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Course Title:- Computer Graphics
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Q(1) Computer graphics:-
Ans =)

(i) Computer graphics:- Computer graphics is a way to communicate the process of information to user. It is use to display the information in form of pictures, charts, graphs and diagrams instead of simple text. In computer graphics discrete picture elements called pixels are use to represent pictures or ~~other~~ other graphics objects.

(ii) Virtual Reality:- Virtual Reality is the use of computer modelling and simulation that enables a person to interact with an artificial three-dimensional (3-D) visual or other sensory environment. It is a computer-simulated reality which replicates an environment, real reality which replicates an or imagined and simulates, a user's physical presence and environment to allow for user interaction.

(iii) Frame:- The term frame is referred to as the total screen area. This the memory area that holds the set of colors value for the screen points. This is the area where the graphics object like image charts the graphics ~~object~~ like diagrams are displayed.

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(iv) Frame buffer:- Frame buffer is also known as the refresh buffer. The picture definition is stored in the frame buffer. It is a large, contiguous piece of computer memory. The picture is built up in the frame buffer one bit at a time.

(viii) Anti-Aliasing:- Anti-Aliasing is a common graphics setting in a graph. It is used to remove the aliasing effect. The aliasing effect is the appearance of jagged edges in a rasterized image.

(ix) Fractal dimension:- A fractal dimension is a ratio for figuring out the complexity of a system given its measurement. It is an index for characterizing fractal patterns or sets by quantifying their complexity as a ratio of the change in detail to the change in ~~to~~ scale.

Ray Casting:-
(x) Ray cast is a rendering ~~be~~ technique that is used in in computer graphics and computational geometry. In Ray casting rays are "cast" directly from the viewpoint.

(v) Raster scan system:- in ~~this~~ this the electron beam is swept across the screen one row at a time from top to bottom. As the electron beam moves across each row

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the beam intensity is turned on & off to create a pattern of illuminated spots.

(vi) Octree representation:-
An octree is generally used to represent relation b/w object in a 3-dimensional space. octree divided the 3D spaces into 8 octree where each octree ~~octree~~ is finally in represented by node.

Q(2) Differentiate between parallel and perspective projection:-
Ans:-

parall projection:-	perspective projection:-
(1) parallel projection represents the object in a different way like telescope.	(1) perspective projection represent the object in 3-D way.
(2) In parall projection these effects are not create	(2) In this, object that are far away appear smaller and objects that are near appear bigger.
(3) Distance of object from center of projection is infinite	(3) Distance of object is finite.

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(4) Two types of parall projection :-

→ ortrographic
→ oblique

(4) Three types of perspective projection

→ one-point perspective
→ two - point "
→ three - point "

(5) It doesn't form realistic view of object

(5) It forms a realistic view of object

(6) It doesn't form ~~realistic~~.
It can give accurate view of object

(6) It can't give accurate view of object

(7) Exam :- used by architecture and engineer

Special

(7) Exam :- ~~Camera~~ Camera lens.

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Special cases of perspective projection :-

for to simplify the perspective calculation, the projection reference point could be limited to z-axis, then.

(I) $x_{prp} = y_{prp} = 0$

$$x_p = x\left(\frac{z_{prp} - z_{vp}}{z_{prp} - z}\right) \cdot \; y_p = y\left(\frac{z_{prp} - z_{vp}}{z_{prp} - z}\right)$$

Sometime, the perspective reference point is fixed at the co-ordinate - origin and.

(II) $(x_{prp}, y_{prp}, z_{prp}) = (0, 0, 0)$:

$$x_p = x \cdot \left(\frac{z_{vp}}{z}\right)$$

$$y_p = y \cdot \left(\frac{z_{vp}}{z}\right)$$

if the view-plane is the uv-plane and there are no restriction on the placement of the projection reference point then we have.

