VAR - 1

10/8/22

COMPUTER GRAPHICS

"DISPLAY MECHANISM" of a computer

Hardware | Software

19th Aug - deadline for grp formation. — DONE

Steps to follow

Modelling - Blueprint / Design the model /application

Rendering - Displaying on the screen

Animation - Adding effects.

Retro fitting - changing something / Replacing the usual

Virtual solution

Computer graphics

Interactive (gaming) | non-interactive (

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Computer Graphics

It is an ~~art~~ "ART" of "DRAWING OBJECTS" using program-ming languages.

(Point, Line, Chart)

$\downarrow$

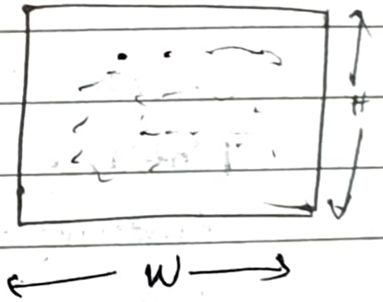
object

$\downarrow$

(Pixel)

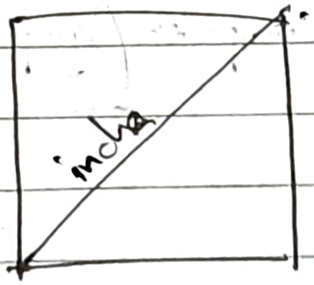
BASIC TERMS

1) Pixel - Smallest Unit.
2) Resolution - W X H
3) PPI - (Pixel / Inch)
4) Aspect Ratio - W : H / $\frac{W}{H}$



5) Frame Buffer
   it's a kind of memory which stores required information about image.

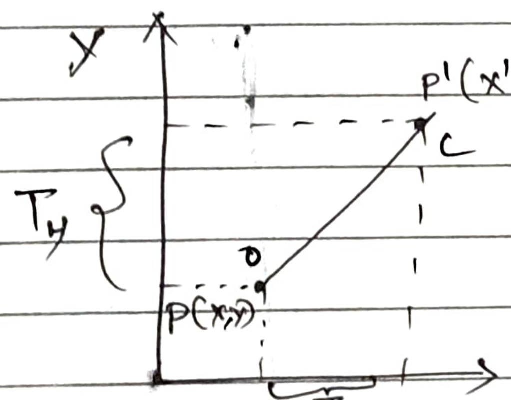
3) $\Rightarrow$



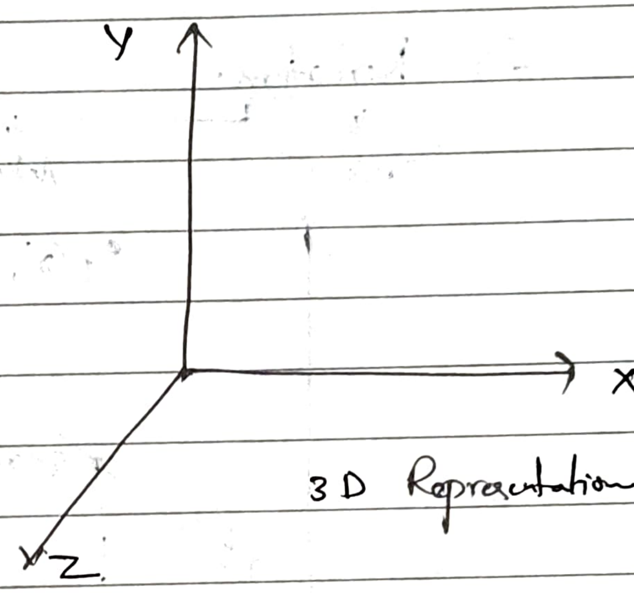
$$\frac{\sqrt{W^2 + H^2}}{\text{inches}} = PPI$$

TRANSFORMATION:- W.R.T 2D

1) Translation



2D Representation



3 D Representation

T_x, T_y are translating factors.

$$P[x, y] = \begin{bmatrix} x \\ y \end{bmatrix}$$

$$P'[x', y'] = \begin{bmatrix} x' \\ y' \end{bmatrix}$$

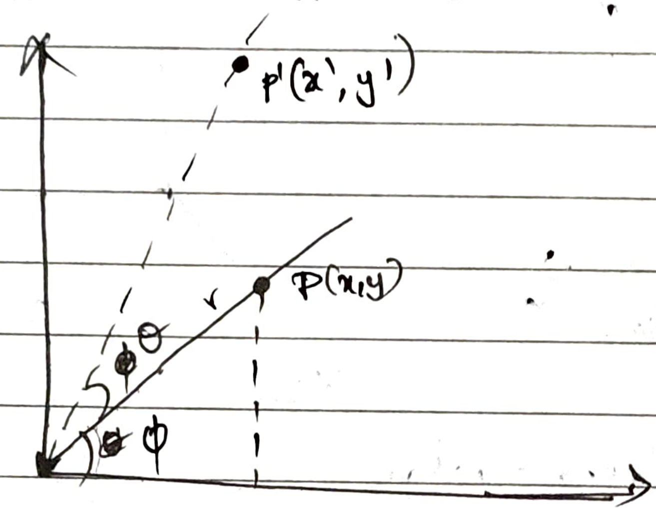
$$x' = x + T_x$$
$$y' = y + T_y.$$

$$P'[x', y'] = \begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} T_x \\ T_y \end{bmatrix}$$

