Assignment- 6

Date
Page

1. Incase of 3D viewing why is it required to consider illumination model? How does it aid in bringing visual realism?

→ In 3D viewing, considering an illumination model is essential because it plays a crucial role in creating visual realism.

→ The illumination model simulates the interaction of light with surfaces in a 3D scene, determining how light sources illuminate objects & how the light is reflected, absorbed, or transmitted by different materials.

→ Incorporating an illumination model aids in achieving visual realism for several reasons:

1. Realistic shading

→ The illumination model allows the renderer to calculate how light interacts with the surfaces of 3D objects.

→ This inform is used to determine how light & shadows appear on different parts of the objects, leading to realistic shading effects, such as smooth gradients & sharp shadows.

2. Depth Perception

→ Power illumination provides visual cues like shading & shadows, which aid in perceiving the depth & spatial relationships bet objects in the scene.

→ This enhances the sense of realism by making the objects look more solid & tangible.

3. Material rendering
→ Diff materials react differently to light. For instance, a metallic surface reflects light more sharply than a matte surface.

4. Ambience & Mood
→ The choice of illumination model can influence the overall ambience & mood of the scene.
→ Diff lighting setups, such as warm or cool lighting, can evoke diff emotions in viewers & enhance the realism by setting an appropriate tone for the scene.

5. Consistency
6. Light Interaction
7. Dynamic lighting

(b) What is illumination model? How does Phong shading algorithm remove drawbacks of Intensity Interpolation? Explain.
→ An illumination model, also known as lighting model or shading model, is a mathematical representation of how light interacts with surfaces in a 3D scene. It is used in

computer graphics & 3D rendering to calculate the colors of pixels on a rendered surface based on the light sources, surface properties, & the observer's viewpoint.

→ The illumination model simulates various light interactions, such as diffuse reflection, specular reflection, ambient lighting & more, to produce realistic effects & shading on 3D objects.

→ One popular illumination model is the Phong illumination model, introduced by Bui Tuong Phong in 1973.

→ It is an extension of the Gouraud shading model, which is based on the intensity interpolation scheme.

→ The Gouraud shading model calculates the intensity at the vertices of polygons & then interpolates these intensities across the polygon's surface to determine the pixel colors.

However, the Gouraud shading model has some drawbacks, & the phong shading algorithm addresses these issues. Here's how the Phong shading alg. improves upon the intensity interpolation scheme:

1) Smooth shading

→ One major drawback of the Gouraud shading model is the presence of visible sharp edges between polygons, especially when the polygons are large or highly curved.

→ Since Gouraud shading interpolates intensities, it can't capture the fine details of shading across the surface of the polygon.

→ In contrast PS alg calculates the shading for each pixel on the polygon's surface based on the normal vectors at each vertex, resulting in smoother shading & eliminating the sharp edge artifacts.

2) Specular Highlights

→ The GS model cannot accurately represent specular highlights, which are bright spots of reflected light seen on shiny surfaces.

→ Since, GS interpolates intensities, the specular highlights are often lost bet'n the vertices.

→ PS, on the other hand, explicitly calculates the specular reflection for each pixel based on the angle bet'n the viewer's direct & the reflected light direct, providing more accurate specular highlights.

3) Surface Detail

→ PS: more capable of representing fine surface details & high-frequency variations in shading.

4) Cost

→ PS → expensive than GS

43) What is the effect of intensity interpolation? Explain the shading algorithm that uses this technique.

→ Intensity interpolation, also known as Gouraud shading, is a technique used in CGIs to simulate the effect of smooth shading on 3D objects rendered on a flat, polygonal surface.

→ It is fast & efficient shading alg. that calculates the shading intensity at the vertices of each polygon & then interpolates these intensities across the surface of the polygon to determine the pixel colors.

→ The purpose of IN is to create the illusion of a smooth transition of lighting & shading across the surface, giving a more realistic appearance to the rendered object.

The GIS algorithm follows these steps:

1. Vertex shading

→ ~~After determining~~ For each vertex of a polygon, the alg. calculates the shading intensity based on the local surface properties, such as the normal vector & the light sources positions & intensities.

→ This shading intensity is typically computed using the Phong reflection model or a similar illumination model.

→ The IN step results in a shading intensity value for each vertex of the polygon.

2- Interpolation

→ After determining the shading intensity at each vertex, the alg. interpolates this intensity across the surface of the polygon.

→ It calculates the shading intensity for each pixel's position on the polygon based on its position relative to the vertices.

3- Pixel Rendering

→ With the interpolated shading intensities for each pixel, the alg. determines the final color for each pixel on the polygon's surface.

