Homogeneous Coordinate System

To perform sequence of transformation such as translation followed by rotation and scaling, we need a sequence of process -

(i) Translate the coordinates

(ii) Rotate the translated coordinates & then

(iii) Scale the rotated coordinates to complete the composite transformation

To shorten this process, we have to use 3×3 transformation matrix instead of 2×2 transformation matrix

To convert a (2×2) matrix to (3×3) matrix we add an extra dummy coordinate (W).

In this way we can represent the points by 3 nos. instead of 2 nos, which is called homogeneous coordinate system

We use homogeneous coordinate b/c. addition creates problem if we want multiple transformations at the same time

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APPOINTMENTS / MEETINGS

i.e

$$[R] = [t_{xy}] + [R_\theta][S][R][\theta]$$

In this system, we can represent all the transformation eqns in a matrix multiplication.

Any (normal) cartesian point $(P(x,y))$ can be converted to homogeneous coordinates by $P'(x_h, y_h, h)$

① TRANSLATION

A translation moves an obj to a different position

$(x,y) \longrightarrow (x_h, y_h, h)$ h = homogeneous value

depending on h, x and y can change

new values

any non zero value

$x_h = x \cdot h$ —①

$y_h = y \cdot h$ —②

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APPOINTMENTS / MEETINGS

8 AM Back to 2D from ① & ②

9 $x = x_h / h$

10 $y = y_h / h$

11 To make calculate easy $h = 1$.

12 eg. $(2,3)$ suppose $h = 2$

1 PM ⇓

2 $(2 \times 2,\ 3 \times 2,\ 2)$

3 ⇓

4 $\begin{array}{ccc} x_h & y_h & h \end{array}$

5 $(4,\ 6,\ 2)$

6 $x' = x \cdot h \quad \left(\frac{4}{2}, \frac{6}{2}\right)$

$\Rightarrow (2,3)$

for 2-D conversion by h.

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Conversion to homogeneous coordinates (3D)

APPOINTMENTS / MEETINGS

8 AM (1) Translation

9 $x' = x + t_x$

10 $y' = y + t_y$.

11

$$\begin{bmatrix} t_x \\ t_y \end{bmatrix} + \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} x' \\ y' \end{bmatrix}$$

12

1 PM

$$\begin{bmatrix} x' \\ y' \\ h \end{bmatrix} = \begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & h \end{bmatrix} * \begin{bmatrix} x \\ y \\ h \end{bmatrix} = \begin{bmatrix} x+t_x \\ y+t_y \\ 1 \end{bmatrix}$$

2

3

4 $1 \times x + 0 \times y + t_x \times h$

5 $x + 0 + t_x h$

6 $0 \times x + 1 \times y + t_y \times h$

$0 + y + t_y h$

$0 + 0 + h \times h$

if $h = 1$

$$\begin{bmatrix} x+t_x \\ y+t_y \\ 1 \end{bmatrix}$$

So.

$$\begin{bmatrix} x' \\ y' \\ h \end{bmatrix} = \begin{bmatrix} x+t_x \\ y+t_y \\ 1 \end{bmatrix}$$

is the translation matrix after translation

8 AM 2. Rotation

9 $x' = x\cos\theta - y\sin\theta$

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

10 In matrix form

11

12 $$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

1 PM

In homogeneous coordinates (anticlockwise θ, h)

2

3 $$\begin{bmatrix} x' \\ y' \\ h \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & h \end{bmatrix} \begin{bmatrix} x \\ y \\ h \end{bmatrix}$$

4

5

6 ③ Scaling

$x' = x \cdot S_x$

$y' = y \cdot S_y$

i.e. $$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} S_x & 0 \\ 0 & S_y \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

Or

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

1

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APPOINTMENTS / MEETINGS

8 AM 5. Shearing

9 X shear

$$\begin{bmatrix} x' \\ y' \\ h \end{bmatrix} = \begin{bmatrix} 1 & S_{hx} & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

10

11

12

1 PM Y shear

$$\begin{bmatrix} x' \\ y' \\ h \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ S_{hy} & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

2

3

4

5 ⑥ Reflection

6 Reflection around x axes

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

Reflection around origin

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

Scanned with CamScanner

8 AM Reflection around y axis

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

Reflection about $y = x$

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

Numericals

1. Translate a polygon with coordinates $A(2,5)$, $B(7,10)$ and $C(10,2)$ by 3 units in X direction and 4 units in Y direction.