Generalised eq^n $\Rightarrow$ $\boxed{P' = P + T}$

2) Rotation:

clockwise | Anticlockwise



$x = r\cos\phi$

$y = r\sin\phi$

$x' = r\cos(\theta + \phi)$

$y' = r\sin(\theta + \phi)$

$x' = r[\cos\theta\cos\phi - \sin\theta\sin\phi]$

$= r\cos\theta\cos\phi - r\sin\theta\sin\phi$

$= x\cos\theta - y\sin\theta$

$y' = r[\sin\theta\cos\phi + \cos\theta\sin\phi]$

$= \cancel{y\cos\theta + x\sin\theta}$

$= x\sin\theta + y\cos\theta$

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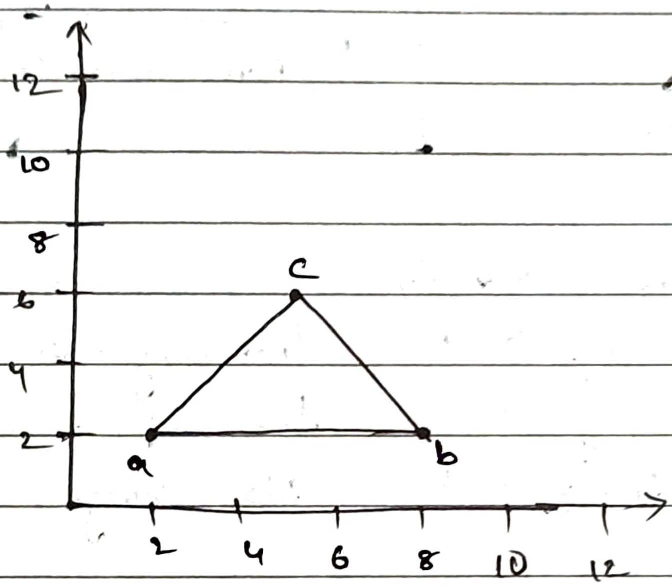
$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

Generalised eq^n $\Rightarrow$ $\cancel{\boxed{P' = PR}}$ $\boxed{P' = RP}$



a(2,2) b(8,2)

c(5,5)

$\theta = 90^\circ$

$P' = RP$

$P' = ? \begin{bmatrix} a \\ b \\ c \end{bmatrix}$

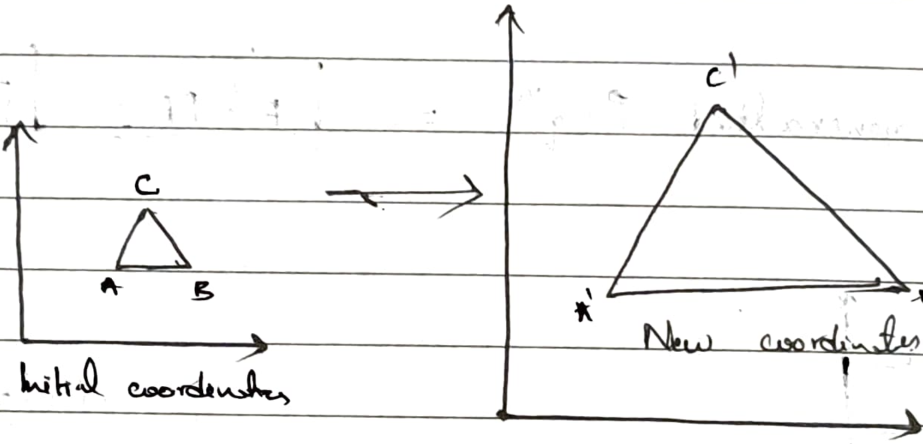
$$R = \begin{bmatrix} \cos 90^\circ & -\sin 90^\circ \\ \sin 90^\circ & \cos 90^\circ \end{bmatrix} = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}$$

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

$$b' = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} 8 \\ 2 \end{bmatrix}$$

$$c' = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} 5 \\ 5 \end{bmatrix}$$

3) **Scaling**: changing the size.



Scaling factors S_x S_y

if $S_x, S_y > 1$ Increasing the size

if $S_x, S_y < 1$ Decreasing the size

if $S_x, S_y = 1$ No change.

$x' = S_x X$

$y' = S_y Y$

Generalised expression = $\boxed{P' = SP}$

$$[x' \; y'] = \begin{bmatrix} S_x & 0 \\ 0 & S_y \end{bmatrix} [X \; Y]$$

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} S_x & 0 \\ 0 & S_y \end{bmatrix} \begin{bmatrix} X \\ Y \end{bmatrix}$$

Example:- A [2, 1] S_x = 3 units A' =

B [5, 1] S_y = 2 units B' =

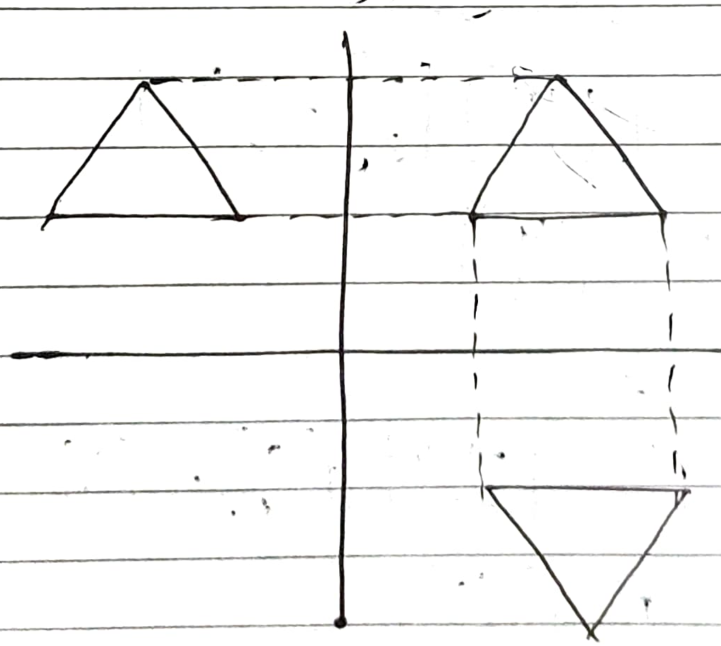
C [4, 4] C' =

$$\therefore A' = \begin{bmatrix} 3 & 0 \\ 0 & 2 \end{bmatrix} \begin{bmatrix} 2 \\ 1 \end{bmatrix} = \begin{bmatrix} 6 \\ 2 \end{bmatrix}$$

$$B' = \begin{bmatrix} 15 \\ 2 \end{bmatrix}$$

$$C' = \begin{bmatrix} 12 \\ 8 \end{bmatrix}$$

4) Reflection:-



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X- axis

$X' = x$

$Y' = -y$

$$\left.\begin{matrix} X' = x \\ Y' = -y \end{matrix}\right\} = \begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

