Name: Khushi Sharma

Sec: 6th 'B'

USN: 1BY20CS088

CGV Assignment

Q1 Build a 2D viewing transformation pipeline and also explain 2D viewing functions in OpenGL?

Ans: The mapping of a two-dimensional, world coordinate scene description to device coordinates is called a two-dimensional viewing transformation.

This transformation is simply referred to as window-to viewport transformation or window transformation.

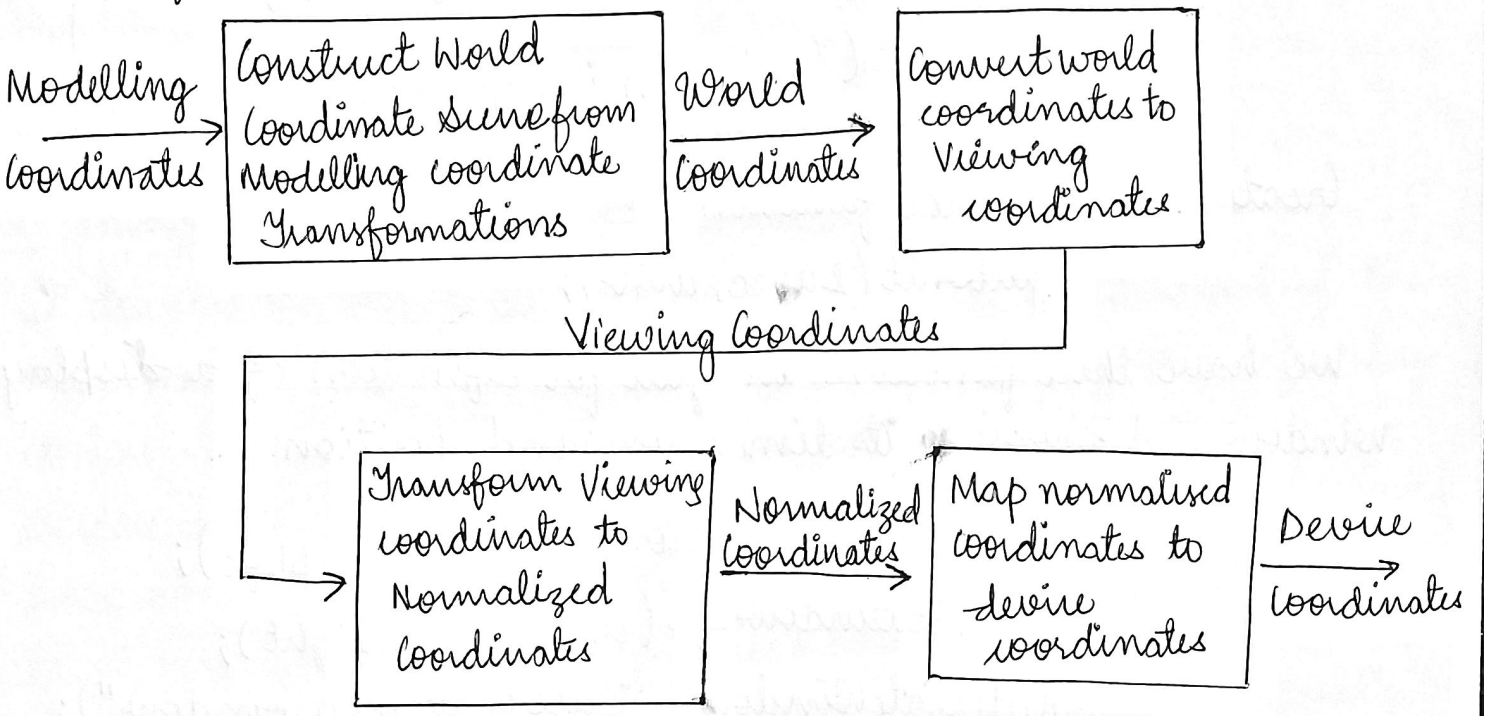


fig. A 2D viewing transformation pipeline

2D viewing functions-

We can use routines (2D routines) along with the OpenGL functions to all the viewing operations we need.