→ This color is computed by combining the shading intensity with the polygon's material properties, such as its color, texture & transparency.

→ The final pixel colors are then displayed on the screen, creating the illusion of smooth shading across the polygon.

Gouraud drawbacks

Q4) How is shading an object using flat shading different from shading it using phong shading technique?

→ Flat shading & Phong shading are two different techniques used in CGs to simulate the way light interacts with objects & how they are shaded.

1) Flat shading

→ It is a basic & computationally less expensive shading technique.

→ In it, the shading of an entire polygon (usually a triangle) is constant across its surface.

→ This means that all the vertices of the polygon have the same color, & this color is used for the entire polygon, regardless of its orientation to the light source.

Advantages:

1) Simplicity
2) Efficiency

Disadvantages

1) Flat Appearance
2) Unnatural Lighting

2) Phong shading

→ It is a more advanced & computationally expensive shading technique.

→ In PS, the shading calculations are performed per pixel instead of per vertex.

→ The shading is interpolated smoothly across

the surface of the polygon based on the normals at each vertex.

Advantages
1) Smooth Appearance
2) Realistic lighting

Disadvantages
1) Computational Cost
2) Overhead

Q5) What are Mach Bands & how can they be removed? Explain the Intensity interpolation scheme as proposed by Gouraud?

Mach Bands
→ Mach Bands are a visual illusion phenomena observed when viewing a gradient or transition betn two colors or shades.
→ When there is a sudden change in intensity (brightness) across adjacent regions, our visual system tends to exaggerate the contrast at the boundaries, creating the appearance of faint bands of light & dark regions.
→ These bands are not actually present in the original image or gradient but are a result of the way our eyes perceive changes in intensity.

o Removal of Mach bands:

→ To remove or reduce the Mach Bands effect, various anti-aliasing techniques can be employed.

→ These techniques aim to smooth out the intensity transitions, so they appear more natural to the human eye.

→ One such technique is the Gouraud shading.

Intensity Interpolation

→ Gouraud shading (done)

Advantages

1) It is computationally efficient because the interpolation is done only at the vertices, not for every pixel like PS.

→ It provides a visually pleasing & smooth shading effect for curved surfaces without the overhead of per-pixel calculations.

Limitations

→ It does not produce accurate shading on a per-pixel level, as it only interpolates colors between vertices. This can result in less realistic lighting effects compared to PS.

→ It may still exhibit subtle Mach Bands artifacts, especially if the polygons are large or have strong intensity variations

Q8) What are advantages of GIS & PS? Explain the Normal vector interpolation scheme as proposed by Phong?

- 1st part → done
- 2nd part

⇒ Phong shading (Normal vector Interpolation)

→ PS is an extension of GS that improves the accuracy of lighting calculations.

→ One of the key components of PS is the interpolation of surface normals, also known as Normal vector Interpolation. Here's how it works:

1) Vertex Normals:

→ Similar to GS, each vertex of a polygon is associated with a surface normal vector.

→ These vertex normals represent the direction of the surface at those points.

2) Interpolation

→ In PS, instead of interpolating just the colors, the surface normals at the vertices are also interpolated across the polygon's surface to determine the normal direction at each pixel.

3) Per-pixel shading

Using the interpolated normal at each pixel the shading calculations (such as the intensity of light reflection) are performed on a per-pixel basis.

→ This means that each pixel gets its own shading value based on its position & orientation relative to the light sources & camera.

Advantages

- Improved Realism
- Specular Highlights
- Better light Interaction

5) What is the diff bet diffuse & specular reflection? Derive an expression for computing the total intensity of a point illuminated by diff light sources ambient, diffuse & specular.

Diffuse Reflection

→ It refers to the scattering of light in various directions when it interacts with a rough or non-glossy surface.

→ In this type of reflection, the incident light is absorbed & re-emitted by the surface in multiple directions.

→ The intensity of the reflected light is the same for all viewing angles, resulting in

a uniformly lit appearance.

→ It is responsible for providing the overall brightness & color of an object.

Specular reflection

→ It occurs when light hits a smooth or glossy surface & reflects predominantly in a single direction, following the law of reflection.

→ Unlike DR, the intensity of the reflected light varies depending on the viewing angle.

→ SR is responsible for creating highlights & shiny spots on surfaces, which give objects a polished or reflective appearance.