R_x

R_y

$P' = Ref(x)P$

Y- axis

$$\left.\begin{matrix} x' = -x \\ y' = y \end{matrix}\right\} = \begin{bmatrix} x' \\ -y' \end{bmatrix} = \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

R_x

R_y

$P' = Ref(y)P$

Example :- A (3,4)

B (2,3)

C (4,3)

$Ref(x) = A'?\ B'?\ C'?$

$$A' = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \begin{bmatrix} 3 \\ 4 \end{bmatrix} = \begin{bmatrix} 3 \\ -4 \end{bmatrix}$$

$$B' = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \begin{bmatrix} 2 \\ 3 \end{bmatrix} = \begin{bmatrix} 2 \\ -3 \end{bmatrix}$$

$$C' = \begin{bmatrix} 4 \\ -3 \end{bmatrix}$$

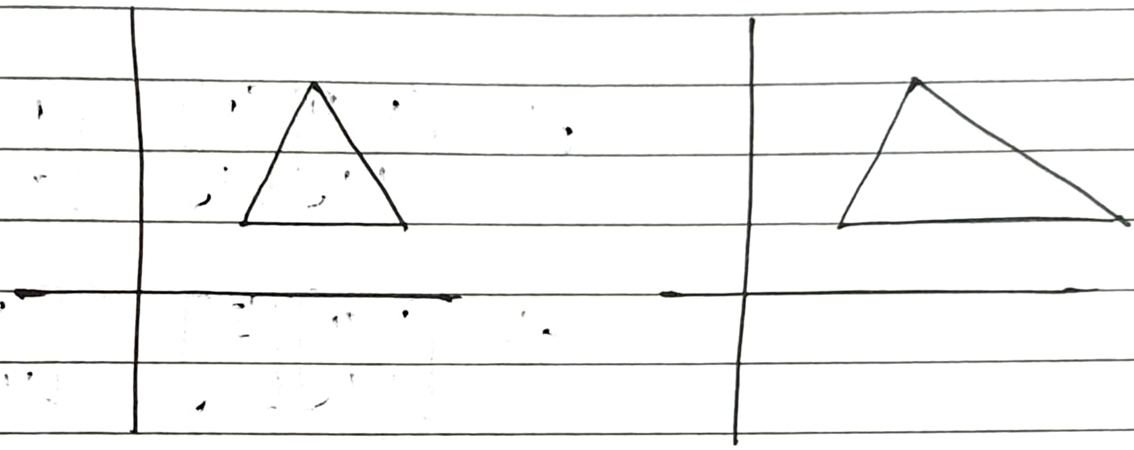
$Ref(y) \Rightarrow$

$$A' = \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 4 \end{bmatrix} = \begin{bmatrix} -3 \\ 4 \end{bmatrix}$$

$$B' = \begin{bmatrix} -2 \\ 3 \end{bmatrix}$$

$$C' = \begin{bmatrix} -4 \\ 3 \end{bmatrix}$$

5) **Shearing** : changing the shape.



x-axis

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & Sh_x \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

$x' = x + Sh_x * y$

$y' = y$

Y-axis

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ Sh_y & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

$x' = x.$

$y' = y + Sh_y * \cancel{y}\, x$

Example:-

$A = (2, 2)$ $B(1, 1)$ $C = (3, 1)$

$Sh_x = 1$; $Sh_y = 2$

$A' = ?$ $B' = ?$ $C' = ?$

x-axis $\Rightarrow$ $A' = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 2 \\ 2 \end{bmatrix} = \begin{bmatrix} 4 \\ 2 \end{bmatrix}$

$B' = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 2 \\ 1 \end{bmatrix}$

$C' = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 1 \end{bmatrix} = \begin{bmatrix} 4 \\ 1 \end{bmatrix}$

y

Y - axis :

$A' = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 2 \\ 2 \end{bmatrix} = \begin{bmatrix} 2 \\ 4 \end{bmatrix}$

$B' = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 \\ 2 \end{bmatrix}$

$C' = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 \\ 4 \end{bmatrix}$

Cheatsheet

Transformations w.r.t 2D coordinates

1) Scaling
$$\begin{bmatrix} S_x & 0 \\ 0 & S_y \end{bmatrix}$$

2) Rotation (clockwise)
$$\begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix}$$

(Anticlockwise)
$$\begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}$$

3) Translation
$$\begin{array}{c} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \\ t_x \quad t_y \end{array}$$

4) Reflection (x)
$$\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$$

(Y)
$$\begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix}$$

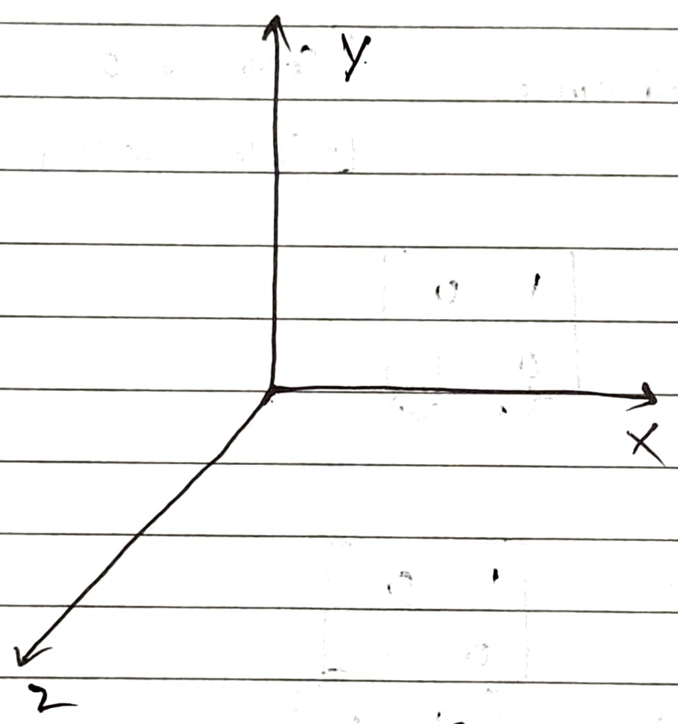
5) Shearing (x)
$$\begin{bmatrix} 1 & Sh_x \\ 0 & 1 \end{bmatrix}$$

Shearing (Y)
$$\begin{bmatrix} 1 & 0 \\ Sh_y & 1 \end{bmatrix}$$

Homogeneous system is introduced to reduce the complex-
-ity of a series of operations.

