① Surface Rendering :-

• Surface representations are good and sufficient for object that have homogeneous material distributions and are not translucent or transparent.

- Such representations are good only when object boundaries are important.
- The main reason why surface rendering is important is because, surface rendering can be used in video games, virtual reality and computer aided design etc

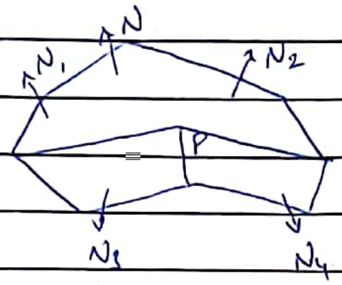
I. Gouraud Shading :-

This intensity interpolation scheme, developed by Gouraud and usually referred to as Gouraud Shading, renders a polygon surface by linear interpolating intensity value across the surface. Intensity values for each polygon are coordinate with the value of adjacent polygons along the common edges, thus eliminating the intensity discontinuites that can occur in flat shading.

Each polygon surface is rendered by performi following calculations:

i) Determining the average unit normal vector at each polygon vertex.
ii) Apply an illumination model to each vertex to determine the vertex intensity.
iii) Linear interpolate the vertex intensities over the surface of the polygon.

At each polygon vertex, we obtain in a normal vector by averaging the surface normals of all polygons sharing that vertex as shown in figure →



Thus for any vertex position V, we acquire the unit vertex normal with the calculation

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

Once we have the vertex normals, we can determine the intensity at the vertices from a lighting model.

Gouraud shading discards the intensity discontinuities associated with the constant shading model but it has some other deficiencies Highlights on the surface are sometimes displayed with anomalous shapes, and the linear intensity interpolation can cause bright or dark intensity streaks, called Match bands, to appear on the surface These effects can be decreased by dividing the surface into a higher number of polygon faces or by using other methods

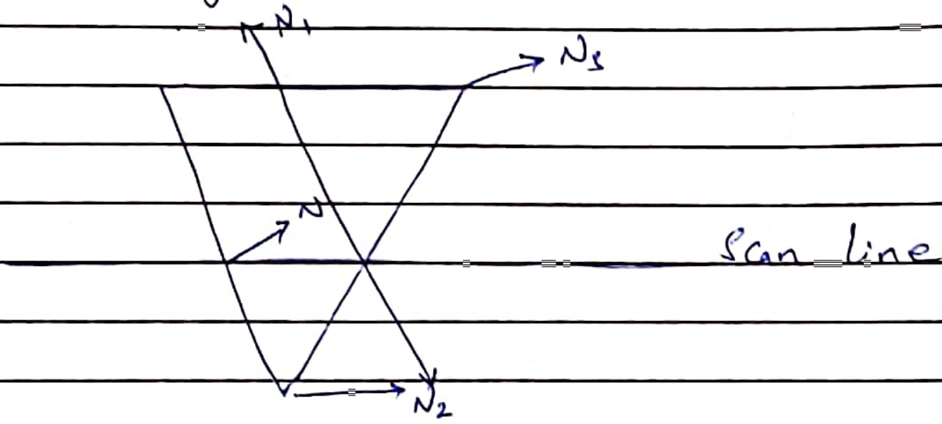
II **Phong Shading :-**

A more accurate method for rendering a polygon surface is to interpolate the normal vector and then apply the illumination model to each surface point. This method displays more realistic highlights on a surface and greatly reduces the Match band effect.

A polygon surface is rendered by performing the following steps →

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

Interpolation of the surface normal along a polygon edge b/w two vertices are shown in figure.



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

(2) Need Of Hidden Surface Removal Technique:-

i) One of the most challenging problems in computer graphics is the removal of hidden part from images of solid objects.

ii) In real life, the opaque material of these objects obstructs the light rays from hidden parts and prevents us from seeing them.

iii) In the computer generation no such automatic elimination takes place when objects are projected onto the screen coordinates system.

iv) Instead, all parts of every object, including many parts that should be invisible are displayed.

v) To remove these parts to create more realistic image, we must apply a hidden line or hidden surface algorithm to set of objects.

vi) The algorithm operates on different kinds of scene models, generate various forms of output or cater to image of different complexities.

vii) All use some form of geometric sorting is used to distinguish visible parts of object from those that are hidden.

viii) Just as alphabetical sorting is used to differentiate word near the beginning of the alphabet from those near the ends.

ix) Geometric sorting locates objects that lie near the observer and are therefore visible.

x) Hidden lines and hidden surface algorithm capitalize on various forms of coherence to reduce the computing required to generate an image.

xi) Different types of coherence are related to different forms of order or regularity in the image.

xii) ~~Scan line~~ Frame coherence in a sequence of images designed to show motion recognizes that successive frames are very similar.

xiii) Object coherence results from relationships between different objects or between separate parts of the same object.

