Indian Institute of Information Technology Allahabad
C2 Quiz Answers

1.
(a) Differentiate between Object Space Method and Image Space Method for hidden line and surface elimination. **[2]**

Sol.

The difference between Object Space Method and Space Method are as follows:

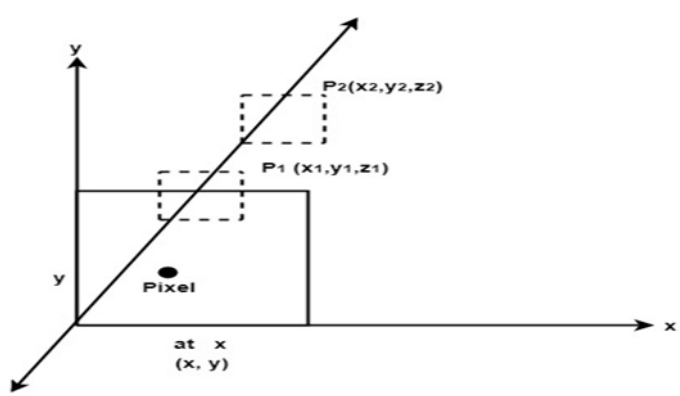
Object Space Method:
1. In object space methods, hidden line and surface elimination is performed based on the relationships and properties of objects in the 3D scene.
2. The visibility of lines and surfaces is determined by analyzing the geometric properties of objects, such as their position, orientation, and depth relative to the viewer.

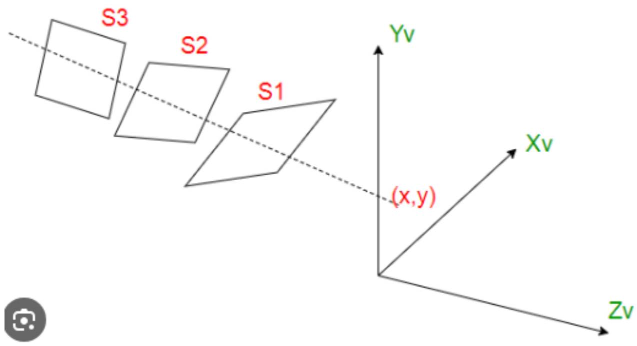
Image Space Method:
1. In image space methods, hidden line and surface elimination is performed directly in the 2D image space after projection from 3D space.
2. The visibility of lines and surfaces is determined by analyzing the image pixels and their attributes, such as color, intensity, or depth.

(b) Explain with example the Z-buffer algorithm for visible surface determination. Write 2 advantages and 2 disadvantages of this method. **[3]**

Sol.

The depth buffer algorithm, also known as the z-buffer algorithm, is a technique used for visible surface detection in computer graphics. It is particularly important in 3D rendering to determine which objects or parts of objects are visible and should be rendered on the screen.





Example: Consider a scene with two overlapping objects, a cube, and a sphere. The cube is closer to the viewer than the sphere. The depth buffer algorithm ensures that only the visible parts of each object are rendered by comparing pixel depths.

Cube: Depth = 10 units
Sphere: Depth = 15 units
When rendering pixels:

Pixel at (x, y) on the cube has a depth of 10 units. It passes the depth test and is rendered.
Pixel at (x, y) on the sphere has a depth of 15 units. It fails the depth test as it's farther than the cube's pixel, so it is not rendered.

Advantages: 1. Realistic Rendering: It accurately handles overlapping objects and renders only visible surfaces, leading to realistic 3D scenes.
2. Flexibility: Works well with complex scenes involving multiple objects and varying depths.
Disadvantages: 1. Memory Usage: Requires additional memory for the depth buffer, which can be significant for high-resolution displays and complex scenes.
2. Precision Issues: In scenes with very small depth differences, precision errors can occur, leading to artifacts like z-fighting

(c) Explain the working of Back face culling method using a suitable diagram. What is the command in OpenGL to enable depth testing?