(III) $z_{vp} = 0$:

$$x_p = x\left(\frac{z_{prp}}{z_{prp} - z}\right) \quad y_p = y\left(\frac{z}{z_{prp} - z}\right)$$

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$$y_p = y\left(\frac{z_{prp}}{z_{prp}-z}\right) - y_{prp}\left(\frac{z}{z_{prp}-z}\right)$$

with the uv-plane as the view-plane and the projection reference point on the ~~zv~~ zview axis, the perspective equation are:-

$$x_{prp} = y_{prp} = z_{prp} = 0$$

$$x_p = x\left(\frac{z_{prp}}{z_{prp}-z}\right)$$

$$y_p = y\left(\frac{z_{prp}}{z_{prp}-z}\right)$$

Q3) Explain the cohen-sutherland clipping Algorithm:

Ans:- (1) Read two end-points of the line say $P_1(x_1, y_1)$ and $P_2(x_2, y_2)$

(2) Read two corners (left-top and right bottom) of the window, say $(wx_1, wy_1, wx_2, and\ wy_2)$

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(3) Assign the region codes for two end-points P_1 and P_2 using following steps.

Initialize code with bits 000

set Bit-1 if $(x < wx_1)$
Bit-2 if $(x > wx_2)$
Bit-3 if $(y < wy_2)$
Bit-4 if $(y > wy_1)$

Region code – TBRL → left, → Right
↓ Top, ↓ Bottom

line clipping:- It is performed by using the line clipping algorithms. The line algo are:

(1) Cohen Sutherland line Clipping Algorithm
(2) Midpoint Subdivision line Clipping Algo.
(3) Liang-Barsky line clipping Algo.

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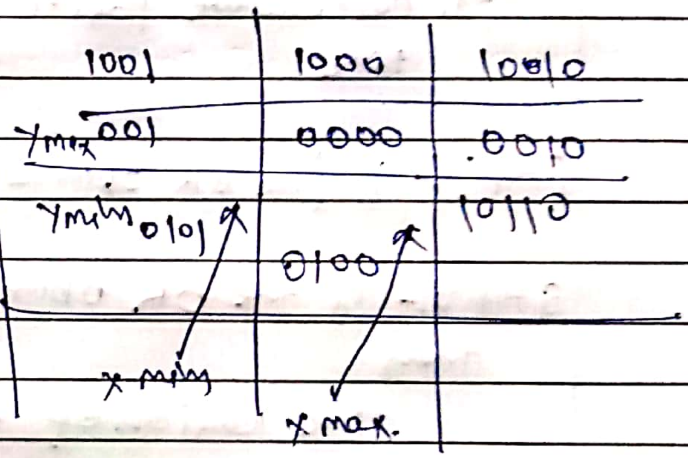
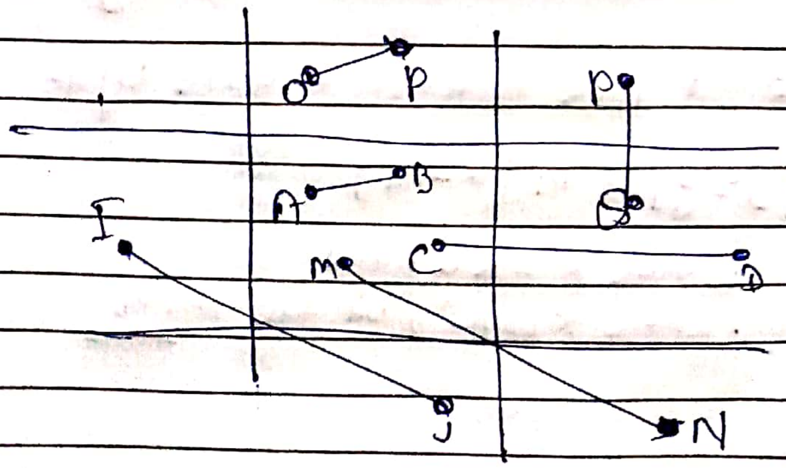
Clipping case:- if the line is neither visible case nor invisible case.

region 1	region 2	region 3
region 4	region 5	region 6
region 7	region 8	region 6
		region 9



bits assigned to 9 region

Following figure show lines of various types:



line AB is the visib case
line OP is an invisible case
line PQ is an invisible
IJ are clipping candidate
MN are clipping
line CD are clipping candidate

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Algorithms of cohen sutherland line clipping :-

Step 1: calculate positions of the both endpoint of the line.

Step 2 :- perform OR operation on both of these end-point

Step 3 :- If the OR operation give 0000
then
line considered to be visible
else
perform AND operation on both end points
If And ≠ 0000
then the line is invisible
else
And = 0000
line is considered the clipping case.

(a) if bit 1 is '1' line intersect with left.