$A' = A + T$

$$= \begin{bmatrix} 2 \\ 5 \end{bmatrix} + \begin{bmatrix} 3 \\ 4 \end{bmatrix} = \begin{bmatrix} 5 \\ 9 \end{bmatrix}$$

$B' = B + T$

$$= \begin{bmatrix} 7 \\ 10 \end{bmatrix} + \begin{bmatrix} 3 \\ 4 \end{bmatrix} = \begin{bmatrix} 10 \\ 14 \end{bmatrix}$$

$C' = C + T$

$$= \begin{bmatrix} 10 \\ 2 \end{bmatrix} + \begin{bmatrix} 3 \\ 4 \end{bmatrix} = \begin{bmatrix} 13 \\ 7 \end{bmatrix}$$

2. A point (4,3) is rotated counterclockwise by angle of 45°. Find the rotation matrix and the resultant point.

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

$$= \begin{bmatrix} \cos 45 & \sin 45 \\ -\sin 45 & \cos 45 \end{bmatrix}$$

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

$$P' = \begin{bmatrix} 4 \cdot 3 \end{bmatrix} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} \\ -1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix}$$

$$= \begin{bmatrix} 4/\sqrt{2} - 3/\sqrt{2} & 4\sqrt{2} + 3\sqrt{2} \end{bmatrix}$$

$$= \begin{bmatrix} 1/\sqrt{2} & 7/\sqrt{2} \end{bmatrix}$$

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APPOINTMENTS / MEETINGS

Composite transformation

A ~~computer~~ number of transformations or sequence of transformations can be combined into single one called as composition.

The resulting matrix is called as composite matrix. The process of combining is called as concatenation.

A composite transformation is when two or more transformations are performed on a figure to produce a new figure.

1. Derive composite matrix

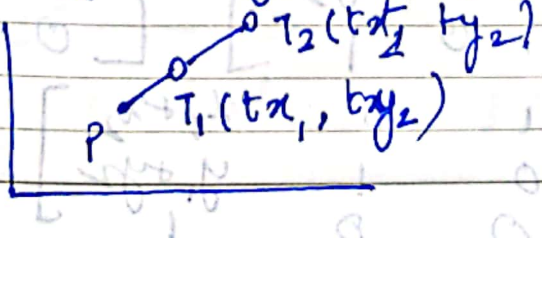
A) Translation –

We will apply translation two times on an object (T_1 and T_2)

Suppose $P(x, y)$ is the object

after T_1 and T_2 is applied the object will be $P'(x', y')$

So $P' = T_2(x_2\ y_2)\left[T_1(x_1, y_1) \cdot P\right]$



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As we know matrix multiplication is not cumulative but it is associative

$A.B \neq B.A$ where A & B are matrices

but $(A.B).C = A.(B.C)$

So similarly

$$P' = T_2(x_2, y_2) \cdot [T_1(x_1, y_1) \cdot P]$$

can also be written as

$$\Rightarrow [T_2(x_2, y_2)\, T_1(x_1, y_1)] \cdot P$$

This is called <u>composite Translation matrix</u>.

now ~~lets~~ lets see & solve

$$T_2(x_2, y_2) \cdot T_1(x_1, y_1)$$

04 SUNDAY

$$\Rightarrow \begin{bmatrix} 1 & 0 & x_2 \\ 0 & 1 & y_2 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & x_1 \\ 0 & 1 & y_1 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} 1 & 0 & x_1+x_2 \\ 0 & 1 & y_1+y_2 \\ 0 & 0 & 1 \end{bmatrix}$$

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This composite translation matrix is additive in nature so it can also be written as

$$P' = T(x_1 + x_2, y_1 + y_2) \cdot P$$

② Rotation

We will apply Rotation two times on an object ~~(R(θ₂) & R(θ₁))~~ ~~R(θ₂) &~~ θ_2 & θ_1