UNIT-4

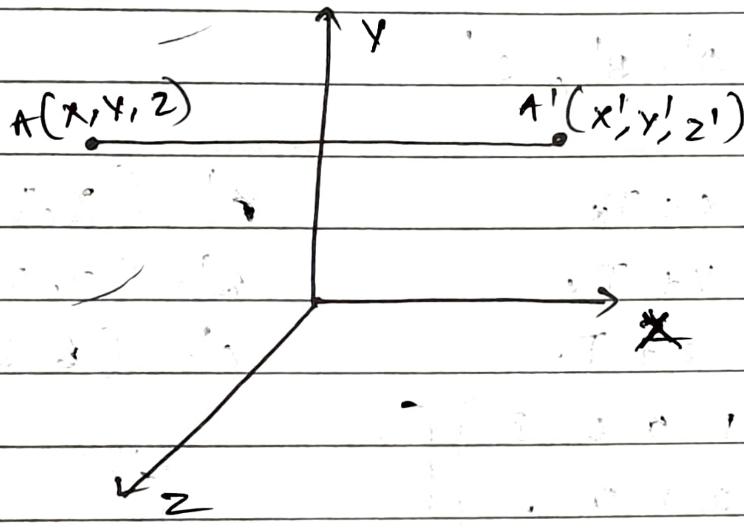
3D



→ Translation
→ Rotation
→ Scaling
→ Shearing
→ Reflection

TRANSFORMATIONS w.r.t 3D

I) Translation



T_x, T_y, T_z are translation factors.

$$x' = x + T_x$$
$$y' = y + T_y$$
$$z' = z + T_z$$

Generalized form:

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & T_x \\ 0 & 1 & 0 & T_y \\ 0 & 0 & 1 & T_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} x + T_x \\ y + T_y \\ z + T_z \\ 1 \end{bmatrix}$$

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A $(0,3,6)$ $T_x = 3$

B $(4,5,9)$ $T_y = 2$

C $(3,4,8)$ $T_z = 4.$

Calculate A', B', C'

$x' = x + T_x$

$y' = y + T_y$

$z' = z + T_z$

$A' = (3,5,10)$

$B' = (7,7,13)$

$C' = (6,6,12)$

$$A' \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 1 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ 3 \\ 6 \\ 1 \end{bmatrix} = \begin{bmatrix} 3 \\ 5 \\ 10 \\ 1 \end{bmatrix}$$

$$B' \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 1 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 4 \\ 5 \\ 9 \\ 1 \end{bmatrix} = \begin{bmatrix} 7 \\ 7 \\ 13 \\ 1 \end{bmatrix}$$

$$C' \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 3 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 1 & 4 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 4 \\ 8 \\ 1 \end{bmatrix} = \begin{bmatrix} 6 \\ 6 \\ 12 \\ 1 \end{bmatrix}$$

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2) <u>Scaling</u> : process of increasing the size or decreasing the size.

If $S_x, S_y, S_z > 1$ Increasing the size

If $S_x, S_y, S_z < 1$ Decreasing the size

If $S_x, S_y, S_z = 1$ Same size.

→ Uniform scaling $S_x = S_y = S_z = 1$

→ Differential scaling $S_x \neq S_y \neq S_z$

$$x' = x * S_x$$
$$y' = y * S_y$$
$$z' = z * S_z$$

Generalized representation:

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} S_x & 0 & 0 & 0 \\ 0 & S_y & 0 & 0 \\ 0 & 0 & S_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

Ex:- A(3, 1, 2)
B(1, 2, 1)
C(0, 1, 1)

$$\begin{bmatrix} 2 \\ 1 \\ 3 \end{bmatrix}$$

$S_x = 2$, $S_y = 1$, $S_z = 3$

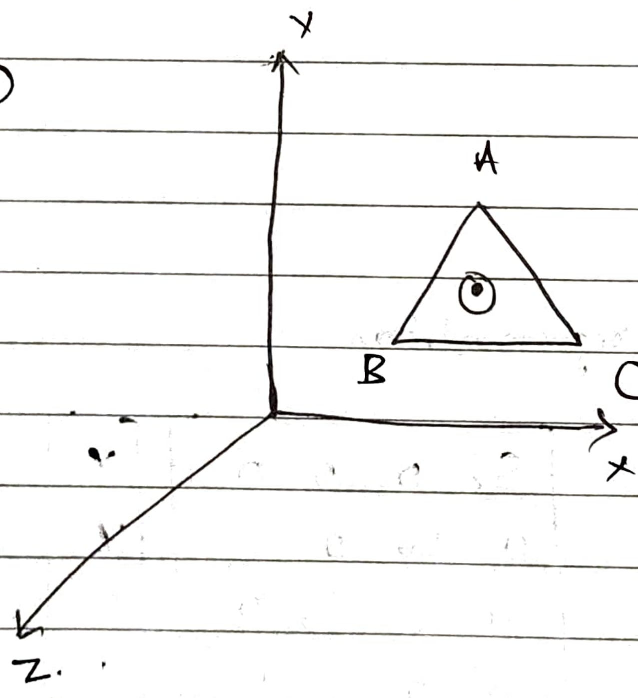
$A' = ?$ $B' = ?$ $C' = ?$

$A' = (6, 1, 6)$ $\cancel{B' = (}$

$B' = (2, 2, 3)$

$C' = (0, 1, 3)$

(1)