$y_3 = y_1 + m(x - x_1)$

where $x = x_{wmin}$
where x_{wmin} is the min,

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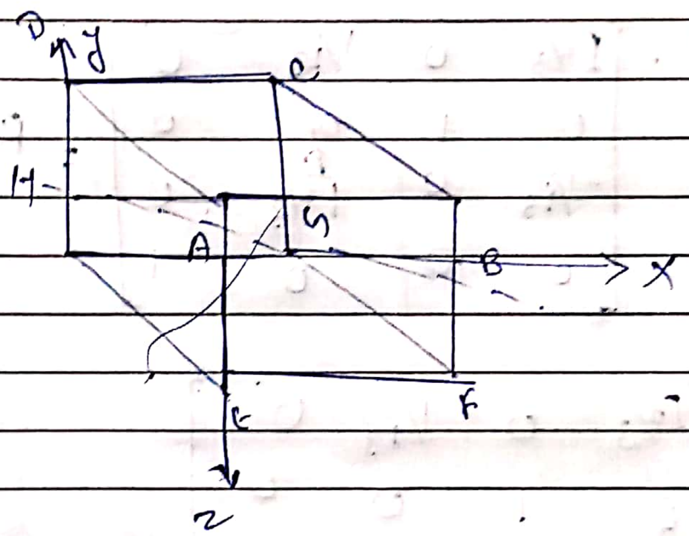
Q(4) A cub is defined by 8 vertices A (0,0,0), B (2,0,0), C (2,2,0), D (0,2,0), E (0,0,2), F (2,0,2), G (2,2,2) and H (0,2,2). find the final coordinates after it is rotated by 45 degree around a line joining the point (2,0,0), and (0,2,2) :-

Ans:-



Axis of rotation is BH.
first, we need to translate BH to origin.
Translation matrix.

$$T = \begin{bmatrix} 1 & 0 & 0 & -2 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad T^{-1} = \begin{bmatrix} 1 & 0 & 0 & 2 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

T^{-1} = Inverse transformation matrix of translation T.

H (0,2,2) B (2,0,0)

$$|BH| = \sqrt{2^2 + 2^2 + 2^2} = 2\sqrt{3}$$

$(x_1 - x_2)^2$

Scanned with CamScanner

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Direction cosines of BH.

$$a = \frac{0-2}{2\sqrt{3}} = \frac{-1}{\sqrt{3}}, \quad b = \frac{2-0}{2\sqrt{3}} = \frac{1}{\sqrt{3}}, \quad c = \frac{2-0}{2\sqrt{3}} = \frac{1}{\sqrt{3}}$$

Now we need to rotate BH about x-axis by an angle α where.

$$\cos\alpha = \frac{c}{d} \text{ and } \sin\alpha = \frac{b}{d} \Rightarrow \cos\alpha = \frac{1}{\sqrt{2}}, \; \sin\alpha = \frac{1}{\sqrt{2}}$$

$$\text{and } d = \sqrt{b^2 + c^2} \Rightarrow d = \sqrt{\frac{1}{3} + \frac{1}{3}} = \sqrt{\frac{2}{3}}$$

Rotation matrix

$$R_x(\alpha) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1/\sqrt{2} & -1/\sqrt{2} & 0 \\ 0 & 1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

$$R_x^{-1}(\alpha) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & -1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$R_x^{-1}(\alpha)$ is inverse translation matrix of $R_x(\alpha)$

We shall now rotate the rotated BH about y axis by an angle β so that it gets aligned along z-axis

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$\cos\beta = d \Rightarrow \cos\beta = \sqrt{\frac{2}{3}}$

$\sin\beta = -a \Rightarrow \sin\beta = \frac{1}{\sqrt{3}}$

Rotation matrix

$$R_y(\beta) = \begin{bmatrix} \sqrt{2/3} & 0 & 1/\sqrt{3} & 0 \\ 0 & 1 & 0 & 0 \\ -1/\sqrt{3} & 0 & \sqrt{2/3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = R_y^{-1}(\beta) =$$

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

$R^{-1}_y(\beta)$ is the inverse rotation matrix.

for rotation of the image, we rotate the image along z-axis by 45° (as BH is aligned along z-axis)

Rotation matrix

$$R_z(45°) = \begin{bmatrix} 1/\sqrt{2} & -1/\sqrt{2} & 0 & 0 \\ 1/\sqrt{2} & 1/\sqrt{2} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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All the transformation for rotation of the cube can be written as.