Suppose the point is $P(x, y)$ (object)

after θ_1 and θ_2 is applied the the object will be P'.

so $P' = R(\theta_2)\,[R(\theta_1) \cdot P]$

it can also be written as

$$P' = [\underbrace{R(\theta_2) \cdot R(\theta_1)}] \, P.$$

This is called composite rotation matrix.

$$R(\theta) = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$ Basic rotation matrix

~~for~~

$R(\theta_2) \cdot R(\theta_1)$

$$\Rightarrow \begin{bmatrix} \cos\theta_2 & -\sin\theta_2 & 0 \\ \sin\theta_2 & \cos\theta_2 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\theta_1 & -\sin\theta_1 & 0 \\ \sin\theta_1 & \cos\theta_1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} \cos\theta_2\cos\theta_1 - \sin\theta_2\sin\theta_1 & -\sin\theta_1\cos\theta_2 - \sin\theta_2\cos\theta_1 & 0 \\ \sin\theta_2\cos\theta_1 + \cos\theta_2\sin\theta_1 & -\sin\theta_1\sin\theta_2 + \cos\theta_2\cos\theta_1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} \cos(\theta_1+\theta_2) & -\sin(\theta_1+\theta_2) & 0 \\ \sin(\theta_1+\theta_2) & \cos(\theta_1+\theta_2) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$ resulting transformation matrix.

composite rotation matrix is additive in nature

So $P' = R(\theta_2) \cdot R(\theta_1) \cdot P$

$\Rightarrow \underline{R(\theta_1 + \theta_2) \cdot P}$

③ Scaling

We will apply scaling two times on an object P.

after S_x and S_y is applied the new object will be P'

So $P' = S_2 (S_{x_2}\ S_{y_2}) [S_1 (S_{x_1}, S_{y_1}) \cdot P]$

$$= \left[\underbrace{S_2 (S_{x_2}\ S_{y_2})\ S_1 (S_x\ S_y)} \right] \cdot P$$

This is composite scaling matrix

$$= \begin{bmatrix} S_{x_2} & 0 & 0 \\ 0 & S_{y_2} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} S_{x_1} & 0 & 0 \\ 0 & S_{y_1} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} S_{x_2} * S_{x_1} & 0 & 0 \\ 0 & S_{y_2} * S_{y_1} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$P' = S(s_{x_1} \cdot s_{x_2}, s_{y_1} \cdot s_{y_2}) \cdot P$$

composite scaling matrix

Exercise.

Now suppose we want to perform rotation about an arbitrary point, then we can perform it by a sequence of transformations

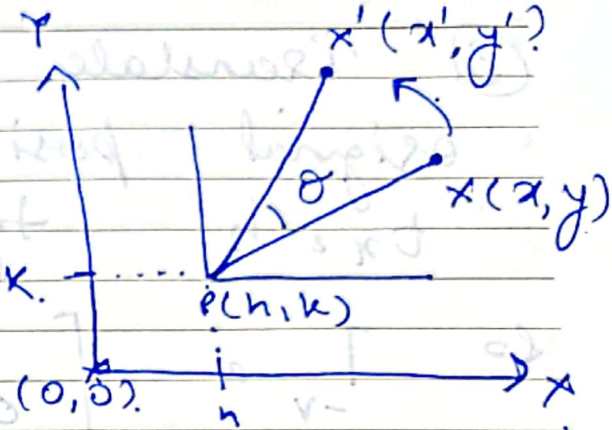
1. Translation
2. Rotation
3. Reverse Translation

The ordering sequence of these number of transformations must not be changed.

Steps :

1. Translate fixed point to origin.

$$T_v = \begin{bmatrix} 1 & 0 & -h \\ 0 & 1 & -k \\ 0 & 0 & 1 \end{bmatrix}$$



→ translation matrix.

we have to decrease h points along x axis and k points along y axis.

so $t_x = -h$ and $t_y = -k$ substituting the value in translation matrix.