i) OpenGL Projection Mode:

Before we select a clipping window and a viewport in openGL we need to establish the appropriate mode for constructing the matrix

to transform from world to screen coordinates.

```
glMatrixMode(GL_PROJECTION);
```

This designates the Projection matrix as the current matrix which is originally set to identity matrix.

ii) Glu Clipping - window function -

To define a 2D clipping window, we can use the OpenGL utility function.

```
gluOrtho2D(xwmin, xwmax, ywmin, ywmax);
glViewPort(xvmin, yvmin, vpwidth, vpheight);
```

Create a Glut display function -

```
glutInit(&argc, argv);
```

We have three functions in Glut for defination of a display window and choosing its dimension and position.

```
glutInitWindowPosition(xtopleft, ytopleft);
glutInitWindowSize(dwidth, dheight);
glutCreateWindow("Title of display window");
```

iii) Setting the Glut Display Mode of Window and color -

```
glutInitDisplayMode(mode);
mode = GLUT_RGB | GLUT_SINGLE | GLUT_DEPTH ,...;
glClearColor(Red, Green, Blue, alpha);
glClearIndex(index);
```

iv) Glut Display Identifier -

```
window ID = glutCreateWindow("display window");
```

v) Current GLUT display window:

```
glutSetWindow (window ID);
```

vi) Other glut Viewing functions (2D) -

```
glLoadIdentity();
glutDestroyWindow(windowID);
glutReshapeWindow(width, height);
glutFullScreen();
glutPushWindow();
glutPopWindow(); , etc.
```

Q2 Build Phong Lightning Model with equations.

Ans: Phong reflection is an empirical model of local illumination. It describes the way a surface reflects light as a combination of the diffuse reflection of rough surfaces with the specular reflection of shiny surface. It is based on Phong's informal observation that shiny surfaces have small intense specular highlights. while dull surfaces have small intense specular highlight while dull. Surfaces have large highlights, while dull surfaces have large highlights, while dull surfaces have large highlights that fall off more gradually.

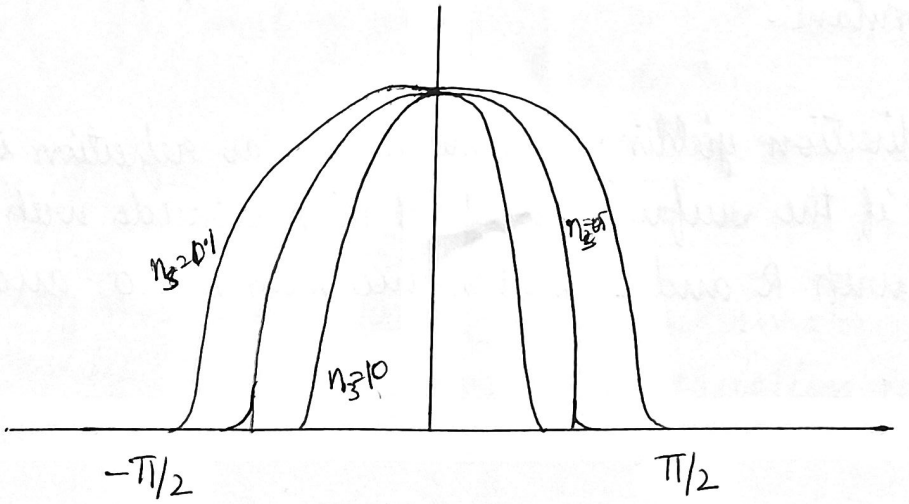


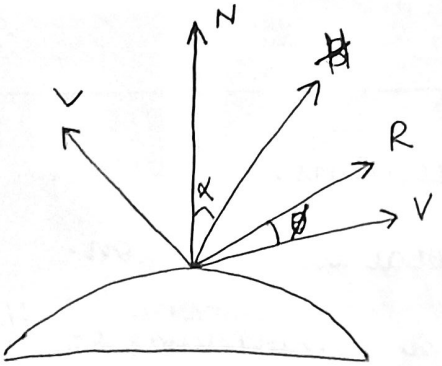
fig effect of the shininess value

Phong model sits the intensity of specular reflection to $\cos^{n_s}\phi$.

$$I_{l,\text{specular}} = W(\theta)\, I_l \cos^{n_s}\phi \,, \quad 0 \le W(\theta) \le 1 \text{ is specular reflection coefficient.}$$

If light direction L and viewing direction V are on the same side of the normal N, or if L is behind the surface, Specular effects do not exist.