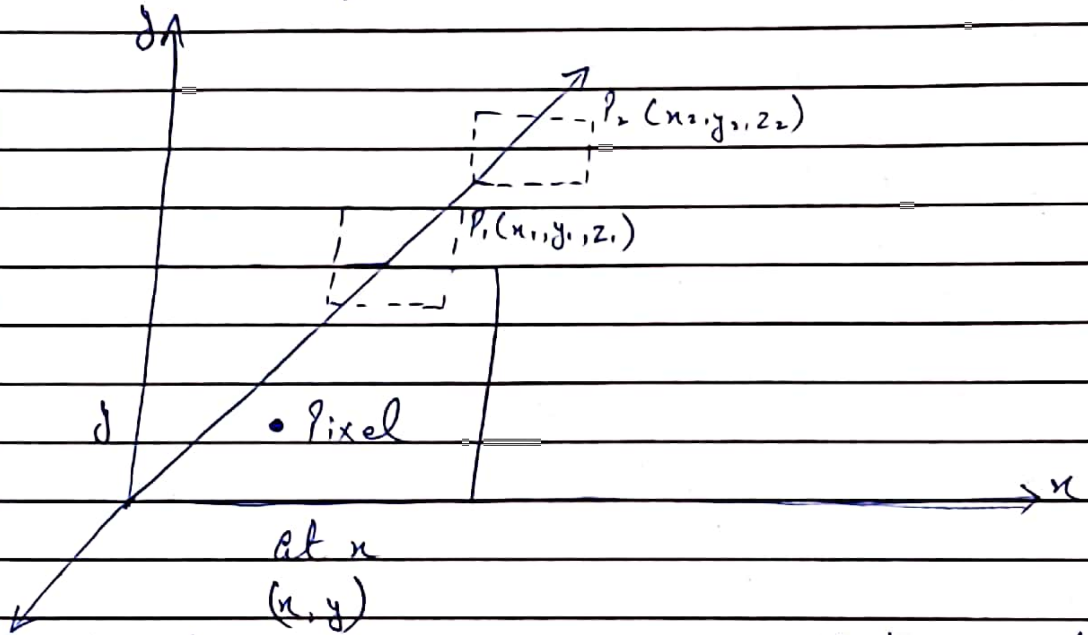
xiv) A hidden surface algorithm is generally designed to exploit one or more of these coherence properties to increase efficiency.

xv) Hidden surface algorithm bears a strong resemblance to two-dimensional scan conversion.

Z-Buffer Algorithm :-

It is a simplest image space algorithm. For each pixel on the display screen, we keep a record of the depth of an object within the pixel that lies closest to the observer. In addition to depth we also record the intensity that should be displayed to show the object. It is an extension of the frame buffer. This algorithm require 2 arrays intensity and depth each of which is indexed by pixel coordinate (x, y)

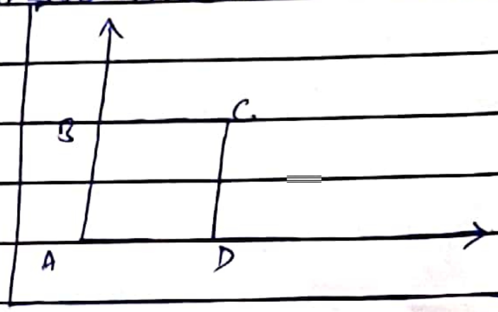
Algorithm :- i) For all pixels on the screen, set depth [x,y] to 1.0 and intensity [x,y] to background value.
ii) For each polygon in the scene, find all pixels (x,y) that lie withing boundaries of a polygon when projected onto the screen.
iii) After all polygon have been ~~replaced~~ processed the intensity array will contain the solution
iv) The depth buffer algorithm illustrate several features common to all hidden surface algorithms



v) First it requires a representation of all opaque surface in scene polygon in this case.
vi) These polygons may be faces of polyhedral recorded in model of scene or may simply represent this opaque sheets in the scene.
vii) ~~scene~~ The kind important feature of algorithm is its use of screen coordinate system.

