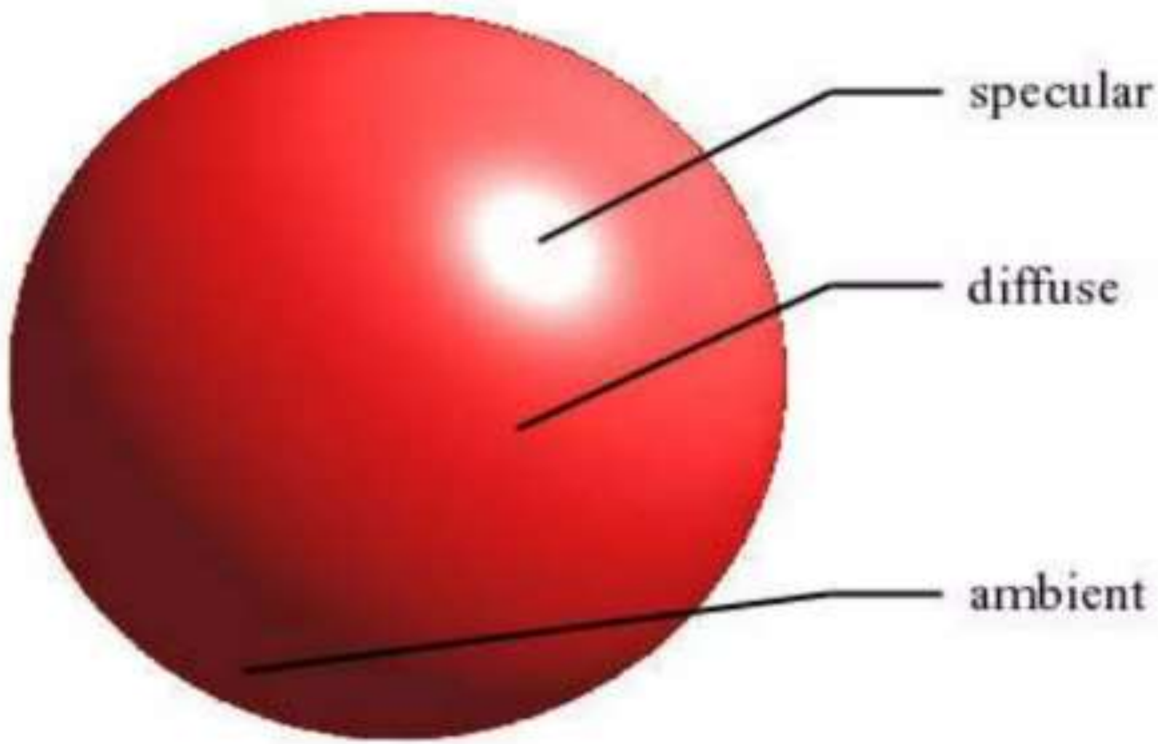
Specular Reflection

In Specular reflection it may possible that some portion of surface generated more light or may produce bright spot.

- This is called **specular reflection.**



Example



Polygon Rendering Methods

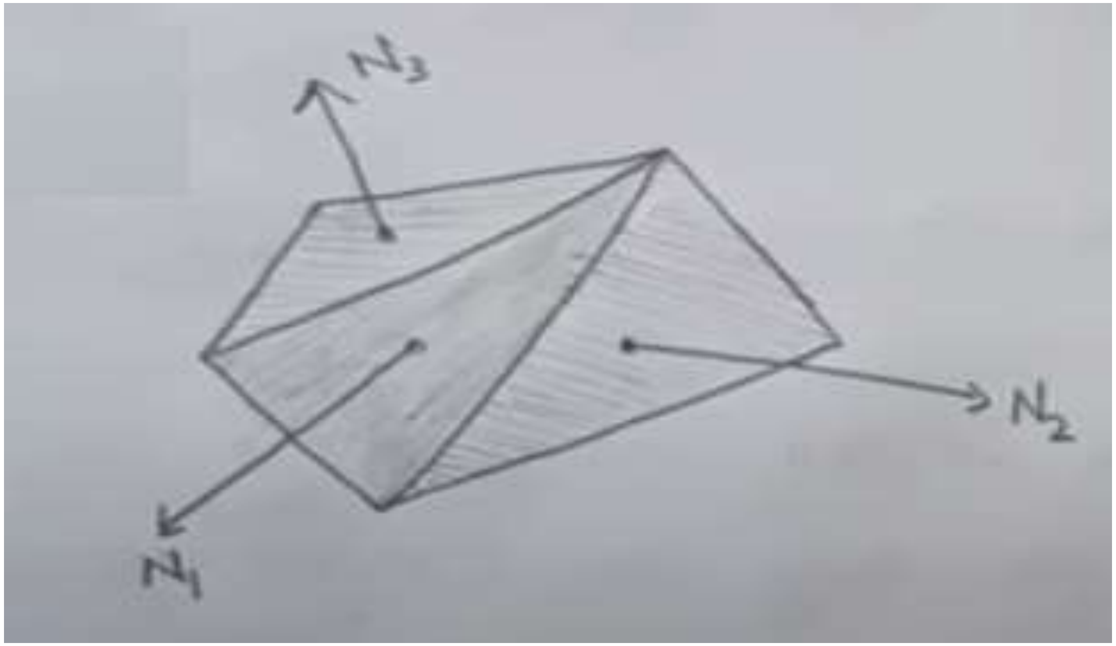
Polygon rendering is the process of determining the color and intensity of each pixel on the surface of a polygon in a 3D space to create a 2D image.