For most opaque materials specular-reflection coefficient is nearly constant k_s.



$$I_{\text{specular}} = \begin{cases} k_s I_l (V \cdot R)^{n_s}, & V \cdot R > 0 \text{ & } N \cdot L > 0 \\ 0, & \text{otherwise} \end{cases}$$

$$R = (2N \cdot L)\, N - L \,.$$

The normal N may vary at each point to avoid N computation angle ϕ is replaced with an angle α defined by a halfway vector H between L and V.

$$\text{Coefficient} \Rightarrow H = \frac{L+V}{|L+V|}$$

If the light source and viewer are relatively far from the object, α is constant.

H is the direction yielding maximum specular reflection in the viewing direction V if the surface normal N with coincide with H. If V is coplanar with R and L and hence with N too and thus

$$\alpha = \frac{\phi}{2} \,.$$

Q3 Apply homogenous coordinates for translation, rotation and scaling via matrix representation.

Ans :- The three basic 2-D transformations are translation, rotation and scaling

$$P' = M_1 \cdot P + M_2$$

P' & P represents column vectors.

Matrix $M_1 \rightarrow$ 2x2 array containing multiplicative factors

$M_2 \rightarrow$ 2 elements column matrix containing translation term $\begin{bmatrix} x_t \\ y_t \end{bmatrix}$.

For translation, M_1 is identity matrix $P' + T$ where $T = M_2$.
For rotation and scaling, M_2 contains translational terms associated with pivot point or scaling.

Homogenous coordinates

$P' = P + T$ for translation where $T = \begin{bmatrix} tx \\ ty \end{bmatrix}$

$P' = R \cdot P$ for rotation where $R = \begin{bmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{bmatrix}$

$P' = S \cdot P$ for scaling where $S = \begin{bmatrix} Sx & 0 \\ 0 & Sy \end{bmatrix}$

In general, $P' = M_1 \cdot P + M_2$

Using homogenous coordinates, the transformations could be combined easily. Here we reformulate equation to eliminate matrix addition.

In homogenous coordinate system, we combine multiplicative and translational terms by expanding the 2 x 2 matrix representation

to 3 x 3 matrix representation. Also expand the matrix representation for coordination position.

We represent each Cartesian co-ordinate (x, y) with homogenous co-ordinate (x_h, y_h, h) where $x = x_h/h$, $y = y_h/h$

$(h*x, h*y, h)$

set $h = 1$ then $(x, y, 1)$

Homogenous coordinates representation for translation, scaling and rotation are as follows:

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & tx \\ 0 & 1 & ty \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \quad \rightarrow \text{Translation}$$

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} Sx & 0 & 0 \\ 0 & Sy & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \quad \rightarrow \text{Scaling}$$

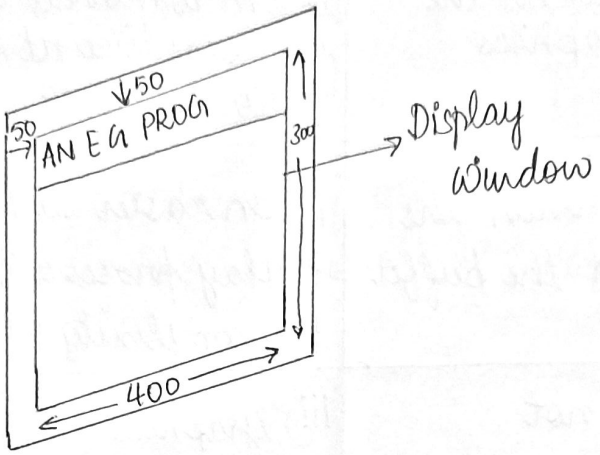
$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \quad \rightarrow \text{Rotation}$$

Q4 Outline the differences between Raster Scan displays and Random Scan displays.