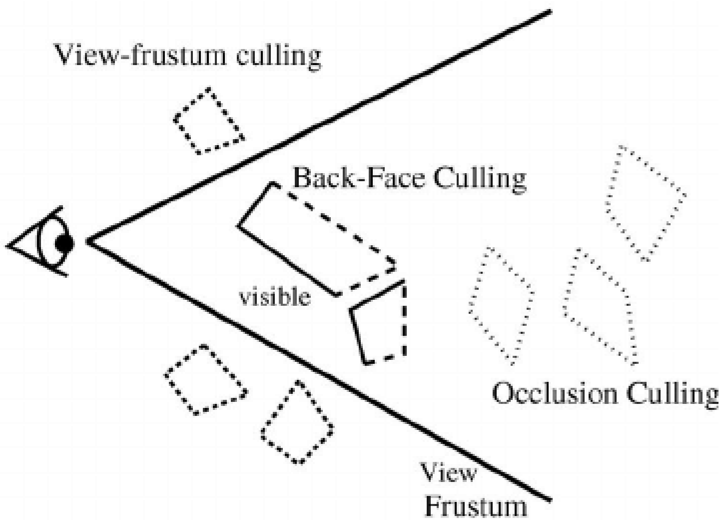
Sol.

Back-face culling is a technique used in computer graphics to improve rendering efficiency by only drawing the faces of a 3D object that are visible to the viewer.Here's how it works:

1. Determining Face Visibility: When rendering a 3D object, each face (or polygon) has a normal vector that indicates its orientation. The normal vector points outward from the front side of the face. By comparing the direction of the normal vector with the viewing direction (typically defined by the camera), we can determine if the face is facing towards or away from the viewer.

2. Back-Face Culling: Back-face culling involves discarding faces that are facing away from the viewer (i.e., their normals point away from the camera).

In OpenGL to enable depth testing, you can use glEnable(GL_DEPTH_TEST) to turn on depth testing.



2.
(a) What are Illumination and Shading models?
[2]

<u>Sol.</u>

Illumination and shading models are fundamental concepts in computer graphics that deal with how light interacts with surfaces in a 3D scene to create realistic and visually appealing images.

Illumination Models:

1. Ambient Light: Represents the general background light in a scene that illuminates all objects uniformly. It doesn't have a specific source and helps to simulate indirect lighting.
2. Diffuse Reflection: Describes how light scatters or spreads evenly across a surface. It depends on the surface's orientation relative to the light source and is responsible for creating basic visibility of objects.

Shading Models:

1. Flat Shading: Assigns a single color to each polygon, regardless of its orientation relative to light sources. It creates a flat, cartoonish appearance.
2. Gouraud Shading: Interpolates vertex colors across polygons to create a smoother transition of shading between vertices. It's computationally less intensive than Phong shading but can produce gradient-like effects.

(b) What are the three Shading models for polygons? Explain the working of the shading model which generates best visual results among the three models. What is Mach-Band effect and which shading model suffers from this effect?

Sol.

Shading Models:

1. Flat Shading: Assigns a single color to each polygon, regardless of its orientation relative to light sources. It creates a flat, cartoonish appearance.
2. Gouraud Shading: Interpolates vertex colors across polygons to create a smoother transition of shading between vertices. It's computationally less intensive than Phong shading but can produce gradient-like effects.
3. Phong Shading: Calculates shading at each pixel by interpolating normals across the surface. It provides more accurate specular highlights and is computationally more expensive than Gouraud shading.

Among these three shading models, Phong shading typically generates the best visual results due to its ability to calculate shading at a per-pixel level, resulting in smoother gradients, accurate specular highlights, and a more realistic appearance overall.

A polygon surface is rendered using Phong shading by carrying out the following steps:

1. Determine the average unit normal vector at each polygon vertex.
2. Linearly & interpolate the vertex normals over the surface of the polygon.
3. Apply an illumination model along each scan line to calculate projected pixel intensities for the surface points.

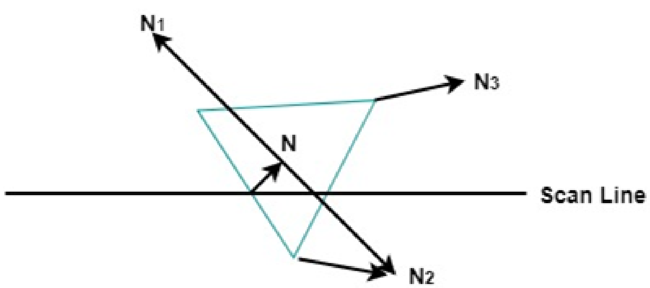


Fig: Interpolation of surface normals along a polygon edge.

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

The **Mach-Band effect** is a visual phenomenon where exaggerated contrast occurs at the boundaries between light and dark areas. It is particularly noticeable when adjacent areas have a slight difference in brightness. This effect can make these boundaries appear more pronounced than they actually are, leading to artificial enhancements in perceived contrast.

