Computer Graphics and Multimedia Systems SCS1302

Unit 2

Syllabus

SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY FACULTY OF COMPUTING

SCS1302	COMPUTER GRAPHICS AND MULTIMEDIA SYSTEMS	L	T	P	Credits	Total Marks
		3	0	0	3	100

COURSE OBJECTIVES

- To gain knowledge to develop, design and implement two and three dimensional graphical structures.
- To enable students to acquire knowledge of Multimedia compression and animations.
- To learn creation, Management and Transmission of Multimedia objects.

UNIT 1 BASICS OF COMPUTER GRAPHICS 9 Hrs.

Output Primitives: Survey of computer graphics - Overview of graphics systems - Line drawing algorithm - Circle drawing algorithm - Curve drawing algorithm - Attributes of output primitives - Anti-aliasing.

UNIT 2 2D TRANSFORMATIONS AND VIEWING 8 Hrs.

Basic two dimensional transformations - Other transformations - 2D and 3D viewing - Line clipping - Polygon clipping - Logical classification - Input functions - Interactive picture construction techniques.

UNIT 3 3D CONCEPTS AND CURVES 10 Hrs.

3D object representation methods - B-REP , sweep representations, Three dimensional transformations. Curve generation - cubic splines, Beziers, blending of curves- other interpolation techniques, Displaying Curves and Surfaces, Shape description requirement, parametric function. Three dimensional concepts – Introduction - Fractals and self similarity- Successive refinement of curves, Koch curve and peano curves.

Syllabus

UNIT 4 METHODS AND MODELS **8 Hrs.**

Visible surface detection methods - Illumination models - Halftone patterns - Dithering techniques - Polygon rendering methods - Ray tracing methods - Color models and color applications.

UNIT 5 MULTIMEDIA BASICS AND TOOLS **10 Hrs.**

Introduction to multimedia - Compression & Decompression - Data & File Format standards - Digital voice and audio - Video image and animation. Introduction to Photoshop - Workplace - Tools - Navigating window - Importing and exporting images - Operations on Images - resize, crop, and rotate - Introduction to Flash - Elements of flash document - Drawing tools - Flash animations - Importing and exporting - Adding sounds - Publishing flash movies - Basic action scripts - GoTo, Play, Stop, Tell Target

Max. 45 Hours

TEXT / REFERENCE BOOKS

1. Donald Hearn, Pauline Baker M., "Computer Graphics", 2nd Edition, Prentice Hall, 1994.
2. Tay Vaughan ,"Multimedia", 5th Edition, Tata McGraw Hill, 2001.
3 Ze-Nian Li, Mark S. Drew ,"Fundamentals of Multimedia", Prentice Hall of India, 2004.
4 D. McClelland, L.U.Fuller ,"Photoshop CS2 Bible", Wiley Publishing, 2005.
5 James D. Foley, Andries van Dam, Steven K Feiner, John F. Hughes, "Computer Graphics Principles and Practice, 2nd
6 Edition in C, Audison Wesley, ISBN - 981 -235-974-5
7 William M. Newman, Roberet F. Sproull, " Principles of Interactive Computer Graphics", Second Edition, Tata McGraw-Hill Edition.

Course Objective(CO)

CO1: Construct lines and circles for the given input.

CO2: Apply 2D transformation techniques to transform the shapes to fit them as per the picture definition.

CO3: Construct splines, curves and perform 3D transformations

CO4: Apply colour and transformation techniques for various applications.

CO5: Analyse the fundamentals of animation, virtual reality, and underlying technologies.