2. Now Perform Rotation (R_θ)

We are rotating anticlockwise through θ so θ will be positive. so

$$R_\theta = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$ - Rotation matrix

APPOINTMENTS/MEETINGS

(3) Translate the point back to original position.

$t_x = h \quad t_y = k.$

$$T_{-v} = \begin{bmatrix} 1 & 0 & h \\ 0 & 1 & k \\ 0 & 0 & 1 \end{bmatrix}$$

Together the three steps we have to make a Transformation matrix.

$$[T_{-v}]\,[R_\theta]\,[T_v]$$

The operation precedence is from right to left

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New object Transformation matrix

$\Rightarrow$ T . old object matrix

$\Rightarrow$ Answer.

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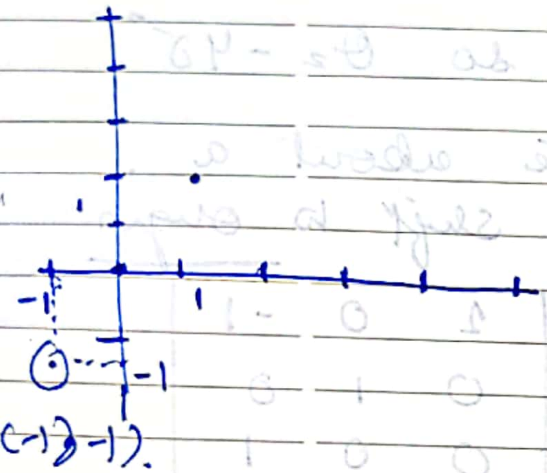
APPOINTMENTS / MEETINGS

Question 1

Perform 45° rotation of a Δ A(0,0), B(1,1) C(5,2) about the point (-1,-1)



1. We have to find rotation about (-1, -1)
2. first we find point around origin
3. Perform Rotation
4. shift the point again to original position

Transformation matrix

$$T = \underbrace{\begin{bmatrix} 1 & 0 & -1 \\ 0 & 1 & -1 \\ 0 & 0 & 1 \end{bmatrix}}_{T_{-v}} \underbrace{\begin{bmatrix} \cos 45 & -\sin 45 & 0 \\ \sin 45 & \cos 45 & 0 \\ 0 & 0 & 1 \end{bmatrix}}_{Ro} \underbrace{\begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix}}_{T_v}$$

~~New object ma~~

I3z

$$\text{Object matrix} = \cancel{\begin{bmatrix} 0 & 0 \\ 1 & 1 \\ 5 & 2 \end{bmatrix}}$$ This is

$$\text{Object matrix} = \begin{bmatrix} 0 & 1 & 5 \\ 0 & 1 & 2 \end{bmatrix}$$

when converting to homogeneous coordinates $\begin{bmatrix} 0 & 1 & 5 \\ 0 & 1 & 2 \\ 1 & 1 & 1 \end{bmatrix}$

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APPOINTMENTS / MEETINGS

Q. Consider a square $A(1,0)$, $B(0,0)$, $C(0,1)$, $D(1,1)$. Rotate pt by 45° clockwise about the point $A(1,0)$.

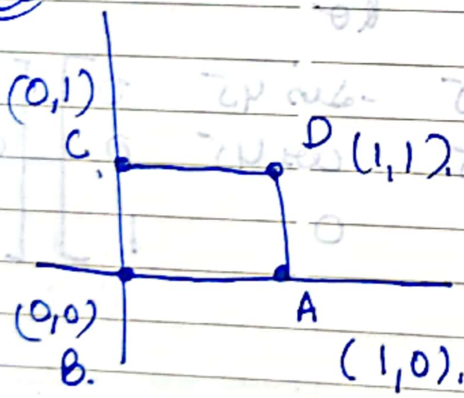
Soln. clockwise rotation so $\theta = -45^\circ$

① We have to rotate about a fixed point. We have to shift to origin

so

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

② Rotation clockwise



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

$$= \begin{bmatrix} \cos(-45) & -\sin(45) & 0 \\ \sin(-45) & \cos(-45) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

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

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sin	All
tan	cos

APPOINTMENTS / MEETINGS

8 AM

9

③. Again translation

10

$t_x = 1$

11

$t_y = 0.$

12

$$T_V = \begin{array}{cccc} A & B & C & D \\ \end{array}$$
$$T_V = \begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