$$R = T^{-1} \cdot R_x^{-1}(\alpha) \cdot R_y^{-1}(\beta) \cdot R_z(45°) \cdot R_y(\beta) \cdot R_x(\alpha) \cdot T$$

$$T^{-1} \cdot R_x^{-1}(\alpha) \cdot R_y^{-1}(\beta)$$

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

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

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

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

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$R_y(\beta) \cdot R_x(\alpha) \cdot T$

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

$$\begin{bmatrix} 1 & 0 & 0 & -2 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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

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

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$$T^{-1} R_x^{-1}(\alpha) . R_y^{-1}(\beta) . R_z(45) . R_y(\beta) . R_x(\alpha) . T$$

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

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

$$= \begin{bmatrix} 1/\sqrt{3} & -1/\sqrt{3} & -1/\sqrt{3} & 2 \\ 1/\sqrt{12}+1/2 & -1/\sqrt{12}+1/2 & 1/\sqrt{3} & 0 \\ 1/\sqrt{12}-1/2 & -1/\sqrt{12}-1/2 & 1/\sqrt{3} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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

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$$\begin{bmatrix} \frac{1}{3}+\frac{\sqrt{2}}{3} & -\frac{\sqrt{6}}{6}-\frac{1}{3}+\frac{\sqrt{2}}{6} & -\frac{1}{3}+\frac{\sqrt{2}}{6}+\frac{\sqrt{6}}{6} & \frac{4}{3}-\frac{2\sqrt{3}}{3} \\ -\frac{1}{3}+\frac{\sqrt{2}}{6}+\frac{\sqrt{6}}{6} & \frac{1}{3}+\frac{\sqrt{2}}{3} & -\frac{\sqrt{2}}{6}+\frac{1}{3}+\frac{\sqrt{6}}{6} & -\frac{\sqrt{6}}{3}-\frac{\sqrt{2}}{3}+\frac{2}{3} \\ -\frac{\sqrt{6}}{6}-\frac{1}{3}+\frac{\sqrt{2}}{6} & -\frac{\sqrt{6}}{6}-\frac{\sqrt{2}}{6}+\frac{1}{3} & \frac{1}{3}+\frac{\sqrt{2}}{3} & -\frac{\sqrt{2}}{3}+\frac{2}{3}+\frac{\sqrt{6}}{3} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$= R(45^\circ)$

The vertices of the cube can be written in a matrix as,

$$V = \begin{array}{c} \begin{array}{cccccccc} A & B & F & E & H & D & C & G \end{array} \\ \begin{bmatrix} 0 & 2 & 2 & 0 & 0 & 0 & 2 & 2 \\ 0 & 0 & 0 & 0 & 2 & 2 & 2 & 2 \\ 0 & 0 & 2 & 2 & 2 & 0 & 0 & 2 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix} \end{array}$$

To get the final coordinates, we multiply R and V. we get,

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$$
\begin{array}{cccc}
A & B & F & E \\
\end{array}
$$

$$
\begin{bmatrix}
\frac{4}{3}+\frac{2\sqrt{2}}{3} & 2 & \frac{\sqrt{2}}{3}+\frac{\sqrt{6}}{3}+\frac{4}{3} & -\frac{\sqrt{2}}{3}+\frac{2}{3}+\frac{\sqrt{6}}{3} \\
-\frac{\sqrt{6}}{6}-\frac{\sqrt{2}}{3}+\frac{2}{3} & 0 & -\frac{\sqrt{2}}{3}+\frac{2}{3}+\frac{\sqrt{6}}{3} & \frac{4}{3}-\frac{2\sqrt{3}}{3}+\frac{4}{3} \\
-\frac{\sqrt{2}}{3}+\frac{2}{3}+\frac{\sqrt{6}}{3} & 0 & \frac{2}{3}+\frac{2\sqrt{2}}{3} & -\frac{\sqrt{6}}{3}+\frac{\sqrt{2}}{3}+\frac{4}{3} \\
1 & 1 & 1 & 1
\end{bmatrix}
$$