(3) Given: Square is given with coordinates A(0,0), B(0,3), C(3,0), D(3,3)

i) For scaling, the transformation matrix is given as.



$$S = \begin{bmatrix} S_x & 0 & 0 \\ 0 & S_y & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Given: $S_x = 2$ and $S_y = 3$

$\therefore$

$$S = \begin{bmatrix} 2 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Now above is the matrix after performing scaling operations

ii) For rotation by 45° in anticlockwise direction,

The transformation matrix is

$$R = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Given: $\theta = 45°$

$$\therefore R = \begin{bmatrix} \cos 45° & \sin 45° & 0 \\ -\sin 45° & \cos 45° & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\Rightarrow R = \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 0 \\ -1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Thus, above is the matrix after performing rotation operation.

iii) For translation, the matrix is given as

$$T = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ t_x & t_y & 1 \end{bmatrix}$$

Given: $t_x = 3$, $t_y = 6$

$$\therefore T = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 3 & 6 & 1 \end{bmatrix}$$

Now, for all the three transformations, transformation matrix will be product of S, R and T.

$$\therefore S.R.T = \begin{bmatrix} 2 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 0 \\ -1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 3 & 6 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 2/\sqrt{2} & 2/\sqrt{2} & 0 \\ -3/2 & 3/\sqrt{2} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 3 & 6 & 1 \end{bmatrix}$$

$$S.R.T = \begin{bmatrix} 2/\sqrt{2} & 2/\sqrt{2} & 0 \\ -3/\sqrt{2} & 3/\sqrt{2} & 0 \\ 3 & 6 & 1 \end{bmatrix}$$

Now, suppose the new coordinates be A', B', C' & D'

$$\begin{bmatrix} A' \\ B' \\ C' \\ D' \end{bmatrix} = \begin{bmatrix} A_x & A_y & 1 \\ B_x & B_y & 1 \\ C_x & C_y & 1 \\ D_x & D_y & 1 \end{bmatrix} S.R.T$$

$$= \begin{bmatrix} 0 & 0 & 1 \\ 0 & 3 & 1 \\ 3 & 0 & 1 \\ 3 & 3 & 1 \end{bmatrix} \begin{bmatrix} 2/\sqrt{2} & 2/\sqrt{2} & 0 \\ -3/\sqrt{2} & 3/\sqrt{2} & 0 \\ 3 & 6 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 3 & 6 & 1 \\ -9+3\sqrt{2}/\sqrt{2} & 9+6\sqrt{2}/\sqrt{2} & 1 \\ 6+3\sqrt{2}/\sqrt{2} & 6+6\sqrt{2}/\sqrt{2} & 1 \\ -3+3\sqrt{2}/\sqrt{2} & 15+6\sqrt{2}/\sqrt{2} & 1 \end{bmatrix}$$

$A' = (3, 6)$

$B' = \left(\dfrac{-9+3\sqrt{2}}{\sqrt{2}}, \dfrac{9+6\sqrt{2}}{\sqrt{2}}\right)$

$C' = \left(\dfrac{6+3\sqrt{2}}{\sqrt{2}}, \dfrac{6+6\sqrt{2}}{\sqrt{2}}\right)$

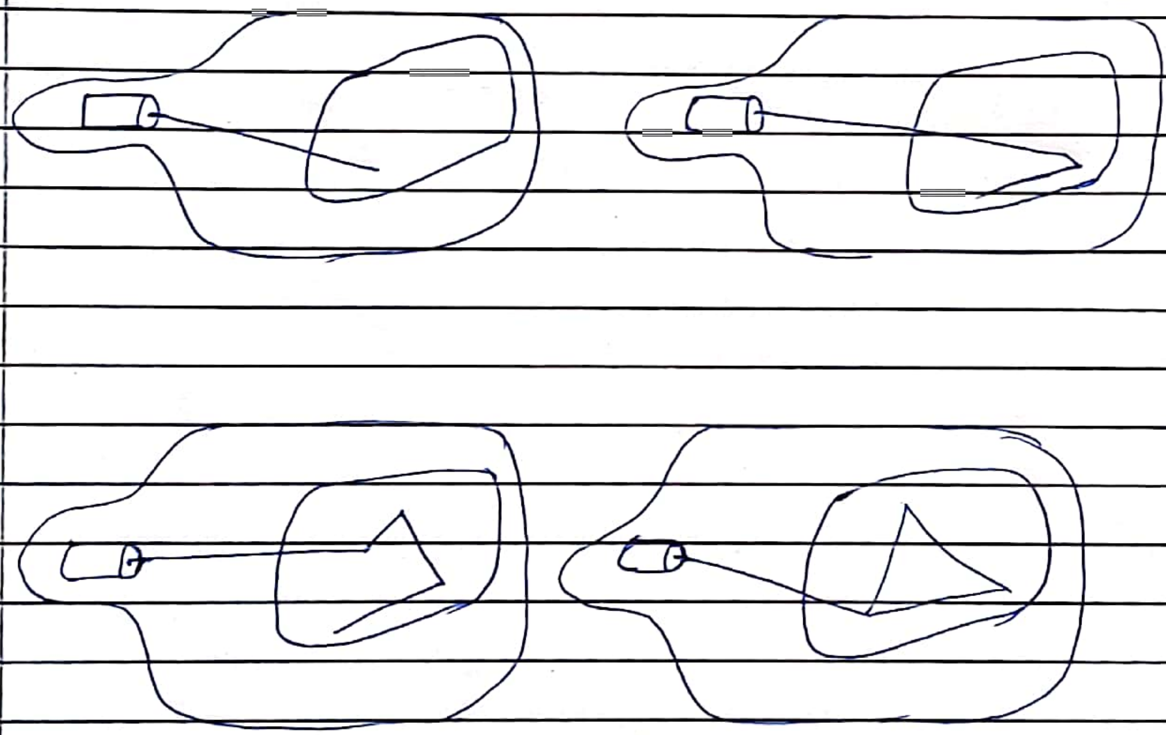
$D' = \left(\dfrac{-3+3\sqrt{2}}{\sqrt{2}}, \dfrac{15+6\sqrt{2}}{\sqrt{2}}\right)$