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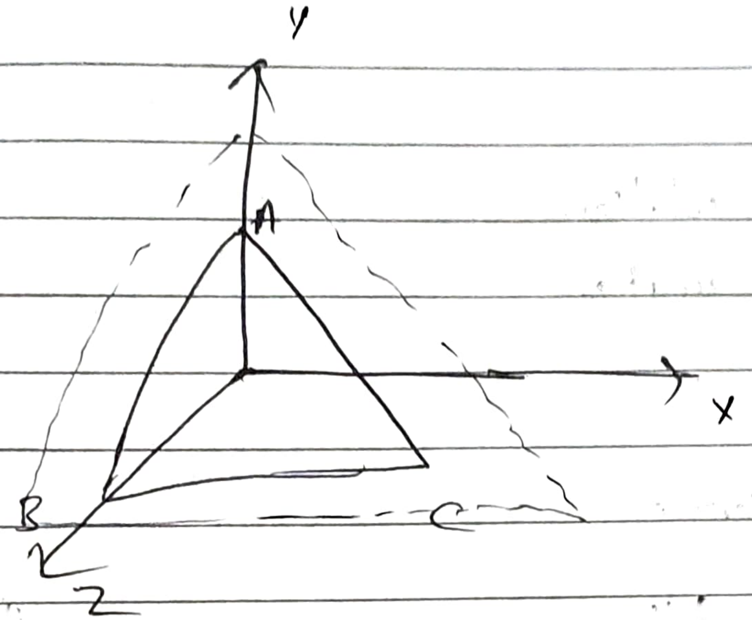

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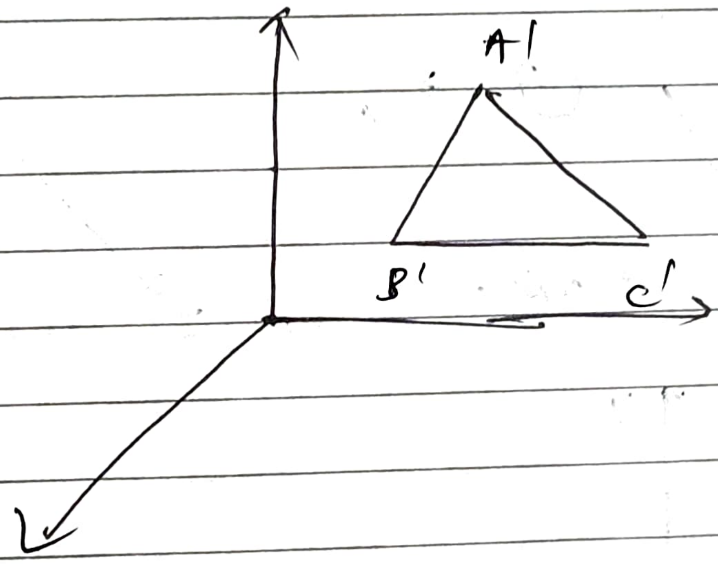
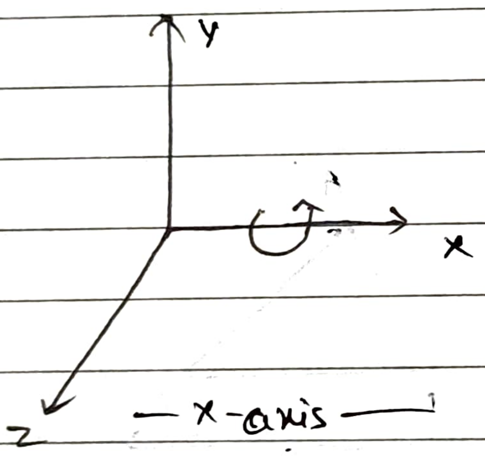