1 PM

2

new object matrix After transformation

3

4

$$\left[T_{-V}\, R_\theta\, T_V \right] . X \text{ (object matrix)}$$

5

6

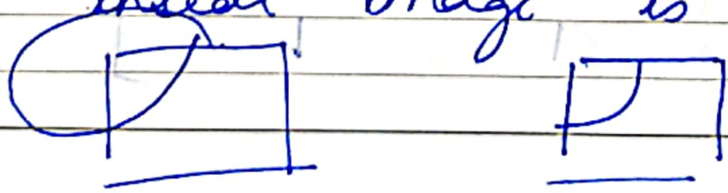
2) $$\begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 0 \\ -1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -1 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

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

	P (old)	P' (new)
A	1, 0	1, 0
B	0, 0	$1-\sqrt{2}$, $1/\sqrt{2}$
C	0 1	1, $\sqrt{2}$
D	1, 1	$1+1/\sqrt{2}$, $1/\sqrt{2}$

Ans

Clipping –
The technique of hiding that part of the drawing one is not interested in is called clipping. We can clip a point line, polygon or a curve.
The portion left outside the region of the window in graphics is called the clipped part and the process of displaying the inside image is called clipping.



Appointments / Meetings

Window and Viewport

2D Viewing

A graphics package allows a user to specify which part of a defined picture is to be displayed and where that part is to be displayed on the display device using a concept called $\boxed{\text{clipping}}$.

* Any conventional cartesian coordinate system referred to as the <u>world coordinate</u> Reference frame can be used to define the picture

* for a 2D picture <u>a view</u> is selected by specifying a sub area of the total picture area

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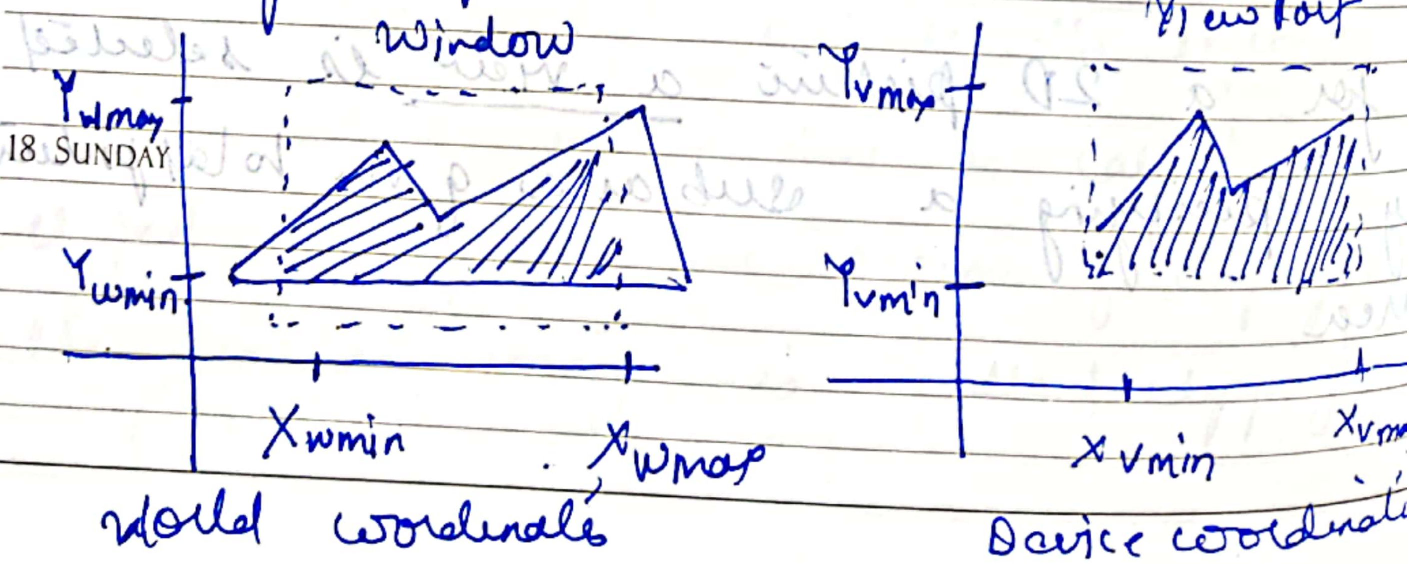
8 AM

* The picture parts within the selected areas are then mapped to specific areas of the device coordinates.