To combine scaling, rotation and translation, homogeneous coordinates are used. 2d coordinates positions are represented in 3d coordinates

④ I Random Scan Display :

It uses an electron beam which operates like a pencil to create a line image on the CRT screen. The picture is constructed out of a sequence of straight line segments. Each line segment is drawn on the screen by directing the beam to move from one point on the screen to next, where its x & y coordinates define each point. After drawing the picture. The system cycles back to the first line and design all the lines of the image 30 to 60 time each second.

Random scan monitors are also known as vector displays or stroke-writing displays



⇒ **Advantages :-**

i) A CRT has the electron beam directed only to the parts of screen where an image is to be drawn.

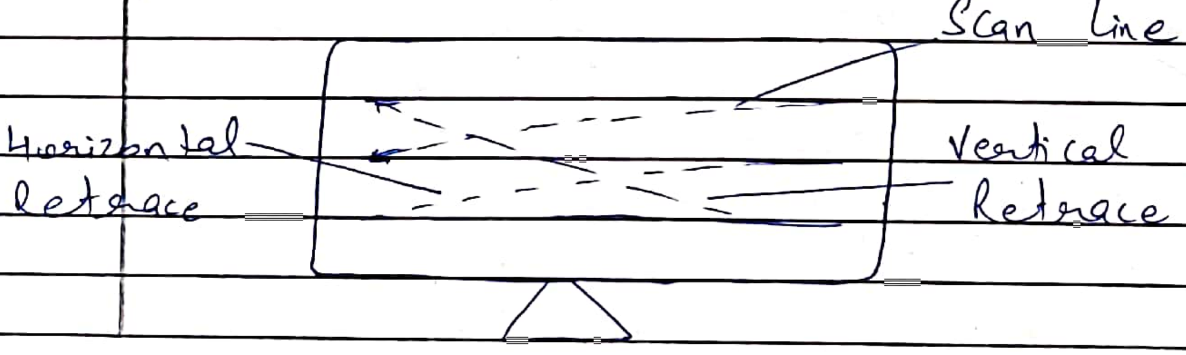
ii) Produce smooth line drawings.

iii) High resolution.

Disadvantages :-

i) Random scan monitors cannot display realistic shades scenes.

II **Raster Scan Display :-** It is based on intensity control of pixels in the form of a rectangular box called Raster on the screen. Information of on and off pixel is stored in refresh buffer or frame buffer. Televisions in our houses are based on Raster scan method. The raster scan system can store information of each pixel position, so its suitable for realistic display of objects. It provides a refresh rate of 60 to 80 frames per second.