3. Answer the following questions briefly

(a) Explain the process of lip-sync

(b) How would you animate a character walking or running
(c) What are some challenges in animating non-human characters

Sol.

a) Lip-syncing is the art of synchronizing a character's mouth movements with spoken dialogue. Animators dissect phonetics, accents, and emotions to ensure lip movements mirror speech naturally. This meticulous process demands precise timing and attention to detail, resulting in a seamless fusion of sound and visuals.

b) Animating locomotion is a complex choreography between physics and aesthetics. Observing real-world motion and translating it into a character's gait involves studying weight distribution, balance, and momentum. By manipulating keyframes and interpolation, animators create a fluid and convincing movement that contributes to a character's believability.

c) Breathing life into non-human characters demands a unique approach. Whether animating animals, fantastical creatures, or inanimate objects, animators must understand their unique anatomy and movement. Balancing realism with creative interpretation presents a challenge that requires innovation and a deep understanding of character essence.

4.
(a) State keys differences between a CPU, a vector processor and a GPU. **[1]**

Sol.

- A central processing unit (CPU)S the hardware within a system which carries out the instructions of a computer program by performing the basic arithmetical, logical, and I/0 operations of the system.
- Graphics processing (GPU is a specialized electronic circuit (for images intended for output to a display) designed to rapidly manipulate and alter memory to accelerate Buildings of Images in a frame buffer. Today GPUs are very efficient at manipulating computer graphics, and their structure makes them more effective than general-purpose CPUs for algorithms where processing of large blocks of data is done in parallel.
- A vector processor!array is a CPU that implements an instruction set containing instructions that operate on I-D arrays of data known as vectors . Contrast to a scalar processor, whose instructions operate on single data items. Vector

processors can greatly improve performance on certain workloads, notably numerical simulation and similar tasks.

(b) Explain the CUDA memory model with respect to the grid, block and thread. **[2]**

Sol.

CUDA (Compute Unified Device Architecture) is a parallel computing platform and programming model developed by NVIDIA for general-purpose computing on its GPUs (Graphics Processing Units).

The CUDA memory model organizes memory access in a hierarchical manner, which is essential for understanding how data is accessed and utilized by threads in a CUDA program. The memory model is closely tied to the concept of grids, blocks, and threads, which are fundamental components of CUDA programming.

(c)What is the statement of Amdahl's Law? How does it affect the performance of computing with GPU and without GPU? **[2]**

Sol.

Amdahl's Law is a principle in computer architecture and parallel computing that quantifies the potential speedup of a system when only part of it is improved and is expressed by the following formula:

$$S_{\text{latency}}(s) = \frac{1}{(1-p) + \frac{p}{s}}$$

When it comes to computing with GPUs (Graphics Processing Units) versus without GPUs, Amdahl's Law comes into play in the following ways:

1. Without GPUs (Serial Processing):

In traditional serial processing, where computations are handled by the CPU (Central Processing Unit), Amdahl's Law implies that the speedup achieved by improving CPU performance is limited by the portion of the workload that can be parallelized.

2. With GPUs (Parallel Processing):

GPUs are designed for parallel processing and excel at handling highly parallelizable tasks such as graphics rendering, scientific simulations, machine learning computations, and more.

5. Explain 2D/ 3D Texturing and MipMaps. **[3]**

<u>Sol.</u>

1. 2D Texturing: In computer graphics, 2D texturing refers to the process of applying a 2D image (texture) onto a 2D or 3D surface to enhance its visual appearance. Textures can represent various surface properties such as color, roughness, bumpiness, and patterns.
2. 3D Texturing: 3D texturing extends the concept of texturing to three-dimensional objects. It involves mapping textures onto the surfaces of 3D models to simulate complex material properties and details.
3. MipMaps are precomputed, scaled-down versions of textures used in computer graphics to optimize rendering performance and improve visual quality, especially during texture mapping onto surfaces.MipMaps are created by generating progressively smaller versions of the original texture, where each MipMap level is half the size (in both width and height) of the previous level.