Different polygon rendering methods in computer graphics:

- Constant Intensity Shading/Flat Shading
- Gouraud Shading
- Phong Shading

Constant Intensity Shading/Flat Shading

- It is a simple & very fast method to specify color for an object of polygon rendering. It is also called Flat shading.
- In this method every point has **constant intensity**. All point of polygon has same intensity value.



Constant Intensity Shading/Flat Shading

- Flat shading assumes that each polygon is strictly planar & all the points on the polygon have exactly the same kind of lighting treatment.
- This shading technique thus displays all the points in a polygon with a single color.
- It defines a single color for a face implementation of it may vary but the main idea is that we use only one surface normal per polygon.
- Discontinuity of colors can be observed in different faces of the polygon

Gouraud Shading

- It is developed by Gouraud. This rendering is done by **<u>intensity interpolation.</u>**
- Intensity levels are calculated at each vertex & interpolated across the surface.
- This intensity interpolation scheme renders the polygon surface by linearly interpolating intensity values across the surface. Intensity values for each polygon are matched with the values of adjacent polygons along the common edges.
- This it eliminates the intensity discontinuities that occurs in flat shading. This technique uses the concept of intensity interpolation.

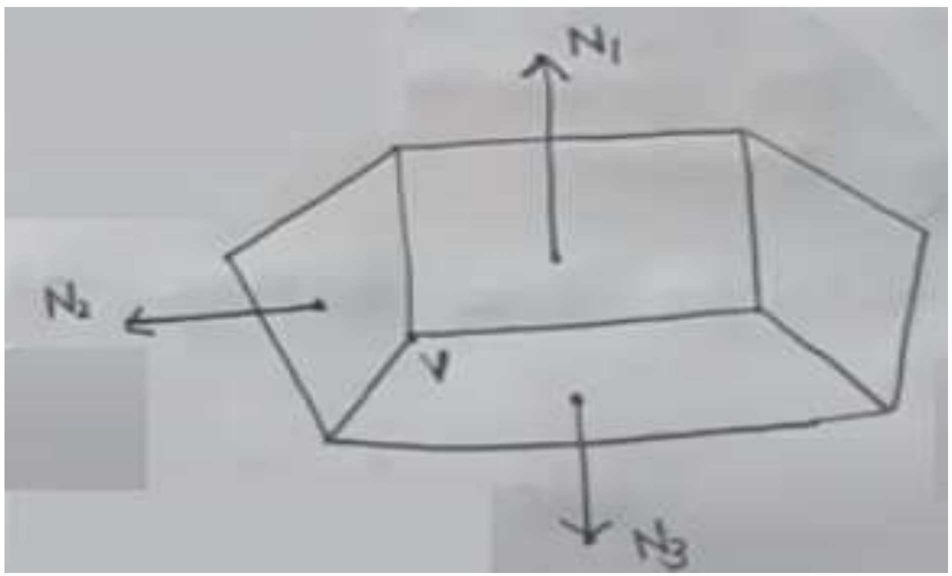
Gouraud Shading

- Calculations to be performed for each polygon surface rendered with Gourand shading:

  1) Determine average unit normal vector at each polygon vertex.