⇒ Advantages :-

i) Realistic Image
ii) Million Different Colors to be generated
iii) Shadow Scenes are possible

⇒ Disadvantages :-

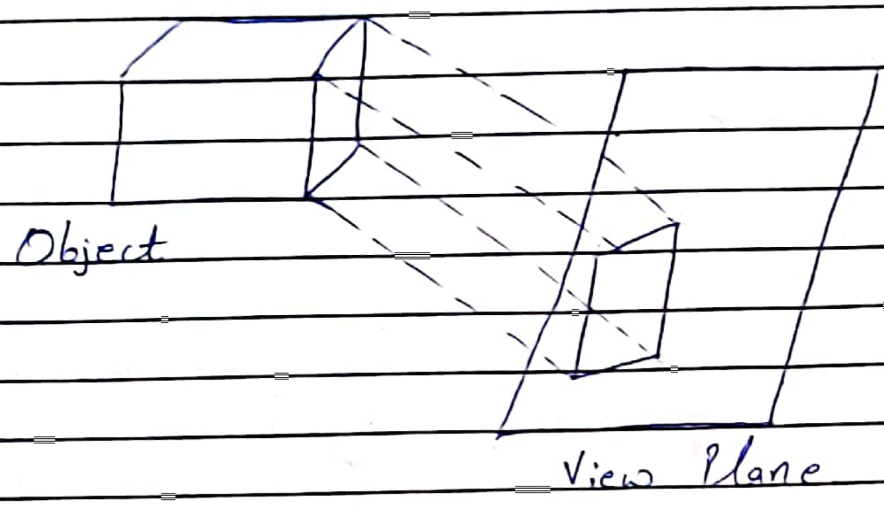
i) Low Resolution
ii) Expensive

(5) a) I. Parallel Projection :-

They are used by architects and engineers for creating working drawing of the object, for complete representations require two or more views of an object using different planes.

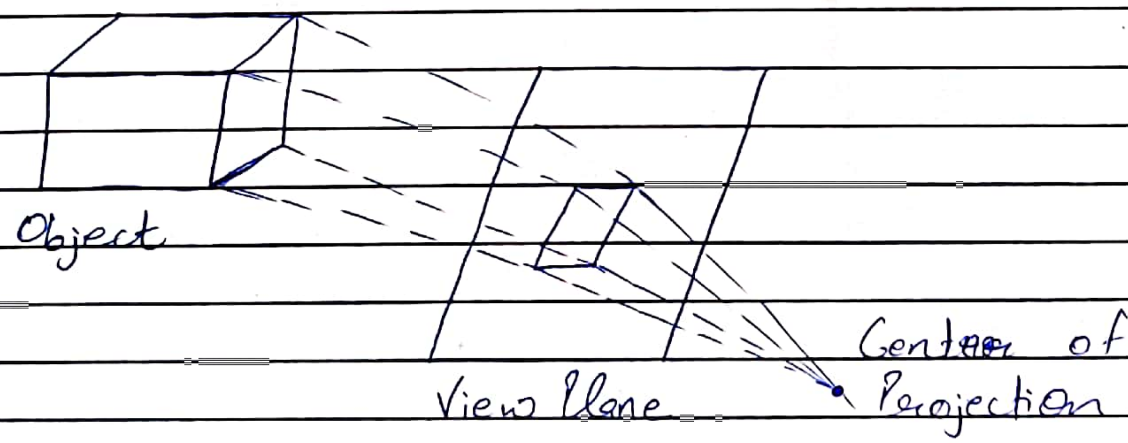
These projection use to display picture in its true shape and size when projections are perpendicular to view plane then is called orthographic projection. The parallel projection is formed by extending parallel lines from each vertex on the object until they intersect the plane of the screen. The point of intersection is the projection of the vertex.

Here, is the diagram which clearly shows



II. Perspective Projection :-

In this lines of projection do not remain parallel. The lines converge at a single point called a centre of projection. The projected image on the screen is obtained by points of intersection of converging lines with the plane of the screen. The image on the screen is seen as of viewers eye were located at the centre of projection, lines of projection would correspond to path travel by light beam originating from object.



b) **Sutherland - Hodgeman Polygon Clipping :-**

It is performed by processing the boundary of polygon against each window corner or edge. first of all entire polygon is clipped against one edge, then resulting polygon is considered, then the polygon is considered against the second edge, so on for all four edges.

⇒ **Four Possible Situations while Processing :-**

i) If the first vertex is an outside the window, the second vertex is inside the window. Then second vertex is added to the output list. The point of intersection of window boundary and polygon side is also added to the output line.

ii) If both vertexes are inside window boundary. Then only second vertex is added to the output list

iii) If the first vertex is inside the window and second is an outside window. The edge which window is added to output list.

iv) If both vertices are the outside window, then nothing is added to output list

⇒ **Short Coming :-** i) It clips to each window boundary one at a time

ii) It has a random edge choice.
iii) It has redundant edge-line cross calculations.
iv) It requires a considerable amount of memory.
v) Clipping against top, right, left and bottom edge is done and stores all the data so wastage of memory for storing intermediate polygons.