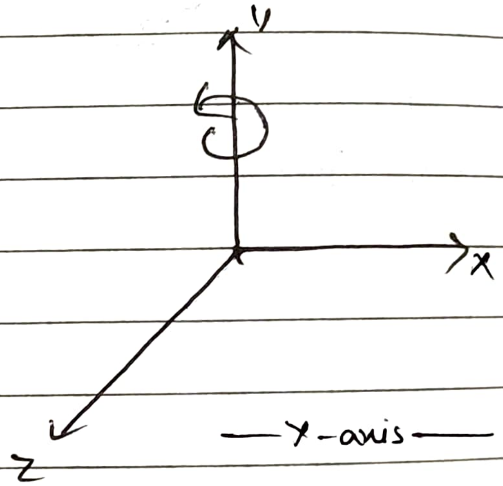
3) <u>Rotation</u>

→ Angle of rotation
→ Axis of rotation

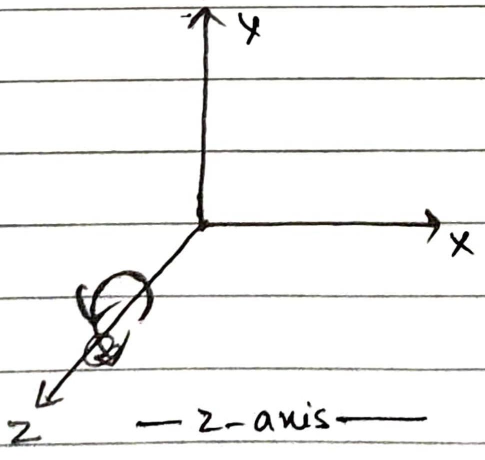
Anti clockwise



— x-axis —

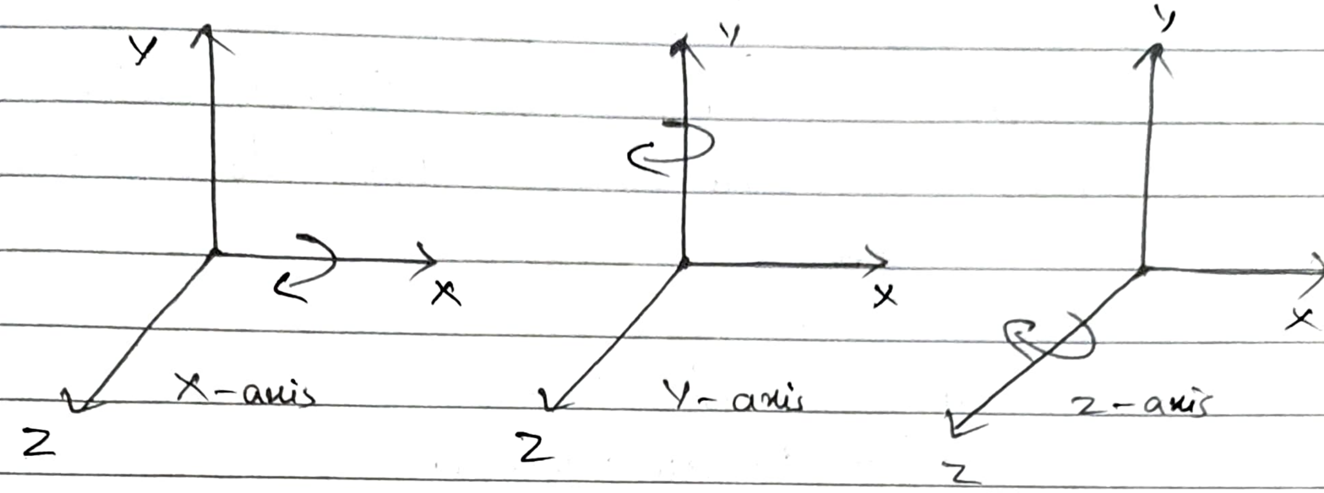


— y-axis —



— z-axis —

Clockwise



$$\begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \text{Z-axis}$$

$x' = x\cos\theta - y\sin\theta$

$y' = x\sin\theta + y\cos\theta$

$\boxed{z' = z}$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta & 0 \\ 0 & \sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \text{X-axis}$$

$\boxed{x' = x}$

$y' = y\cos\theta - z\sin\theta$

$z' = y\sin\theta + z\cos\theta$

$$\begin{bmatrix} \cos\theta & 0 & \sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta & 0 & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \text{Y-axis.}$$

$x' = z\sin\theta + x\cos\theta$

$\boxed{y' = y}$

$z' = z'\cos\theta - x\sin\theta$

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~~[illegible]~~

Ex:- $\rightarrow A(1,2,3)$ Angle of rotation $= 90^\circ$

Find new coordinates for x, y, Z rotation?

x-axis

$x' = 1$

$y' = 2\cos 90^\circ - 3\sin 90^\circ = -3$

$z' = 2\sin 90^\circ + 3\cos 90^\circ = 2.$

Y-axis

$x' = 3\sin 90^\circ + 1\cos 90^\circ = 3$

$y' = 2$

$z' = 3\cos 90^\circ - \sin 90^\circ = -1$

Z-axis

$x' = \cos 90^\circ - 2\sin 90^\circ = -2$

$y' = \sin 90^\circ + 2\cos 90^\circ = 1$

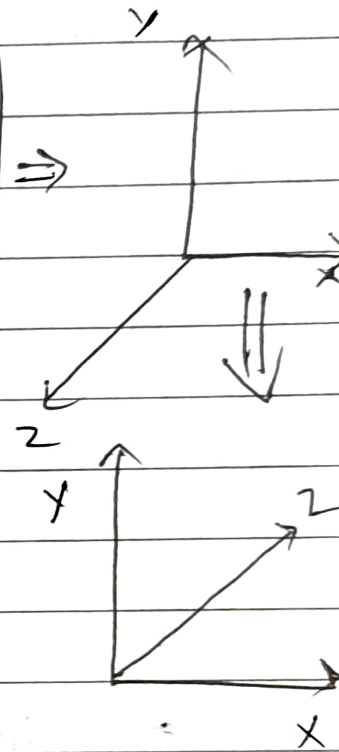
$z' = 3.$

$A_x(1,-3,2)$; $A_y = (3,2,-1)$; $A_z(-2,1,3)$

4) Reflection

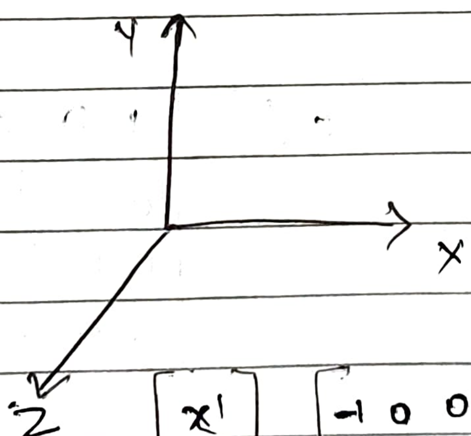
① W.R.T XY Plane (R_e^{XY})

$$P' = \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} \Rightarrow$$

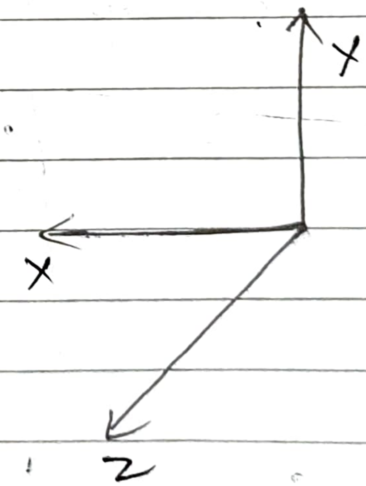


②

② W.R.T YZ Plane (R_e^{YZ})