RANDOM SCAN DISPLAY	RASTER SCAN DISPLAY
i) In random scan display, the beam is moved between the end points of the graphics primitives.	i) In raster scan display, the beam is moved all over the screen one scanline at a time from top to bottom and then back to top.
ii) Vector display flickers when the number of primitives in the buffer becomes too large.	ii) In raster display the refresh display process is independent of the complexity of the image.
iii) Scan conversion is not required.	iii) Graphics primitives are specified in terms of their endpoints and must be converted into their corresponding pixel in the frame buffers.
iv) Scan conversion hardware is not required.	iv) Because each primitive must be scan converted, real time dynamics is for more computational and required separate scan conversion hardware.
v) Vector display derives a continous and smooth lines.	v) Raster display can display mathematically smooth lines, polygons and boundaries of curved primitives only by approximately them with pixel on the raster-grid.
vi) Cost is more.	vi) Cost is low.
vii) Vector display only draws lines and characters.	vii) Raster display has abelity to display areas filled with solid colors or patterns.

Q5 Demonstrate OpenGL functions for displaying window management using GLUT?

Ans: GLUT supports two types of windows: top level windows and subwindows. Both types support OpenGL rendering and GLUT callbacks. There is a single identifier space for both types of windows.



- We perform the GLUT initialization with the statement

  glutInit(&argc, argv);

- Next, we can state that a display window is to be created on the screen with a given caption for the title bar. This is accomplished with the function

  glutCreateWindow ("An EG Prog");

  where single argument for this function can be any character string.

- The following function call the line segment description to the display window,

  glutDisplayFunc (display);
  ↳ line segment.

- The function glutMainLoop(); must be the last one in our program. It displays the initial graphics and puts the program into an infinite loop that checks for input from devices such as mouse or keyboard.

- The function glutInitWindowPosition (50,100); specifies that the

⊗ Upper left cover of the display window should be placed 50 pixels to the right of the left edge of the screen and 100 pixels down from the top edge of the screen.

- The function glutInitWindowSize (400,300); is used to set the initial pixel width and height of the display window.

- The function glutInitDisplayMode (GLUT_SINGLE | GLUT_RGB); specifies that a single refresh buffer to be used for the display window and that we convert to use the color mode which uses red, green and blue (RGB) components to select values of color.

Q6 Explain OpenGL Visibility Detection Functions?

Ans:- a) OpenGL Polygon-Culling Functions-

Back face removal is accomplished with the functions

glEnable (GL_CULL_FACE);
glCullFace (mode);

where mode is assigned the values GL_BLACK, GL_FRONT, GL_FRONT_AND_BACK

By default, parameter made in glCullFace() has value GL_BACK

The culling routine is turned off with glDisable (GL_CULL_FACE);

b) OpenGL Depth Buffer Functions:

To use the OpenGL depth buffer visibility detection function, we first need to modify the GL utility Toolkit. GLUT initialization function for the display mode to include a request for the depth buffer as well as for refresh buffer.

glutInitDisplayMode (GLUT_SINGLE | GLUT_RGB | GLUT_DEPTH);

Depth buffer value can be initialized with

glClear (GL_DEPTH_BUFFER_BIT);

By default glClear is seat to 1.0.

These routines are activated by following

glEnable(GL_DEPTH_TEST);

and can be deactivated using

glDisable(GL_DEPTH_TEST);

We can also apply depth buffer testing using some other initial values for maximum depth

glClearDepth(maxDepth);

- It can be set to any value between 0 and 1.