$$
\begin{array}{cccc}
H & D & C & G \\
\end{array}
$$

$$
\begin{bmatrix}
0 & -\frac{\sqrt{6}}{3}-\frac{\sqrt{2}}{3}+\frac{2}{3} & -\frac{\sqrt{6}}{3}+\frac{\sqrt{2}}{3}+\frac{4}{3} & \frac{2}{3}+\frac{2\sqrt{2}}{3} \\
2 & -\frac{\sqrt{6}}{3}+\frac{\sqrt{2}}{3}+\frac{4}{3} & \frac{2}{3}+\frac{2\sqrt{2}}{3} & \frac{\sqrt{2}}{3}+\frac{\sqrt{6}}{3}+\frac{4}{3} \\
2 & \frac{4}{3}-\frac{2\sqrt{2}}{3} & \frac{\sqrt{6}}{3}-\frac{\sqrt{2}}{3}+\frac{2}{3} & -\frac{\sqrt{6}}{3}+\frac{\sqrt{2}}{3}+\frac{4}{3} \\
1 & 1 & 1 & 1
\end{bmatrix}
$$

In decimal the new/final co-ordinates are listed as follows.

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Original co-ordinates	final coordinates
A (0, 0, 0)	A (0.39, −0.621, 1−011)
B (2, 0, 0)	B (2, 0, 0)
C (2, 2, 0)	C (0.988, 1.609, −0.621)
D (0, 2, 0)	D (−0.621, 0.988, 0.39)
E (0, 0, 2)	E (1.011, 0.39, 2.621)
F (2, 0, 2)	F (2.621, 1.011, 1.609)
G (2, 2, 2)	G (1.609, 2.621, 0.988)
H (0, 2, 2)	H (0, 2, 2)

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Q5 What do you mean by Bezier Spline curves? Explain with equations. design techniques using Bezier curves.

Ans:- Bezier spline curve is a parameter curve in which control points are used. this method makes use of Bezier function which are a set of polynomials

let us consider n+1 control points, denoted by $P_k = (x_k, y_k, z_k)$ where $0 \le k \le n$: using these points position vector $P(u)$ is formed which describes the path of Bezier polynomial function between P_0 and P_n

$$\boxed{P(u) = \sum_{k=0}^{n} P_k \, BEZ_{k,n}(u)} , u \in [0,1]$$

where $BEZ_{k,n}(u)$ is the Bezier blending function also known as Bernstein polynomials and is given as:

$$\boxed{BEZ_{k,n}(u) = \binom{n}{k} u^k (1-u)^{n-k}}$$

some properties of Bezier curve are as follows.

i) The curve connects the first and last control points of the control polygon.

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(ii) The slope of tangent at the beginning of the curve is along the line joining first two control points, and the slope at the end of the curve is along the line joining the last two end points.

(iii) All control points impact the entire curve.

(iv) All the points on the curve lie inside the convex Hull of the control polygon.

(v) the order of the curve is related to the number of control points.

(vi) No lines can intersect the curve at more than two points if the control points form an open polygon. Hence, the curve is smooth and free of loops. this is called variation. Diminishing property.

(vii) the curve is transformed by applying an affine transformation to its control points and generating the transformed curve from the transformed control point.

Design techniques:

→ complicated curves or higher degree curves can be formed by joining several Bezier section of lower degree. this technique.

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→ gives a better local control over the curve

→ If the first section/piece of the curve has n control points and the next curve section has n control points, then we match curve tangents by placing control point p_1 at the position.

$$\boxed{p'_1 = p_n + \frac{n}{n_1}\left(p_n - p_{n-1}\right)}$$

(using the tangent property of Bezier curves)

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Q(6)A Prove that successive 2D rotation are additive
$R(\theta_1) \cdot R(\theta_2) = R(\theta_1 + \theta_2)$

Ans :- Let assume that we have two Rotations θ_1 and θ_2 respectively, we can represent as,

$$P' = R(\theta_2) \cdot [R(\theta_1) \cdot P]$$
$$= [R(\theta_2) \cdot R(\theta_1)] P \quad (\because \text{associative property of matrix})$$

where,

$$R_{\theta_1} = \begin{bmatrix} \cos\theta_1 & -\sin\theta_1 \\ \sin\theta_1 & -\cos\theta_1 \end{bmatrix}$$

$$R_{\theta_2} = \begin{bmatrix} \cos\theta_2 & -\sin\theta_2 \\ \sin\theta_2 & \cos\theta_2 \end{bmatrix}$$

$$R_{\theta_2} \cdot R_{\theta_1} = \begin{bmatrix} \cos\theta_2 & -\sin\theta_2 \\ \sin\theta_2 & \cos\theta_2 \end{bmatrix} \begin{bmatrix} \cos\theta_1 & -\sin\theta_1 \\ \sin\theta_1 & -\cos\theta_1 \end{bmatrix}$$

$$\begin{bmatrix} \cos\theta_2 \cos\theta_1 - \sin\theta_1 \sin\theta_2 & -\cos\theta_2 \sin\theta_1 - \sin\theta_2 \cos\theta_1 \\ \cos\theta_1 \sin\theta_2 + \sin\theta_1 \cos\theta_2 & -\sin\theta_1 \sin\theta_2 + \cos\theta_1 \cos\theta_2 \end{bmatrix}$$