  2) Apply illumination model to each vertex to calculate the vertex intensity.

  3) Linearly interpolate the vertex intensities over the surface of the polygon.



Gouraud Shading

1) To determine average unit normal vector at each polygon vertex: At each polygon vertex (as shown by point V in the figure), the normal vector is obtained by averaging the surface normal of all polygons sharing that vertex.

$$N_v = \frac{N_1 + N_2 + N_3}{|N_1 + N_2 + N_3|}$$

- Thus, for any vertex V the unit vertex normal will be given by N_v

  K → 1 to n where n is no. of the surfaces in contact with the vertex v.

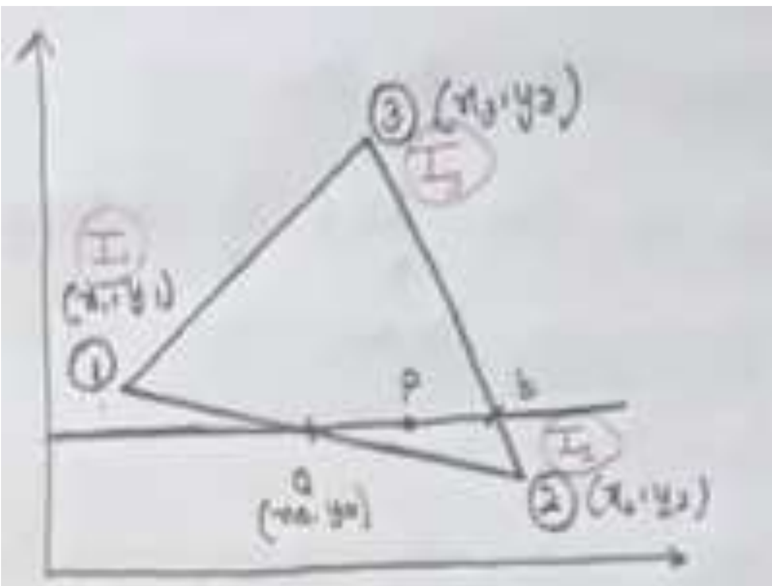
Generalized equation is

$$\boxed{\overline{N_v} = \frac{\sum_{k=1}^{n} N_k}{\left|\sum_{k=1}^{n} N_k\right|}}$$

Gouraud Shading

2) Apply illumination model to each vertex to calculate the vertex intensity.

3) Linearly interpolate the vertex intensities over the surface of the polygon.



Intensity of a: $$I_a = \frac{Y_a - Y_2}{Y_1 - Y_2} I_1 + \frac{Y_1 - Y_a}{Y_1 - Y_2} I_2$$

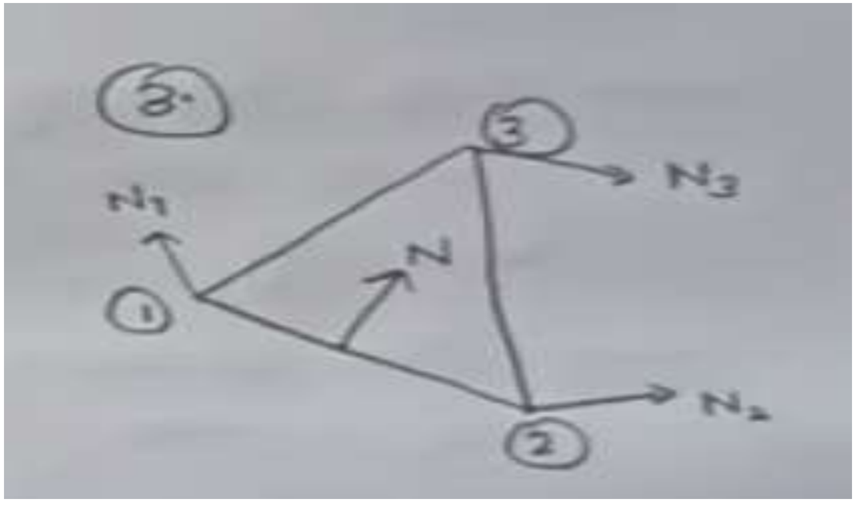
Intensity of b: $$I_b = \frac{Y_b - Y_2}{Y_2 - Y_3} I_3 + \frac{Y_3 - Y_b}{Y_1 - Y_2} I_2$$