As an option, we can normalize values with

glDepthRange(near NormDepth, far NormDepth);

We specify a test condition for the depth buffer routines using

glDepthFunc(test condition);

We can set the status of the depth buffer so that if it is in a read only state or in read-write state.

glDepthMask(write status);

c) OpenGL Wire Frame Surface Visibility Methods -

A wire frame displays of a standard graphics object can be obtained in OpenGL by requesting that only its edges are to be generated.

glPolygonModel(GL_FRONT_AND_BACK, GL_LINE);

But this displays both visible and hidden edges.

d) OpenGL Depth Cuing function -

we can vary the bright of an object as a function of its distance from the viewing position with

glEnable(GL_FOG);

glFogr(GL_FOG_MODE, GL_LINEAR);

This applies the linear depth function to object colors using dmin = 0.0 and dmax = 1.0.

```
glFogf(GL_FOG_START, minDepth);
glFogf(GL_FOG_END, maxDepth);
```

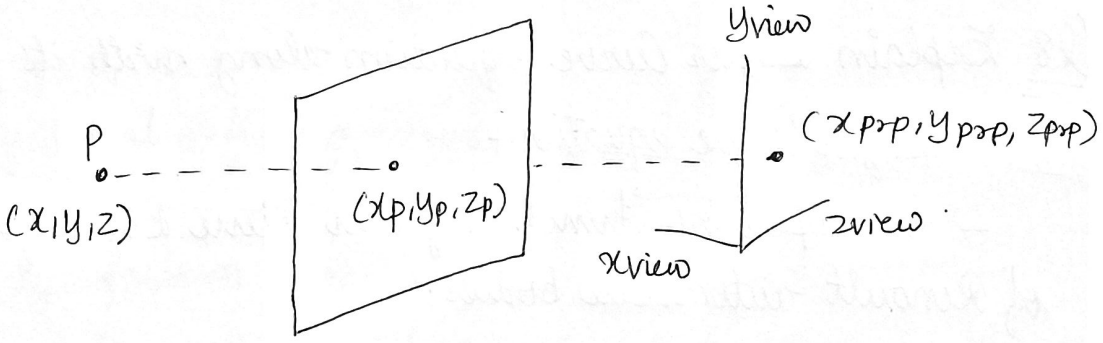
Q7 Write the special cases discussed with respect to Perspective projection transformation coordinates.

Ans :-

We know that,

$$x_p = x\left[\frac{z_{prp} - z_{vp}}{z_{prp} - z}\right] + x_{prp}\left[\frac{z_{vp} - z}{z_{prp} - z}\right]$$

$$y_p = y\left[\frac{z_{prp} - z_{vp}}{z_{prp} - z}\right] + y_{prp}\left[\frac{z_{vp} - z}{z_{prp} - z}\right]$$



Special Cases with respect to Perspective projection transformations

① If projection reference point is on Zview $\Rightarrow x_{prp} = y_{prp} = 0$, then

$$x_p = x\left[\frac{z_{prp} - z_{vp}}{z_{prp} - z}\right]$$

$$y_p = y\left[\frac{z_{prp} - z_{vp}}{z_{prp} - z}\right]$$

② Sometimes the projection reference point is fixed at coordinate at origin and $x_{prp} = z_{prp} = y_{prp} = 0$. Then

$$x_p = x\left[\frac{z_{vp}}{z}\right], \quad y_p = y\left[\frac{z_{vp}}{z}\right]$$

③ If the View plane is uv plane and there are no restrictions on placement of projection reference point then we have

$z_{vp} = 0$:

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

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

④ With the uv plane as the view plane and the projection plane reference point on Z view axis, the perspective equations are

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

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

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

Q8 Explain Bezier Curve equation along with its properties.

Ans :- Bezier Curve equation -

- Developed by French engineer Pierre Bezier for use in design of Renault automobile bodies.
- They have lots of properties that make them highly useful for curve and surface design. They are easy to implement.
- Bezier curve section can be filled to any number of control points.

Equation :

$$P(u) = \sum_{k=0}^{n} p_k \, BEZ_{k,n}(u)$$

where n is no of control pts - 1.

k is n+1 (~~no of control points~~) varing from 0 to n

P_k is position vector coordinate (x_k, y_k, z_k).

