1. Briefly describe the main differences among computer graphics, image processing, and computer vision & image analysis.

Answer:

	Input	Out
Computer Graphics	2D/3D models	2D images
Image processing	2D images	2D images
Computer vision& image analysis	2D images	Descriptions about the images

2. List four types of representations of 3D objects.

Answer: (1) 3D point clouds (2) polygon meshes (3) subdivision surfaces (4) implicit surfaces (5) parametric surfaces (6) voxel representation (7) constructive solid geometry (8) fractals

3. Write out a parametric equation for a 3D sphere of radius r centered at origin.

Answer: $$\begin{cases} x = r\cos(s)\cos(t) \\ y = r\sin(s)\cos(t) \\ z = r\sin(t) \end{cases}$$

4. List the steps for drawing a thin line?

Answer: 1) Set x to x_1 and y to y_1, and shade this pixel;
2) Increase x by 1, and correspondingly $y = y + m$
3) Compute D1 – distance of (x, y) from the center of the upper pixel;
4) Compute D2 – distance of (x, y) from the center of the lower pixel;
5) If D1 < D2 (i.e., the line is closer to the upper pixel), shade the upper pixel; otherwise, shade the lower pixel.
6) if the endpoint (x_2, y_2) is not achieved, turn to 2); otherwise, stop.

5. What are homogeneous coordinates? And why are they introduced in transformations?

Answer:

A 2D coordinate (x, y) (resp. 3D coordinate) can be written as (x_h, y_h, h) (resp. (x_h, y_h, z_h, h))

such that $x_h = hx$, and $y_h = hy$, (resp. $z_h = hz$) where h is a scaling factor. (x_h, y_h, h) (resp. (x_h, y_h, z_h, h)) is called a homogeneous coordinate. Typically, h is set to 1. The homogeneous coordinate of a point (x, y) (resp. (x, y, z)) is $(x, y, 1)$

(resp. $(x, y, z, 1)$).

With homogeneous coordinates, we can build a unified approach to combine the transformations so that the final coordinate positions are obtained directly from the initial coordinate by the product of the transformation matrices.

6. Write out the following three transformation matrices with homogeneous coordinates:

$\boldsymbol{A}$: translation along the vector $\boldsymbol{v} = (4, 0, 2)$

$\boldsymbol{B}$: rotation 30 degrees around the z-axis.

$\boldsymbol{C}$: non-uniform scaling with 2 in x-axis, 3 in y-axis and 4 in z-axis

Answer:

$$\boldsymbol{A} = \begin{bmatrix} 1 & 0 & 0 & 4 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \boldsymbol{B} = \begin{bmatrix} \frac{\sqrt{\{3\}}}{2} & -\frac{1}{2} & 0 & 0 \\ \frac{1}{2} & \frac{\sqrt{\{3\}}}{2} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \boldsymbol{C} = \begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 \\ 0 & 0 & 4 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

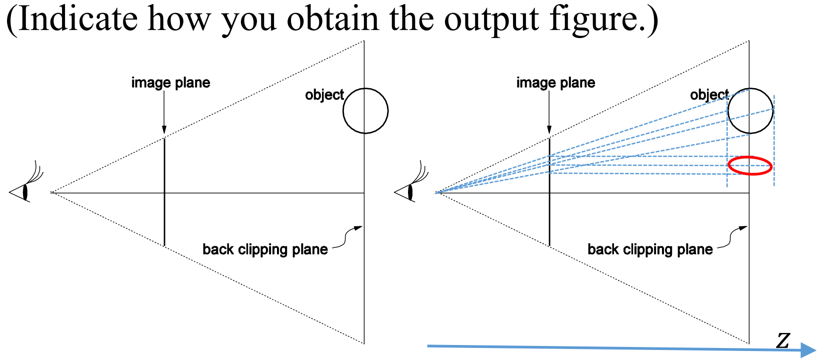
7. Describe the steps for performing a rotation around an arbitrary point?

Answer: (1) translate the reference point to origin

(2) perform the rotation around the origin

(3) translate the rotated object to the reference point

8. Show the output of the following object after perspective **transformation**. (Indicate how you obtain the output figure.)