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we ~~pro~~ know that

$$\cos(\theta_1+\theta_2) = \cos\theta_1 \cdot \cos\theta_2 - \sin\theta_1 \cdot \sin\theta_2$$
$$\sin(\theta_1+\theta_2) = \cos\theta_1 \sin\theta_2 + \sin\theta_1 \cos\theta_2$$

Replacing these values, we get.

$$R(\theta_2) \cdot R(\theta_1) = \begin{bmatrix} \cos(\theta_1+\theta_2) & -\sin(\theta_1+\theta_2) \\ \sin(\theta_1+\theta_2) & \cos(\theta_1+\theta_2) \end{bmatrix}$$

$$= R(\theta_1+\theta_2)$$

This demonstrates that ~~Succe~~ successive rotations are additive $P' = R(\theta_1+\theta_2)P$.

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Q(b)

(b) Ans :- The matrix notation for scaling along S_x and S_y is as given below.

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

~~the~~ the matrix notation for rotation is as given below.

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

$$S \cdot R = \begin{bmatrix} S_x & 0 \\ 0 & S_y \end{bmatrix} \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} = \begin{bmatrix} S_x\cos\theta & S_x\sin\theta \\ -S_y\sin\theta & S_y\cos\theta \end{bmatrix}$$

$$= \boxed{\begin{bmatrix} S_x\cos\theta & S_x\sin\theta \\ -S_x\sin\theta & S_x\cos\theta \end{bmatrix}} \quad \because S_x = S_y \text{ — I}$$

$$= \begin{bmatrix} S_x & 0 \\ 0 & -S_y \end{bmatrix} \quad \because \theta = n\pi \text{ where } n \text{ is integer — II}$$

or

$$R \cdot S = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} S_x & 0 \\ 0 & S_y \end{bmatrix}$$

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$$= \begin{bmatrix} S_x \cos\theta & S_y \sin\theta \\ -S_x \sin\theta & S_y \cos\theta \end{bmatrix}$$

$$= \begin{bmatrix} S_x \cos\theta & S_x \sin\theta \\ -S_x \sin\theta & S_x \cos\theta \end{bmatrix} \quad \because S_x = S_y \text{ --- III}$$

$$= \begin{bmatrix} S_x & 0 \\ 0 & -S_y \end{bmatrix} \quad \because \theta = n\pi \text{ where } n \text{ is integer IV}$$

from equation I and III and equation IV and II it is proved that 2D rotation and scaling commute if $S_x = S_y$ or $\theta = n\pi$ for integral n and otherwise they do not.

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Q (27) Are we using GPU model in our Normal pcs? what are the benefits for using an external GPU module/cards of heterogeneous system? Also explain the GPU pipeline using CUDA architecture by suitable diagram.

Ans:- Every PC needs some sort of GPU (Graphics processing unit). This is due to the fact that absence of a GPU will lead to no image output of the display (monitor). These day the motherboards of the pcs come with an integrated GPU onen it on on the ~~Cpu~~ cpu itself. These GPUs are called integrated GPUs.

Benefits of integrated GPU.

→ user does not need to worry about GPU installation
→ power efficient
→ Issues regarding driver or compatibility are rare.

Downside:

→ Performance is not good in demanding applications like games.

Integrated GPUs are very common in modern pcs they are capable of handling most of the graphics application.

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Following are the benefits of using an external GPU model :-

→ External GPUs enhance parallel computation and hence they can be used to train Deep learning models faster than that on a CPU

→ External GPUs often find application in multitasking. this means that we can use external GPUs to use multiple monitors on a single computer.

→ They are used in PCs to improve performance and run those applications that demand high graphics computation like video games, video editing 3D art and design etc.

A Graphics pipeline is conceptual model which shows what steps are undertaken to convert (render) a 3D scene to a 2D screen.