$BEZ_{k,n}(u)$ is Bernstein Polynomial and is defined as

$$BEZ_{k,n}(u) = C(n,k)\, u^k \cdot (1-u)^{n-k}$$

and $0 \le u \le 1$.

eqn $P(u)$ can be represented as set of three parametric equation for the individual curve -

$$x(u) = \sum_{k=0}^{n} x_k\, BEZ_{k,n}(u)$$

$$y(u) = \sum_{k=0}^{n} y_k\, BEZ_{k,n}(u)$$

$$z(u) = \sum_{k=0}^{n} z_k\, BEZ_{k,n}(u).$$

Properties -

1. Basic functions are real.
2. Degree of polynomial defining curve is one less than number of defining points.
3. Curve generally follows shape of defining polygon.
4. Curve will pass through end point but not all control point.
5. Polygon (Polynomial eqn) equation depends on number of control points.
6. Curves lie within convex hull of the control points.

Q9 Explain normalization transformation of Orthogonal Projection.

Ans:- Normalization transformation of Orthogonal projection can be defined as mapping coordinates into a normalized view volume with coordinates in range -1 to 1.

In this, we assume that the orgonal projection view volume is to be mapped into the symmetric normalization cube within a left handed reference frame.

Also, z coordinate positions for the near and far planes are denoted by z_{near} and z_{far} respectively.

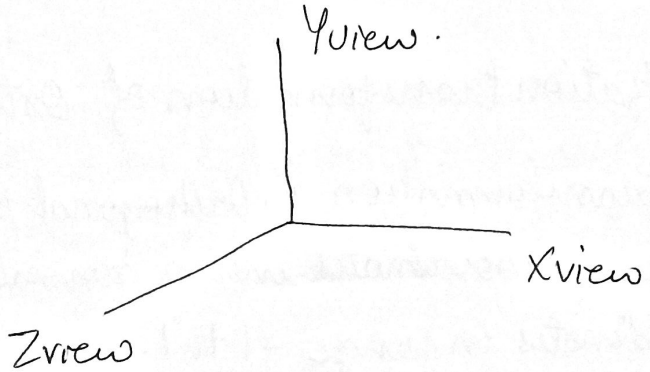
This position $(x_{min}, y_{min}, z_{near})$ is mapped to be the normalized position $(-1, +1, -1)$ and position $(x_{max}, y_{max}, z_{far})$ to $(1, 1, 1)$.

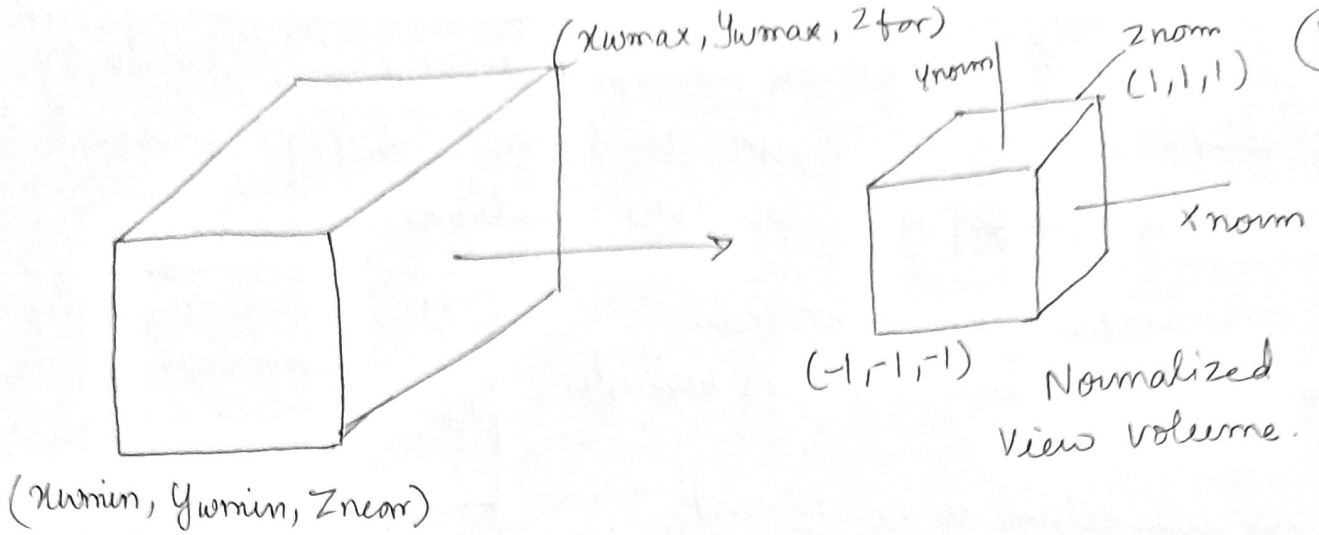
Transforming the rectangular paralleopiped is similar to the method for conveting clipping window into the normalized symmetric square.