Expression

$$I\_total = I\_ambient + I\_diffuse + I\_specular$$

where,

$$I\_diffuse = C\_diffuse * I\_light * \max(0, dot(N, L))$$

$$I\_specular = C\_specular * I\_light * \max(0, dot(R, V))^{shiness}$$

Q8) Explain fast phong approach. How does it differ from other shading approaches?

→ The "fast phong" approach is a variant of the phong shading model that aims to approximate the specular reflection component more efficiently.

→ It is designed to reduce computational complexity while still providing reasonably accurate results compared to traditional Phong shading.

→ The primary diff. betn Fast Phong & other shading approaches lies in the way it handles specular highlights.

Diffs

1. Specular Reflection Approximation

→ In fast Phong, instead of computing the precise reflection direction for each pixel, it approximates the specular reflection using the Half-Vector Phong reflection model.

2. Precomputed Lookup Tables

→ Fast phong employs precomputed lookup tables to store the results of expensive trigonometric calculations, such as dot product & power functions.

→ These lookup tables enable the model to fetch precomputed values directly, reducing the need for costly computations during runtime.

3. Reduces Trigonometric operations

4. Trade-off bet'n Accuracy & Speed.

(Q) Explain constant Intensity shading approach by mentioning its advantages & disadvantages

→ It is one of the simplest & most basic shading approaches used in CG.

→ In this method, the intensity (brightness or color) of a surface is constant across the entire polygon, irrespective of its orientation or lighting conditions.

→ This means that all pixels within a polygon are assigned the same color value, resulting in a flat appearance without any shading effects.

→ It is primarily used in cases where simplicity & low computational cost are more important than realistic lighting effects.

Advantages

1. Simplicity
2. low computational cost
3. Faceted Appearance
4. Artistic Expression

Disadvantages

1. Lack of Realism
2. Faceted Appearance
3. No shadow Effects
4. Limited Use Cases

Q10) Explain the mathematical equations used in case of Gouraud shading for interpolating intensity.

→ Let's assume we have a triangle with 3 vertices V_1, V_2, V_3 & each vertex has an associated intensity value I_1, I_2, I_3 respectively.

1. Barycentric Coordinates:

$u * V_1 + v * V_2 + w * V_3 = P$

where,

(u, v, w) are the barycentric coordinates of the pixel, & P is the position of the pixel in 3D space

2. Interpolation of Intensities

$I\_interpolate = u * I_1 + v * I_2 + w * I_3$

Here,

I_1, I_2 & I_3 are the intensity values at vertices V_1, V_2 & V_3 respectively.

Eg:
Suppose we have a pixel P within the Δ & its barycentric coordinates are (u, v, w) calculated based on its position relative to the vertices V_1, V_2, V_3.
If intensity values at the vertices are $I_1 = 0.5$, $I_2 = 0.8$ & $I_3 = 0.3$, the interpolated intensity $I_{interpolated}$ at pixel P would be:

$$I_{interpolated} = u * I_1 + v * I_2 + w * I_3$$

For eg, if (u, v, w) = (0.3, 0.4, 0.3)
then,

$$I_{interpolated} = 0.3 * 0.5 + 0.4 * 0.8 + 0.3 * 0.3 = 0.59$$

So, the pixel P would have an interpolated intensity of 0.59.

Q11) Explain the mathematical eqns used in case of phong shading for interpolating normals.

1. Barycentric coordinates:
→ Same

2. Interpolation of Normals

N_interpolated = normalize (U * N1 + V * N2 + W * N3)

Here,
N1, N2, & N3 are the vertex normals at vertices V1, V2 & V3 respectively.

3) Normalization

Q.2) In case of GS & PS why do you think it is reqd to compute the avg unit normal vectors?

i) GS

→ In GS, the shading calculations are performed at the vertices of the polygon, & the resulting intensities are then interpolated across the surface.

+ Since the shading model depends on the surface normal at each point, it is crucial to have a consistent & continuous normal direction across the polygon.

When polygons have diff vertex normals, the shading at each vertex may vary significantly leading to visible shading artifacts like sharp edges & discontinuities.
These artifacts can give the object an unrealistic appearance with noticeable

Lighting discontinuities.

→ By computing the avg unit normal vectors at each polygon face (triangle) & using it for shading at each vertex, GS ensures a smooth transition of intensities across the surface.

→ The avg normal provides a better representation of the overall surface orientation within the polygon & helps in reducing shading artifacts at the vertices.

2 Phong shading

→ To reduce the computational cost while maintaining a smooth appearance, PS also relies on computing the avg unit normal vectors at each polygon face.

→ By using the avg normals in PS, the computation of reflection directions is simplified, making it more efficient while still producing reasonably smooth & visually appealing shading results.