Intensity at point p is given by:

$$I_p = \frac{X_b - X_p}{X_b - X_a} I_a + \frac{X_p - X_a}{X_b - X_a} I_b$$

Phong Shading

- It is more accurate method of polygon rendering developed by Phong Bui Tuong.
- Phong shading improves upon Gouraud shading and provides a better approximation of the shading of a smooth surface.
- At each point of the surface, it **interpolates the normal vector** instead of intensity values and applies the illumination model.
- It is also called as normal vector interpolation shading.
- It gives more real highlights of the surface



Phong Shading

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

$$N_v = \frac{N_1 + N_2}{|N_1 + N_2|}$$

Thus, for any vertex V the unit vertex normal will be given by N_v

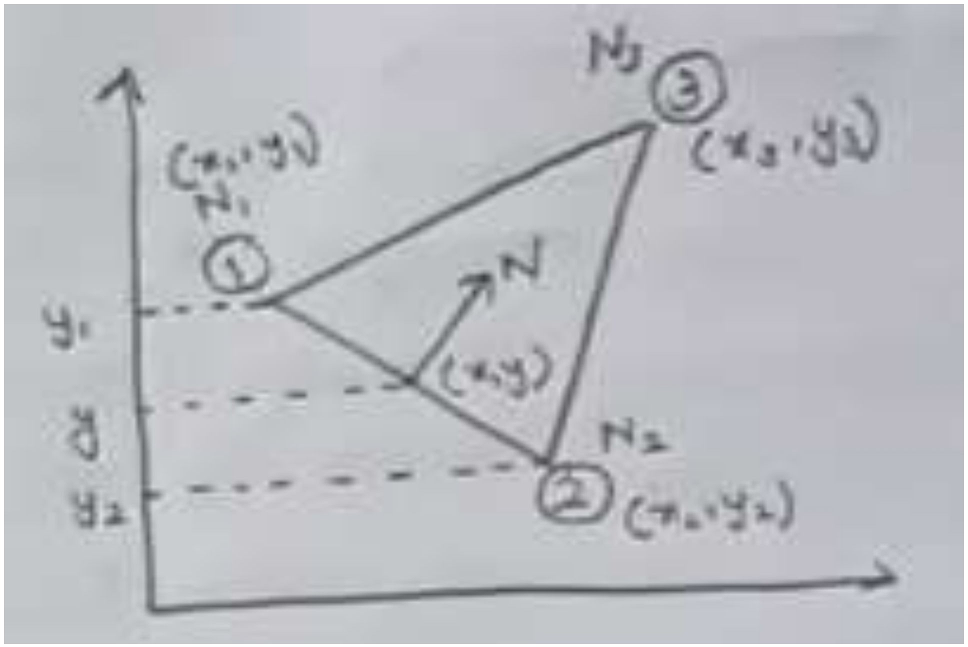
K → 1 to n where n is no. of the surfaces in contact with the vertex v.

Generalized equation is

$$\boxed{\overline{N_v} = \frac{\sum_{k=1}^{n} N_k}{|\sum_{k=1}^{n} N_k|}}$$

Phong Shading

Linearly interpolate the **vertex normals** over the surface of polygon



$$N = \frac{Y - Y_2}{Y_1 - Y_2} N_1 + \frac{Y_1 - Y}{Y_1 - Y_2} N_2$$

Apply the illumination model along each scan to determine projected pixel intensities of surface points

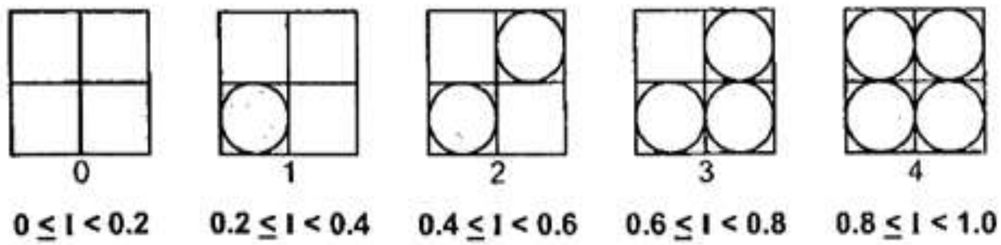
Comparison

Method	Description	Advantages	Disadvantages
Constant Intensity Shading	Also known as flat shading. Every point on the polygon has the same constant intensity value, resulting in a uniform appearance.	Fast rendering method, useful for displaying simple curved surface appearances.	Unrealistic appearance, no consideration for surface smoothness or reflection.
Gouraud Shading	Based on the interpolation of intensities between the vertices of a polygon. Calculates the intensity value for each point by linear interpolation across the surface of the polygon.	Eliminates intensity discontinuities, reduces appearance of banding. More realistic appearance than flat shading.	Less accurate than Phong shading.
Phong Shading	Interpolates the surface's normal vector at each point and applies the illumination model. Gives more realistic highlights to the surface and reduces appearance of match bands.	Provides the most accurate representation of the object's reflection and shading.	Computationally expensive, may result in longer rendering times.