The normalization transformation for the orthogonal projection can be defined as.

$$M_{orthonorm} = \begin{bmatrix} \frac{2}{xw_{max} - xw_{min}} & 0 & 0 & -\frac{xw_{max} + xw_{min}}{xw_{max} - xw_{min}} \\ 0 & \frac{2}{y_{wmax} - y_{wmin}} & 0 & -\frac{y_{wmax} + y_{wmin}}{y_{wmax} - y_{wmin}} \\ 0 & 0 & \frac{-2}{z_{near} - z_{far}} & \frac{z_{near} + z_{far}}{z_{near} - z_{far}} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The matrix is multiplied on the right by the composite viewing transformation RT to produce the complete transformation from world coordinates to normalize orthogonal projection coordinates.





Q10 Explain Cohen-Sutherland line clipping algorithm.

Ans:- Every line endpoint in a picture is assigned a four digit binary value called region code and each bit position is used to indicate whether the point is inside or outside the boundaries of clipping window.

	TOP	
1001	1000	1010
0001	0000 Window clipping	0010 Right
Left		
0101	0100 Bottom	0110

Once we have established region codes for all lines endpoints, we can quickly determine which lines are completely within or outside the clipping window.

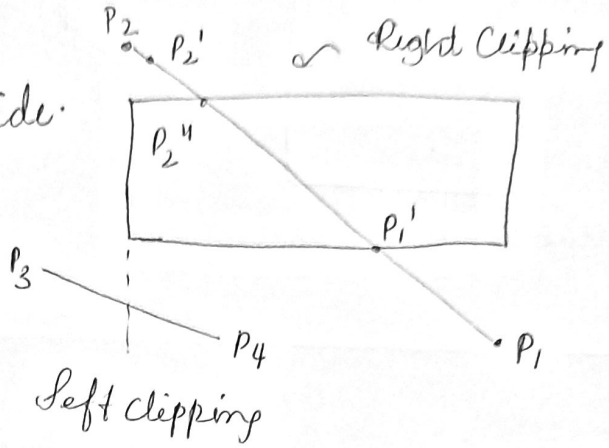
* When the OR operation between 2 endpoints region code is false (0000) for a line segment, the line is inside the clipping window.

* When AND operation between 2 endpoints region code for line segment is true, the line is completely outside the clipping window.

* Lines that cannot be identified as completely inside or outside a clipping window by region codes tests are next checked for intersection points with window border lines

For example - the region code says P_1 is inside and P_2 is outside.

The intersection to be P_2'' and P_1' is clipped off.



For line P_3 to P_4 we define that P_3 is outside left boundary & P_4 is inside therefore intersection of P_3 & P_4' is clipped off.

* To determine boundary point intersection for line equation y coordinate of intersection point with vertical clipping border line can be obtained as -

$$y = y_0 + m(x - x_0).$$

$x = x_{wmin}$ if left border

$x = x_{wmax}$ if right border

$$\text{and } m = \frac{y - y_0}{x - x_0}.$$

and similarly for x coordinate of intersection point with horizontal clipping border line is -

$$x = x_0 + \frac{(y - y_0)}{m}$$

$y = y_{wmin}$ if bottom boundary

$= y_{wmax}$ if upper boundary.