Perspective transformation is computed as:

$x' = d * x / z$
$y' = d * y / z$
$z' = z$
The key point of this question is that the z dimension will retain after the perspective **transformation**, which is different from perspective **projection**.

9. Please list the main differences between parallel projection and perspective projection. And show the main advantage of perspective projection over parallel projection?

Answer:

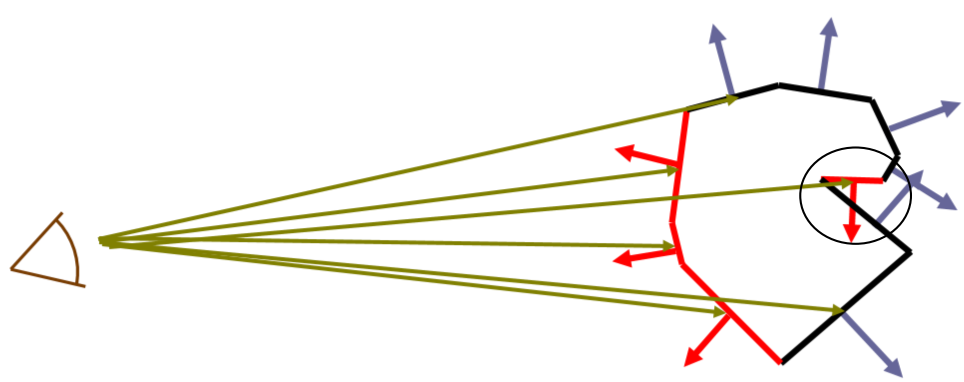
Parallel projection	Perspective projection
The center of projection (COP) is at infinity. All projectors (or projection lines) are parallel. (or parallelism is preserved)	The center of projection (COP) is at a finite distance. All projectors (or projection lines) meet at COP. (or parallelism is not preserved in general)

Perspective projection gives us depth information in photography.

10. Describe the back-face culling algorithm and show a failure case.

For each polygonal face f, compute the vector from viewpoint $\boldsymbol{v}$ to any point $\boldsymbol{p}$ on f
- Invisible if $\boldsymbol{n} \cdot (\boldsymbol{p} - \boldsymbol{v}) >= 0$
- Visible if $\boldsymbol{n} \cdot (\boldsymbol{p} - \boldsymbol{v}) < 0$
where $\boldsymbol{n}$ is the face normal.

The failure case is the concave part of an object.



11. Compare the depth-sorting and the z-buffering methods by showing their advantages and disadvantages, respectively.

Answer:

(1) When there are only a few objects in the scene, this method can be very efficient. However, as the number of objects increases, the sorting process can become very complex and time consuming.

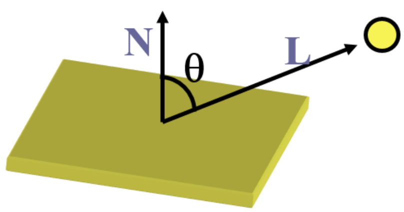
(2) For depth sorting, Certain conditions, such as intersecting polygons or cyclic overlap are not processed correctly.

(3) For z-buffering, because of the need for an addition buffer and the overheads involved in updating the buffer, this method is less attractive in comparison with the depth-sorting method for applications with only a few objects in the scene. However, as the number of objects in the scene increases, the overheads become less important and the method becomes more attractive.

12. With the help of a diagram, write down all types of information that we need to know when we compute the color of a point due to diffusion reflection.

Answer:

$$I_d = k_d * I_L * \cos\theta = k_d * I_L * (\mathbf{N} \cdot \mathbf{L})$$



(1) k_d, the surface diffuse coefficient

(2) θ, the angle between the surface normal and the incoming light ray. (or the surface normal and the direction of incoming light ray).

(3) I_L, the intensity of the incoming light ray.

13. List the main differences on how the Gouraud Shading and Phong Shading methods work. (No need to explain how each of them works.)

Answer: Gouraud shading interpolates color across triangles
Phong shading interpolates normal across triangles

14. List all stages involved in the rendering pipeline.

Answer:

(1) world coordinate transformation
(2) perspective transformation
(3) back-face removal
(4) clipping
(5) rasterization
(6) hidden surface removal
(7) shading