* Transformation from world → device coordinates involves translation, rotation, scaling operations as well as procedures for deleting those part of the picture that are outside the limits of a selected display area.

Viewing Pipeline



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APPOINTMENTS / MEETINGS

Window - દેખાતો ભાગ છે?

Viewport - display થતો ભાગ

1) A world coordinate area selected for display is called a window.

2) An area on a display ~~displa~~ device to which a window is mapped is called a viewport

Window defines - What is to be viewed

Viewport - where it is to be displayed

Mapping of a part of a world coordinate scene to device coordinates is referred to as Viewing Transformation

Sometimes, the 2D viewing transformation is simply referred to as the window to viewport transformation or the WINDOWING TRANSFORMATION

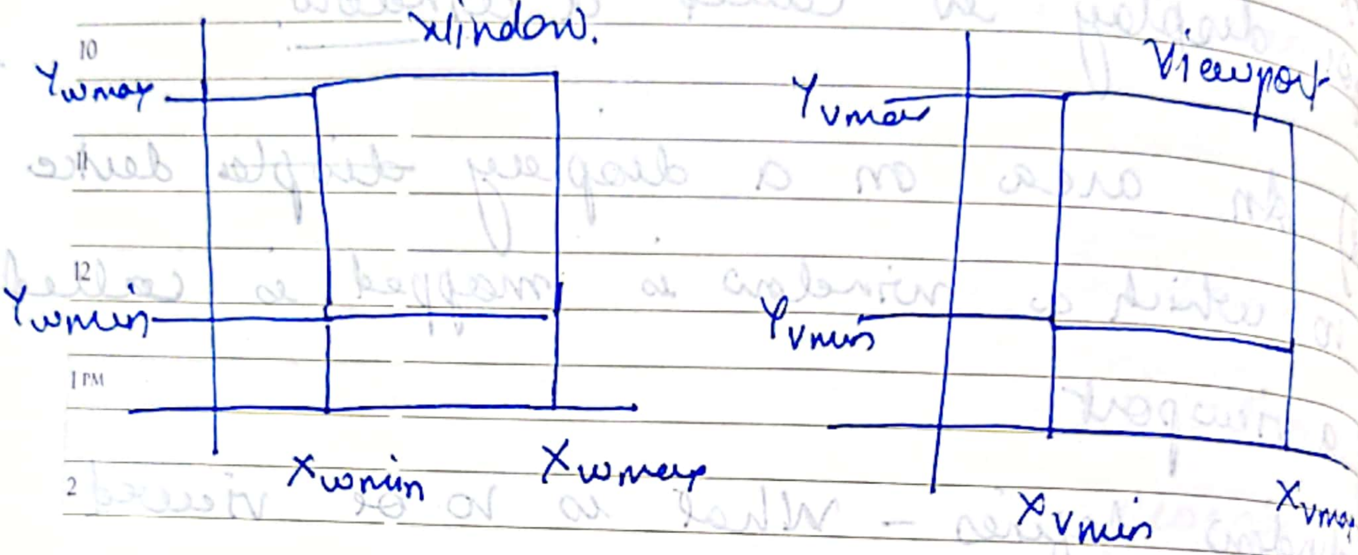
FEBRUARY WEEK 08

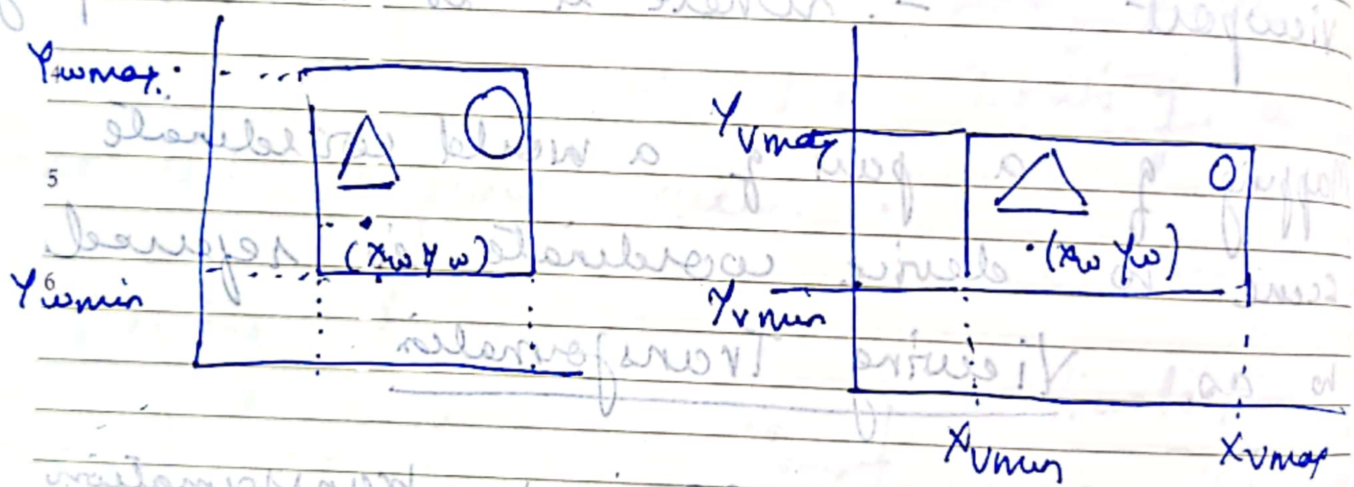
20 TUESDAY

051-314

APPOINTMENTS / MEETINGS

Window → Viewport transformation formula derivation





position (Relative position) will not change only size will change according to window & viewport.

Let us have $(x_w \; y_w)$ given we have to find $(x_v \; y_v)$

$$\frac{X_w - X_{wmin}}{X_{wmax} - x_{wmin}} = \frac{X_v - X_{vmin}}{X_{vmax} - X_{vmin}} \quad (1)$$

because relative posn is same.

$$\frac{Y_w - Y_{wmin}}{Y_{wmax} - Y_{wmin}} = \frac{Y_v - Y_{vmin}}{Y_{vmax} - Y_{vmin}}$$

from Eq 1.

$$X_v - X_{vmin} = \frac{(X_{vmax} - X_{vmin}) \cdot (X_w - X_{wmin})}{(X_{wmax} - X_{wmin})}$$

$$\cancel{X_v - X_{vmin} = \frac{(X_w - X_{wmin})}{X_{wmax} - x_{wmin}}}$$

$$x_v - x_{vmin} = x_w - x_{wmin} * \boxed{\left(\frac{x_{vmax} - x_{vmin}}{X_{wmax} - x_{wmin}}\right)}$$