On the other hand, CUDA is a parallel computing platform and programming model (framework) for general computing on NVIDIA GPUs. It helps developers to harness the parallelism offered by GPU.

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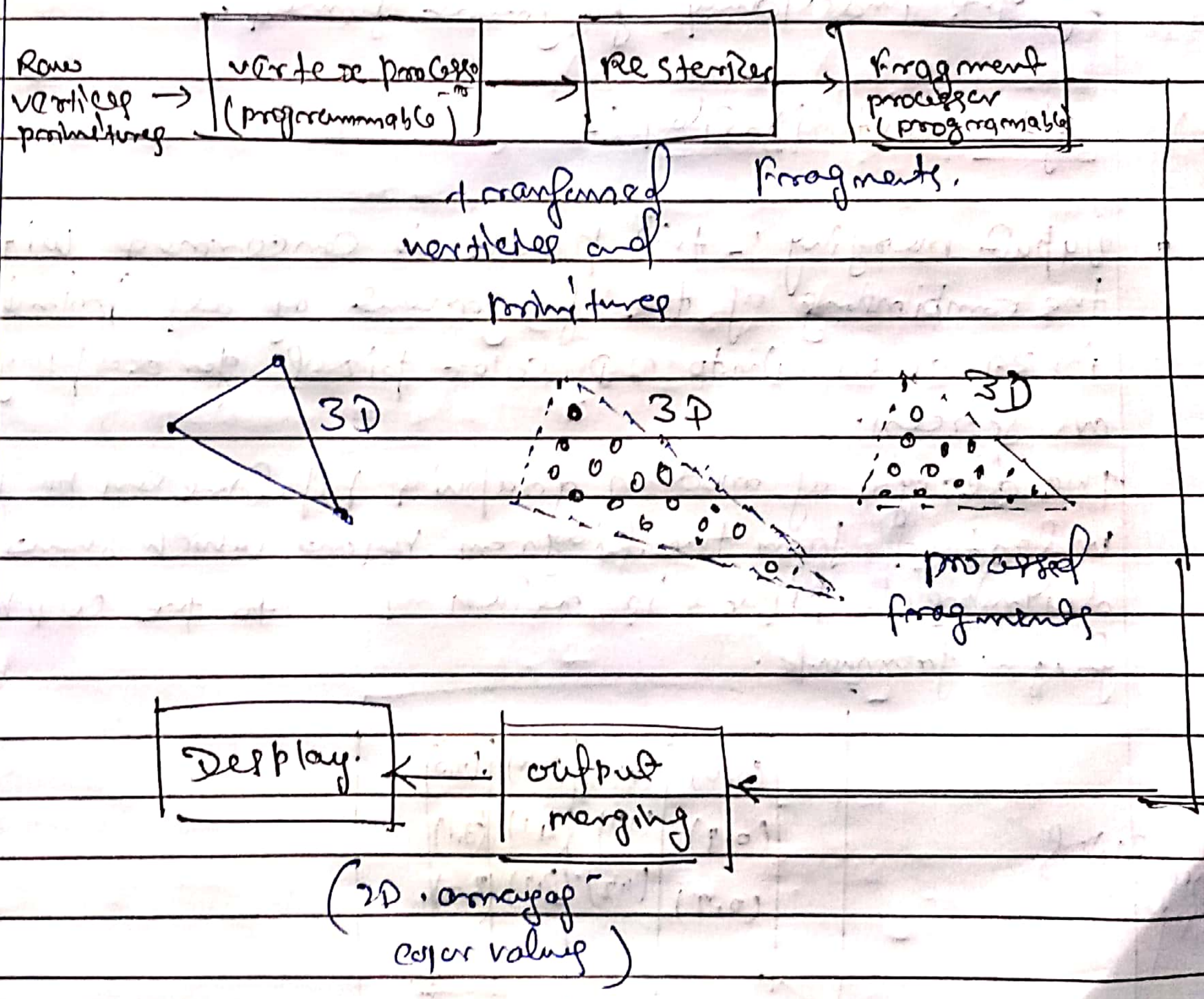
The graphics pipeline



- vertex processing :- It is the phase of the processing and transformations of individual vertices and ~~the~~ normals is done.

- Rasterization :- It is the process of converting each primitive (connected vertices) into a set of fragments. A fragment can be interpreted as a pixel with its attribute such as position color normal and texture.