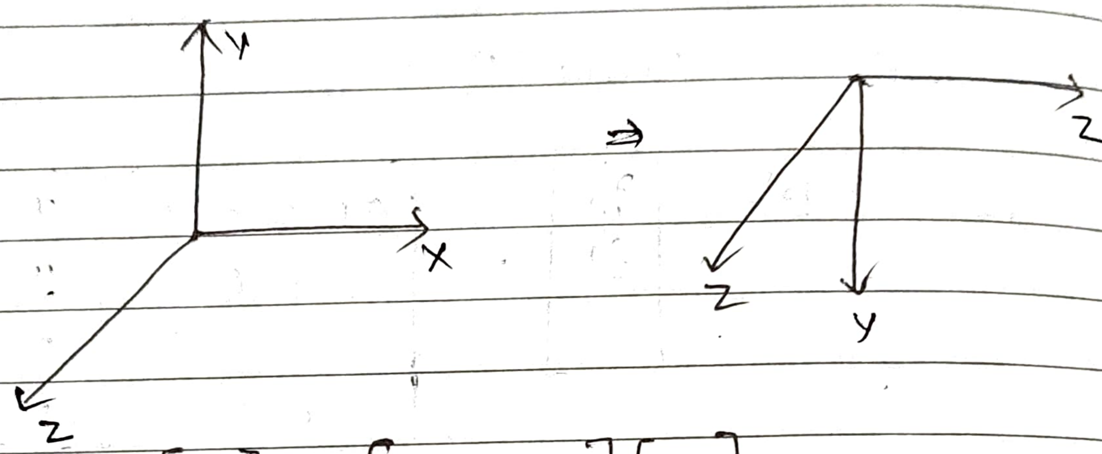


$\Rightarrow$



$$P' = \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

③ W.R.T XZ plane (R_e^{xz})



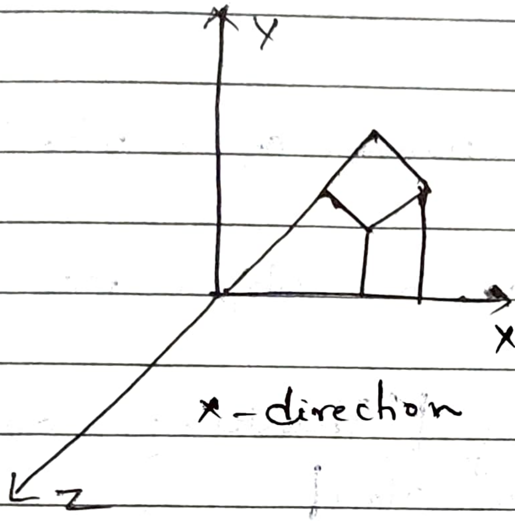
$$P = \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

5) Shearing (3D)

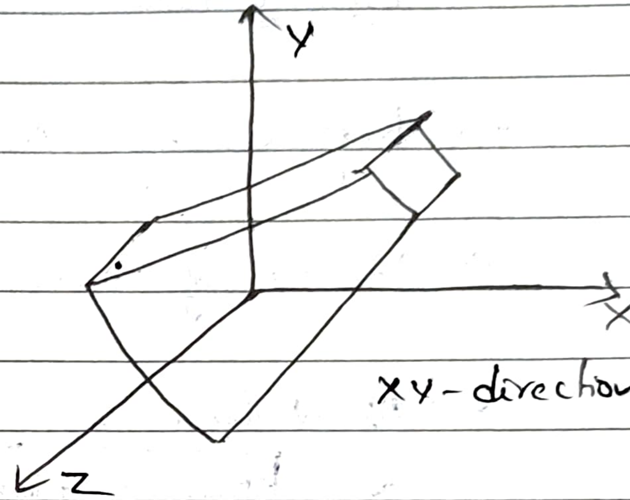
Matrix Representation

$$Sh^x = \begin{bmatrix} 1 & 0 & a & 0 \\ 0 & 1 & b & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad Sh^y = \begin{bmatrix} 1 & 0 & 0 & 0 \\ a & 1 & b & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

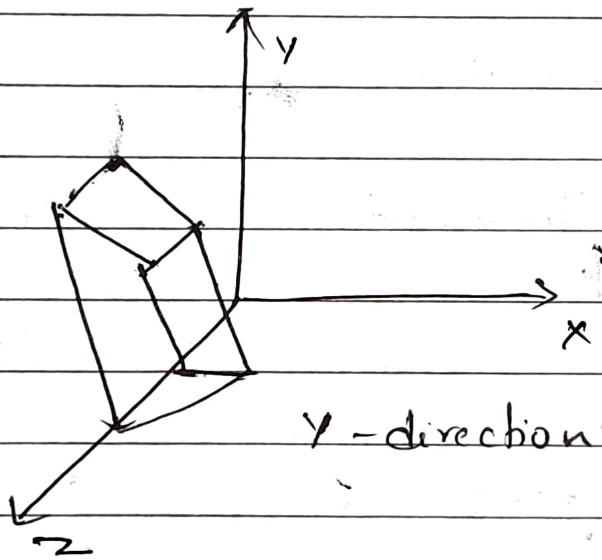
$$Sh^z = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ a & b & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$



x-direction



xy-direction



Y-direction

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PROJECTION

→ Representing (n) dimensional object into (n-1) dimension

→ Process of converting a 3D object into a 2D object

→ Also defined as "mapping" / "Transferring" an object in a $\boxed{\text{project plan / view plan}}$

Steps

Object Representation
↓
Modelling Transformation
↓
Lighting
↓
Viewing pipeline
↓
Scan conversion
↓
~~Viewing Transf~~

Viewing pipeline:

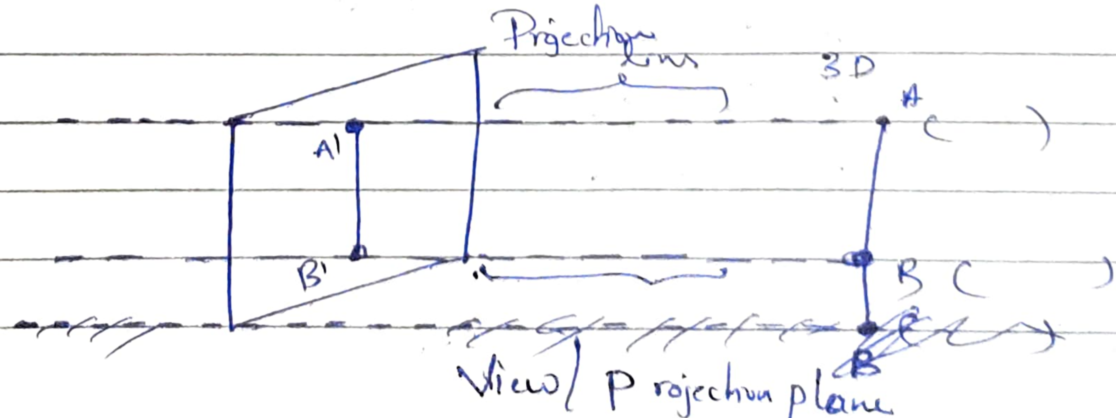
Viewing Transformation
↓
Clipping
↓
Hidden Surface Removal
↓
Projection Transformation
↓
Window to viewpoint Transformation

Local coordinate
↓
Local to world coordinate
↓
World coordinate
↓
World to view coordinate
↓
3D view to 2D view coordinate
↓
view to device coordinate
↓
device to screen coordinate

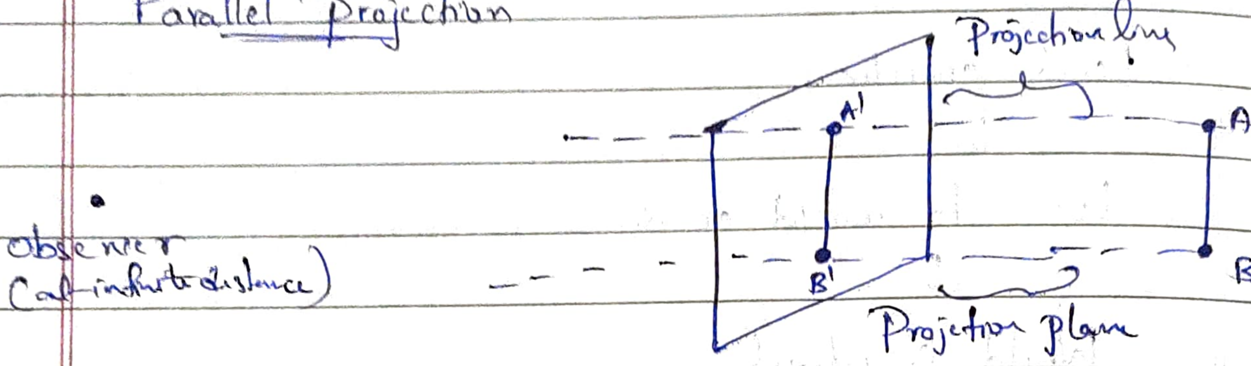
There are 2 types of projection.

↓ Parallel

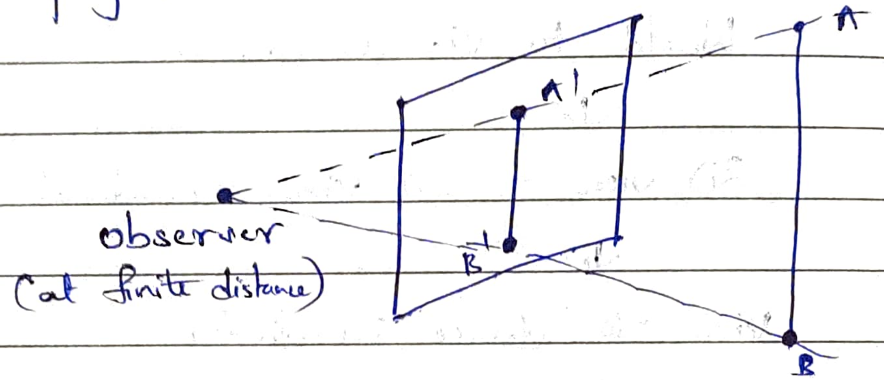
↓ Perspective



Parallel Projection



Perspective projection



Parallel projection divided into 2 types
1. orthographic
2. oblique —— Cavalier
   Cabinet

3 types of perspective Projection
1. One point
2. Two point
3. Three point

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Virtual Reality

Goals

→ Comfortable & Adequate for the task

→ Learn to "BUILD" a "good" VR Experience

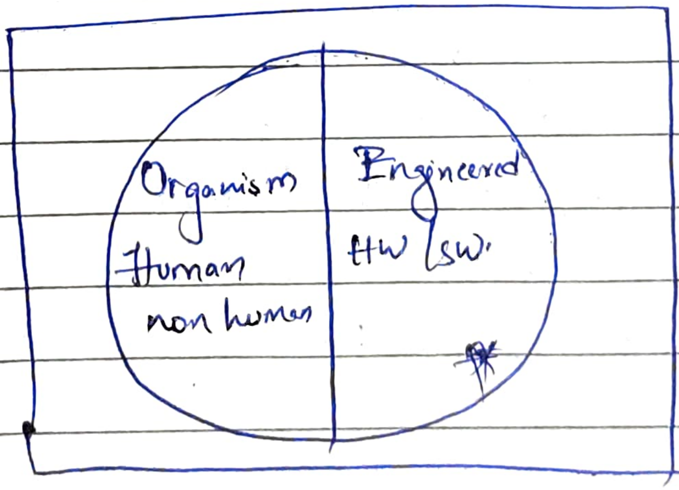
→ Understand "How" VR works (w.r.t hardware)

→ Learn to "criticize" VR

→ Learn "FUNDAMENTALS" to shape the "FUTURE" of VR.

Defination of VR:-

Inducing targeted behaviour in an "organism" by using "ARTIFICIAL" "SENSORY" while the organism has little or no "AWARENESS" of the interface.



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Key words:-

→ Immersion - Completely involved

→ Presence -

→ "Open loop" and "Closed loop"

→ Telepresence

→ Tele operation

→ AR - Augmented Reality

→ Mixed Reality

What does VR include?

- Watching a movie
- Video conferencing
- Talking on the phone
- Playing a video game
- Reading a Book