scaling

APPOINTMENTS / MEETINGS

$$x_v - x_{vmin} = (x_w - x_{wmin}) S_x$$

$$x_v = x_{vmin} \pm (x_w - x_{wmin}) S_x \longrightarrow (1) A$$

$$\cancel{X_v = X_{vmin} \pm (x_w - X_{wmin}) S_x}$$

$$\cancel{X_v = X_{vmin} + (x_w - X_{wmin}) S_x}$$

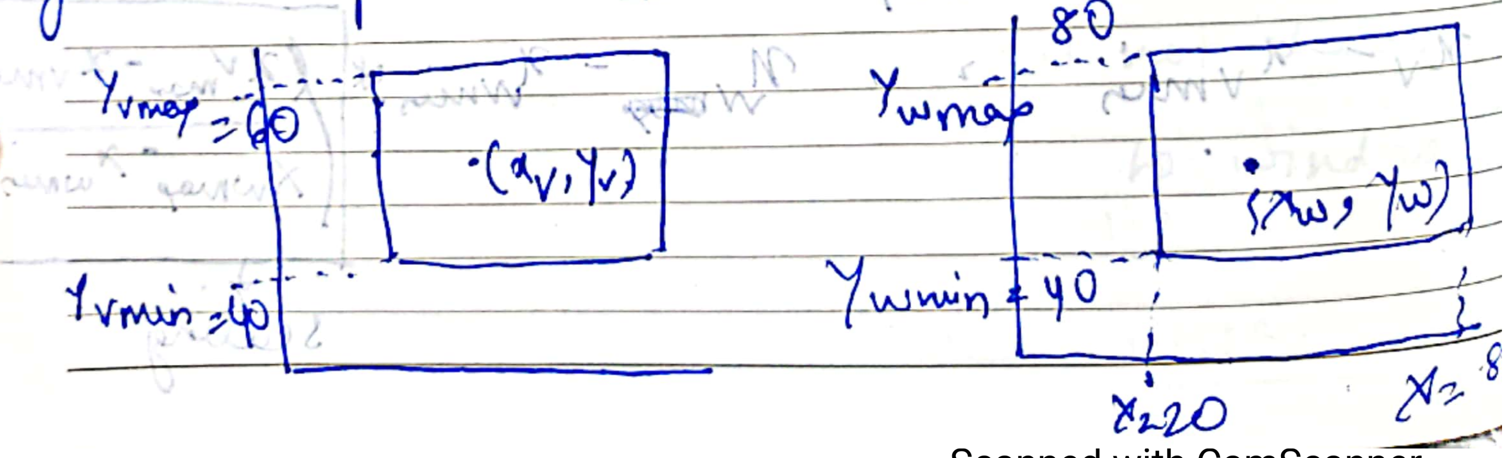
Similary

$$Y_v = Y_{vmin} + (y_w - Y_{wmin}) S_y$$

where S_x and S_y — scaling factor

$$x_v = x_{vmin} + (x_w - x_{wmin}) S_x$$

eg. Viewport window



2007 WEEK 08 FEBRUARY

FRIDAY 23

054-311

March '07						
M	T	W	T	F	S	S
•	•	•	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	•

April '07						
M	T	W	T	F	S	S
30	•	•	•	•	•	1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29

APPOINTMENTS / MEETINGS

8 AM

9

$$S_x = \frac{xV_{max} - x_{vmin}}{x_{wmax} - x_{wmin}}$$

10

11

$$\boxed{S_y = \frac{Y_{vmax} - Y_{vmin}}{Y_{wmax} - Y_{wmin}}}$$

12

1 PM

2

3

4

5

6

$X_{vmin} = 30.$

$X_{vmax} = 60$

$Y_{vmin} = 40$

$Y_{vmax} = 60$

$(X_v, Y_v) = ?$ find out.

$X_{wmin} = 20$

$X_{wmax} = 80$

$Y_{wmin} = 40$

$Y_{wmax} = 80$

$X_w, Y_w = (30, 60)$

$$\frac{X_v - X_{vmin}}{X_{vmax} - X_{vmin}} = \frac{X_w - x_{wmin}}{X_{wmax} - X_{wmin}}$$

$$\Rightarrow \frac{x_v - 30}{60 - 30} = \frac{30 - 20}{80 - 20}$$

Scanned with CamScanner

JANUARY '07

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	•	•	•	•

FEBRUARY '07

M	T	W	T	F	S	S
•	•	•	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	•	•	•	•

APPOINTMENTS / MEETINGS

8 AM

$X_v = 30 = \left(\frac{10}{60}\right) 30$

9

10

$\boxed{x_v = 35}$

11

12

$$\frac{Y_v - Y_{v\,min}}{Y_{v\,max} - Y_{v\,min}} = \frac{Y_w - Y_{w\,min}}{Y_{w\,max} - Y_{w\,min}}$$

1 PM

2

$$\Rightarrow \frac{Y_v - 40}{60 - 40} = \frac{60 - 40}{80 - 40}$$

3

4

$$Y_v - 40 = \frac{20 \times 20}{40}$$

5

6

$$\Rightarrow \boxed{Y_v = 50}$$

Ans

25 SUNDAY