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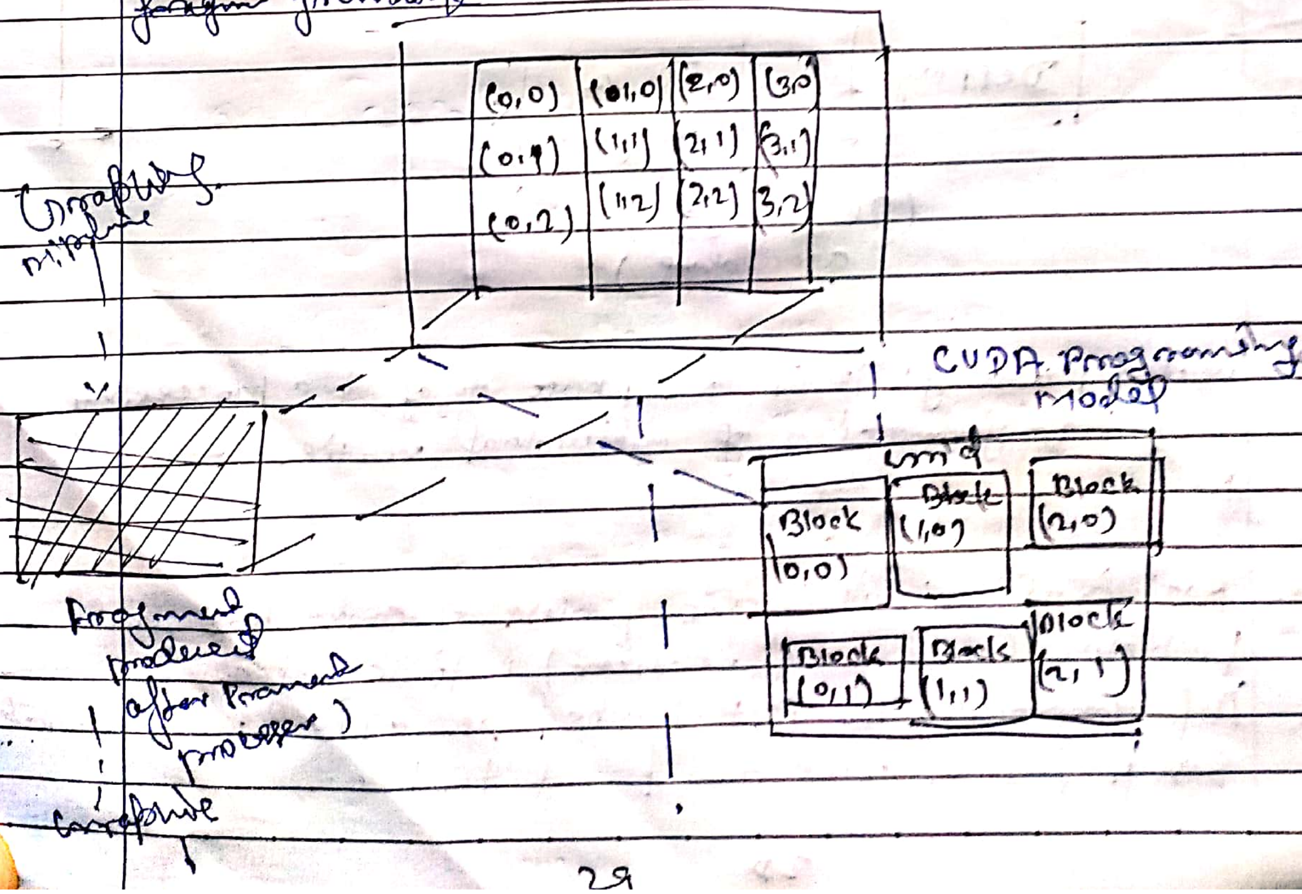
- Fragment processing :- its involve the processing of the individual fragment formed.

After rasterization :-

- Output merging :- this process is concerned with the combining of the fragment of all primitives in 3D space into 2D color pixel for displaying on screen.

The design of modern graphics pipeline can be well understood from the diagram below which shows the designing of pipeline in relation to the CUDA program framework.



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using CUDA, programmers are allowed to avoid graphics related code. further, threads within a block are than able to acess shared memory of each block is executed on one of serial multiprocessor of GPU

The diagram here shows how the CUDA programming model is connected with the graphics pipeline and its related with threads.