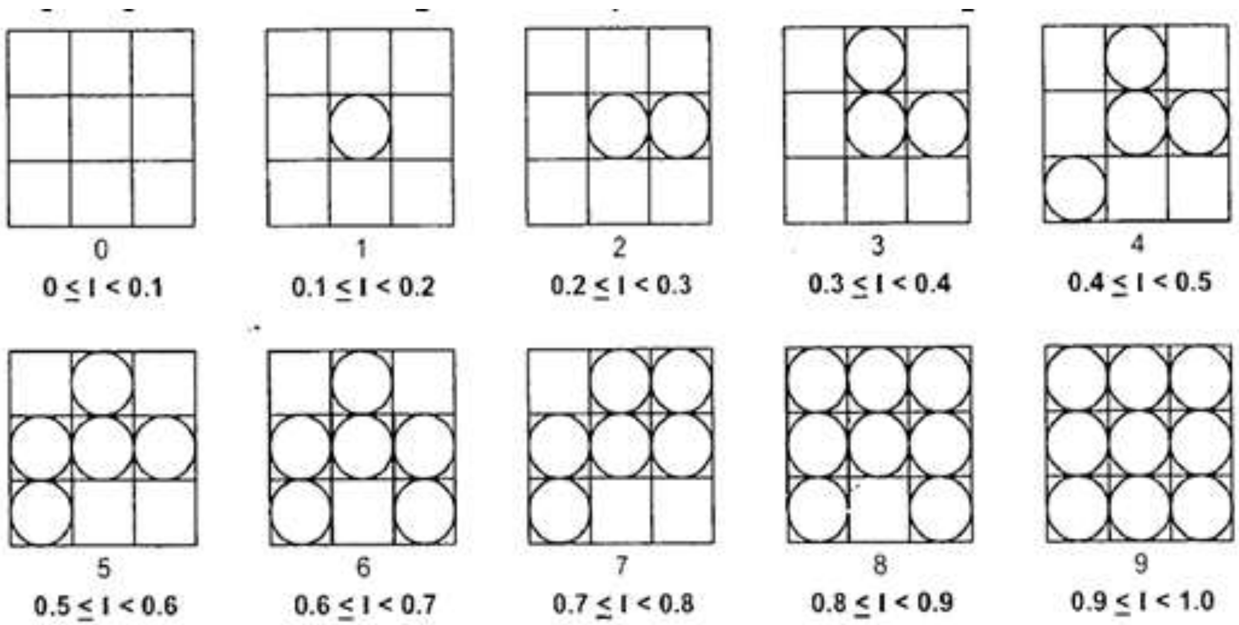
Half tonning Technique:

- Newspaper, photographs simulate a grey-scale image that can printed using only black ink.
- A newspaper picture is, in fact, made up of a pattern of tiny black dots of varying size.
- The human visual system has a tendency to average brightness over small areas, so the black dots and their white background merge and are perceived as an intermediate shade of grey.
- The process of generating a binary pattern of black and white dots from an image is termed half toning.
- In traditional newspaper and magazine production, this process is carried out photographically by projection of a transparency through a 'halftone screen' onto film.
- The screen is a glass plate with a grid etched into it.
- Different screens can be used to control the size and shape of the dots in the half toned image.
- In computer graphics, half toning reproductions are approximated using rectangular pixel region say 2 x 2 pixels or 3 x 3 pixels.
- These regions are called as “Halftone Patters” or “Pixel Patterns”.