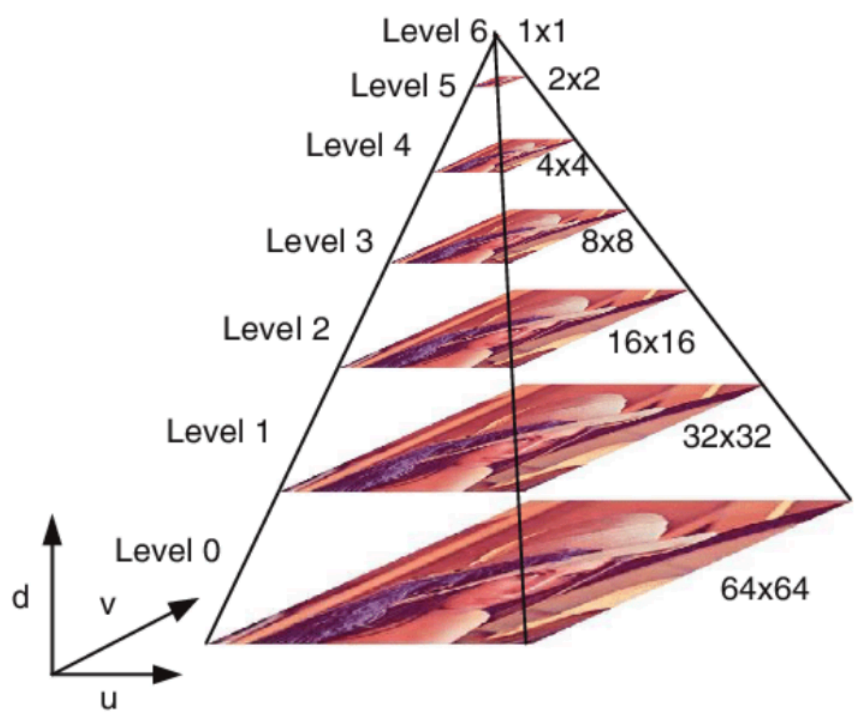


Illustration of a mipmap, where a 64x64 texture is considered

6.

(a) Compare and contrast Radiosity with ray tracing.

<u>Sol.</u>

1. Radiosity: Radiosity is a global illumination technique that simulates indirect lighting by considering light reflection, absorption, and emission between surfaces in a scene.
2. Ray Tracing: Ray tracing is a rendering technique that simulates the behavior of light rays in a scene, including reflection, refraction, and shadow casting.

(b) What are the advantages and disadvantages of each approach in terms of scene complexity and rendering time?

<u>Sol.</u>

1. Radiosity:
   <u>Advantages:</u>
   1. <u>Realistic diffuse lighting</u>: Radiosity captures indirect light diffusion accurately, creating soft and natural-looking shadows.
   2. <u>Suitable for diffuse surfaces</u>: It works well for scenes with mostly diffuse materials, such as interiors with walls and ceilings.

   <u>Disadvantages:</u>
   1. <u>Limited to diffuse interactions</u>: Radiosity does not handle specular reflections, refractions, or complex surface interactions well.
   2. <u>High computational cost:</u> Calculating radiosity involves solving complex equations, leading to longer rendering times for scenes with many surfaces.

2. Ray Tracing:
   <u>Advantages:</u>
   1. <u>Versatile lighting effects</u>: Ray tracing can simulate a wide range of lighting effects, including reflections, refractions, and complex shadows.
   2. <u>Accurate surface interactions</u>: It handles specular reflections and transparent materials realistically, improving visual fidelity.

   <u>Disadvantages:</u>
   1. <u>Complexity for scenes with many light sources</u>: Scenes with multiple light sources or complex geometry can increase rendering time significantly.
   2. <u>Computational intensity</u>: Ray tracing involves tracing multiple rays per pixel and can be computationally demanding, especially for high-resolution images or animations.

(c) Consider a triangle in the image plane. Suppose the intensities I(x, y) have been computed to be I1 = I(40, 14) = 10, I2 = I(60, 34) = 90, I3 = I(80, 24) = 140 Using linear interpolation, calculate the intensity I(50, 19).

Sol.

3. The formula we use is:

$$I(x,y) = I(x_0,y_0) + (I(x_1,y_1) - I(x_0,y_0))(\frac{x-x_0}{x_1-x_0})$$

We will need to interpolate three times. First we interpolate between I_1 and I_2:

$$I(45,19) = 10 + (90-10)(\frac{45-40}{60-40}) = 10 + 20 = 30$$

Next we interpolate between I_1 and I_3:

$$I(60,19) = 10 + (140-10)(\frac{60-40}{80-40}) = 10 + 65 = 75$$

Finally, we interpolate between $I(45,19)$ and $I(60,19)$:

$$I(50,19) = 30 + (75-30)(\frac{50-45}{60-45}) = 30 + 15 = 45$$