2 x 2 pixel patterns for creating five intensity levels are shown in figure



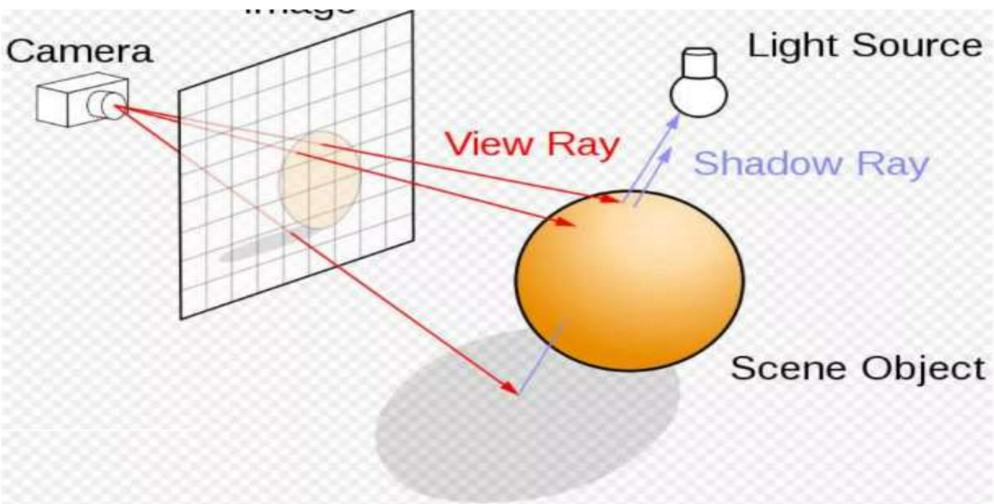
3 x 3 pixel patterns for creating ten intensity levels are shown in figure



Ray Tracing

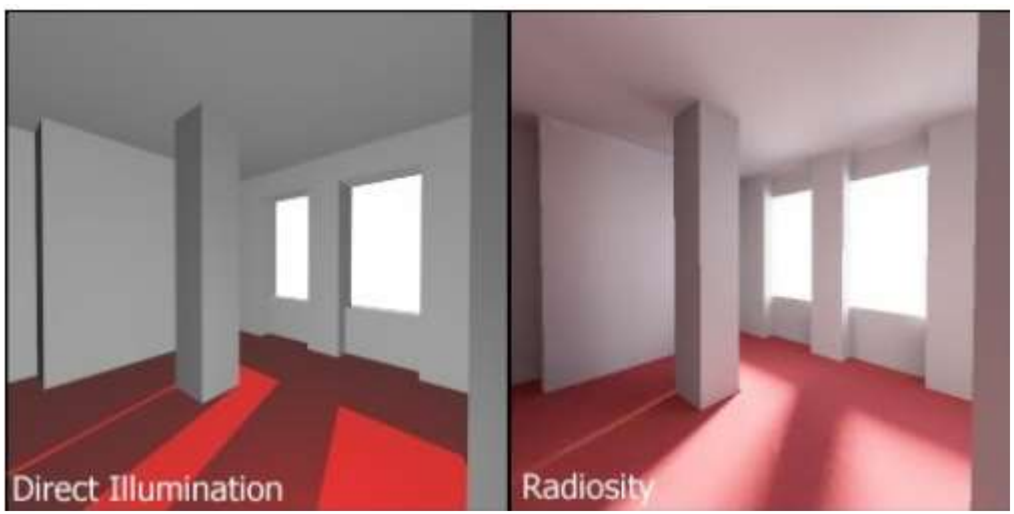
- Ray tracing is a technique for rendering three-dimensional graphics with very complex light interactions. This means you can create pictures full of mirrors, transparent surfaces, and shadows, with stunning results.
- A very simple method to both understand and implement.
- It is based on the idea that you can model reflection and refraction by recursively following the path that light takes as it bounces through an environment

- Builds the image pixel by pixel
- Cast additional rays from the hit point to determine the pixel color
  - Shoot rays toward each light. If they hit something, the object is shadowed from that light, otherwise use “standard model” for the light
  - Reflection rays for mirror surfaces, to see what should be reflected in the mirror
  - Refraction rays to see what can be seen through transparent objects
  - Sum all the contributions to get the pixel color



Radiosity lighting

Radiosity is a rendering technique that focuses on global lighting and works to track the way that light spreads and diffuses around a scene.
This is done in an attempt to simulate the effect of light bouncing around a room.
This is a really good method for recreating natural shading. Have a look in the corner of any room or where the walls meet the ceiling - you'll notice that shadows tend to gather there. This is something that can be recreated really well using radiosity.



Thank you