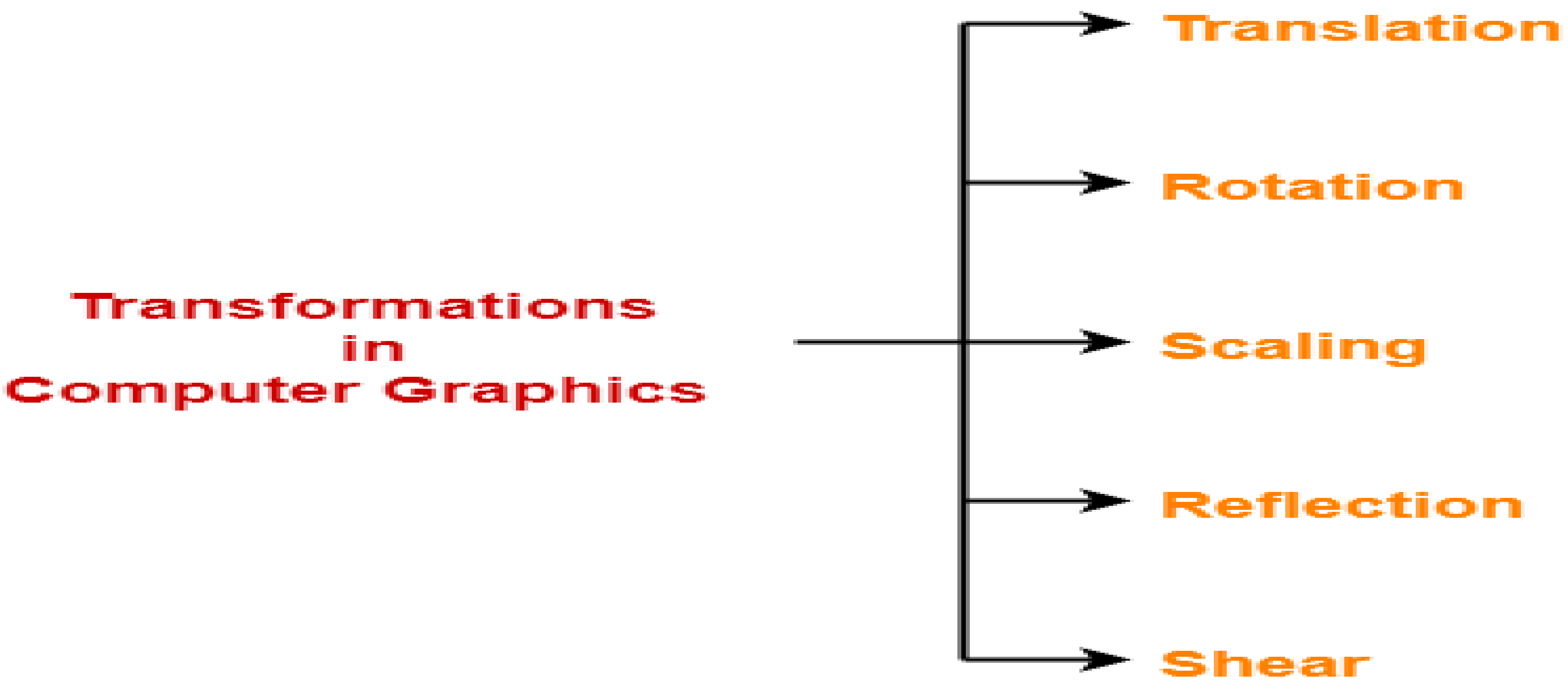
CO6: Develop photo shop applications

2D Transformation in Computer Graphics

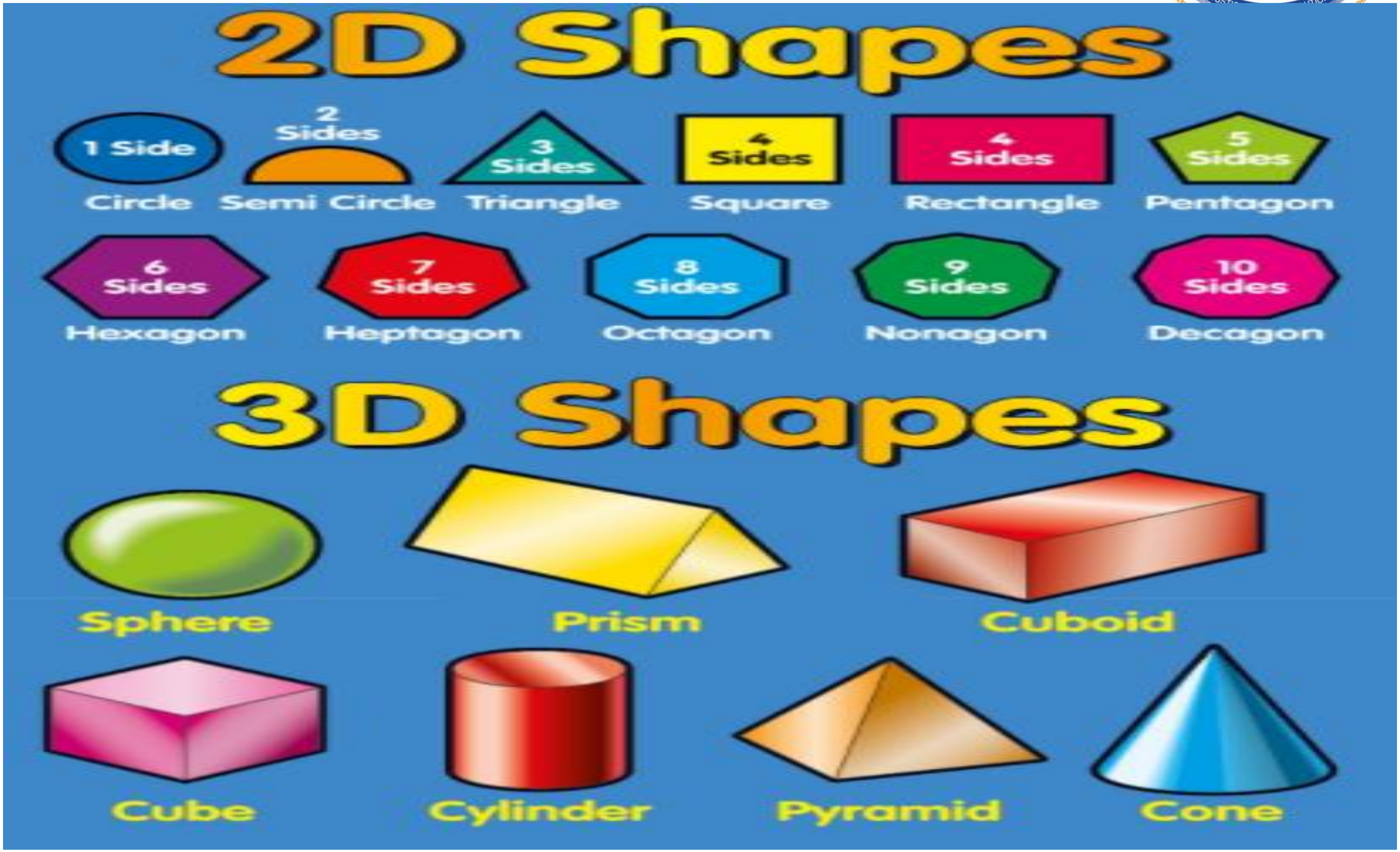
- In Computer graphics, Transformation is a process of modifying and re-positioning the existing graphics.
- 2D Transformations take place in a two dimensional plane.
- Transformations are helpful in changing the position, size, orientation, shape etc of the object.

Transformation Techniques

- In computer graphics, various transformation techniques are:



2D vs 3D


2D Shapes
1 Side
Circle
2 Sides
Semi Circle
3 Sides
Triangle
4 Sides
Square
4 Sides
Rectangle
5 Sides
Pentagon
6 Sides
Hexagon
7 Sides
Heptagon
8 Sides
Octagon
9 Sides
Nonagon
10 Sides
Decagon
3D Shapes
Sphere
Prism
Cuboid
Cube
Cylinder
Pyramid
Cone

2D

3D

2-Dimensional Transformations

The Basic Transformations:

- **Translation**
- **Scaling**
- **Rotation**

Other Transformations:

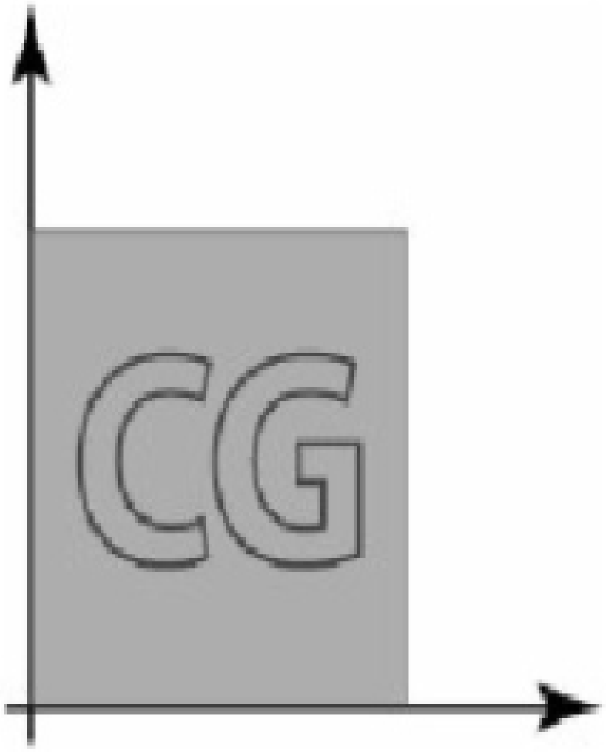
- **Reflection**
- **Shearing**

Translation

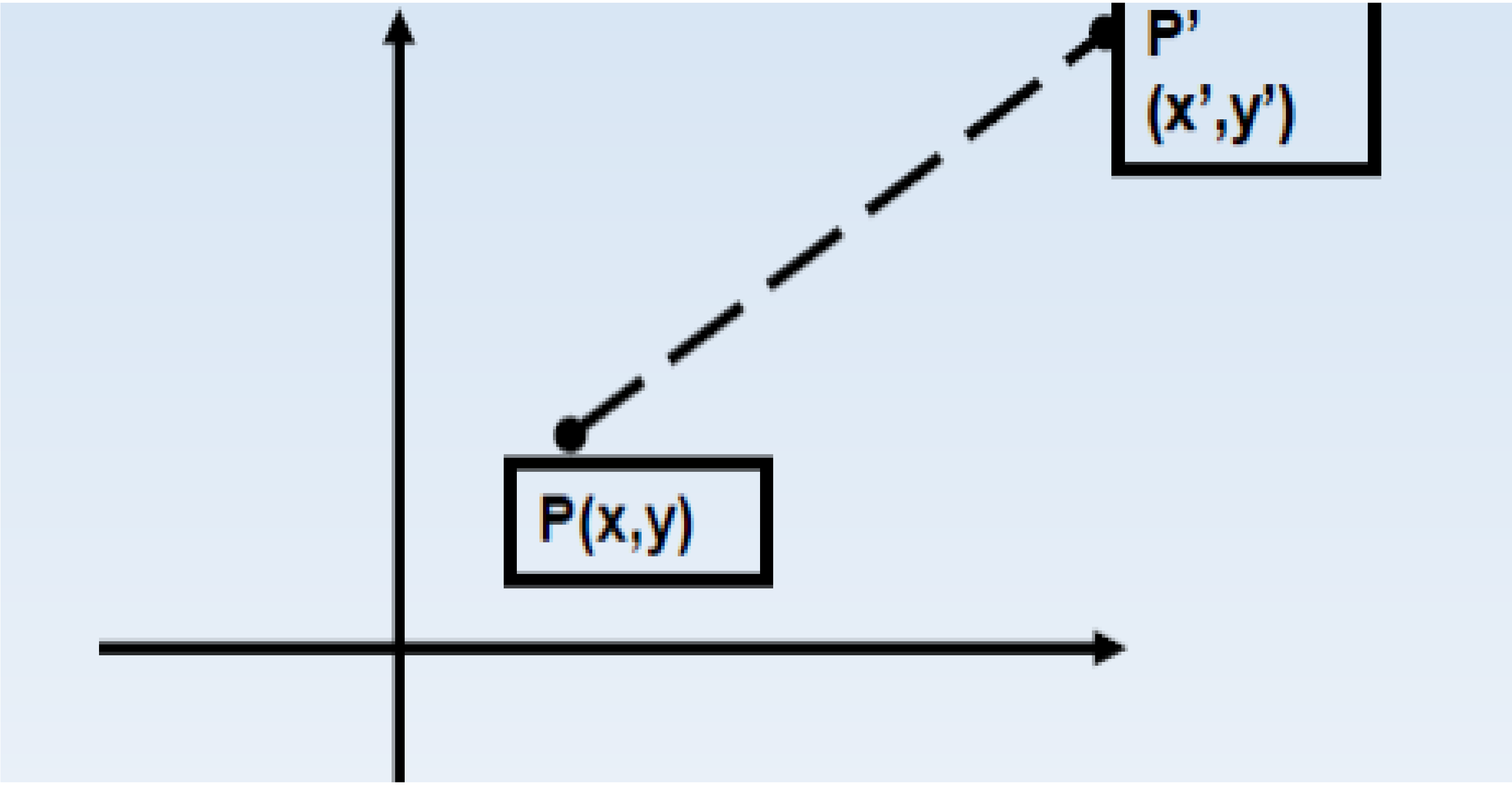
Displacement of an object in a given distance and direction from its original position.

- Rigid body transformation that moves object without deformation
- Initial Position point P (x, y)
- The new point P' (x', y')
- where x' = x + tx , y' = y + ty , tx and ty is the displacement in x and y respectively.

Translation



Translation



The translation pair (tx, ty) is called a translation vector or shift vector

Example: Translation

- Assume you are given a point at (x,y)=(2,1). Where will the point be if you move it 3 units to the right and 1 unit up?

  Ans: (x',y') = (5,2).

- How was this obtained? - (x',y') = (x+3,y+1)

Translation

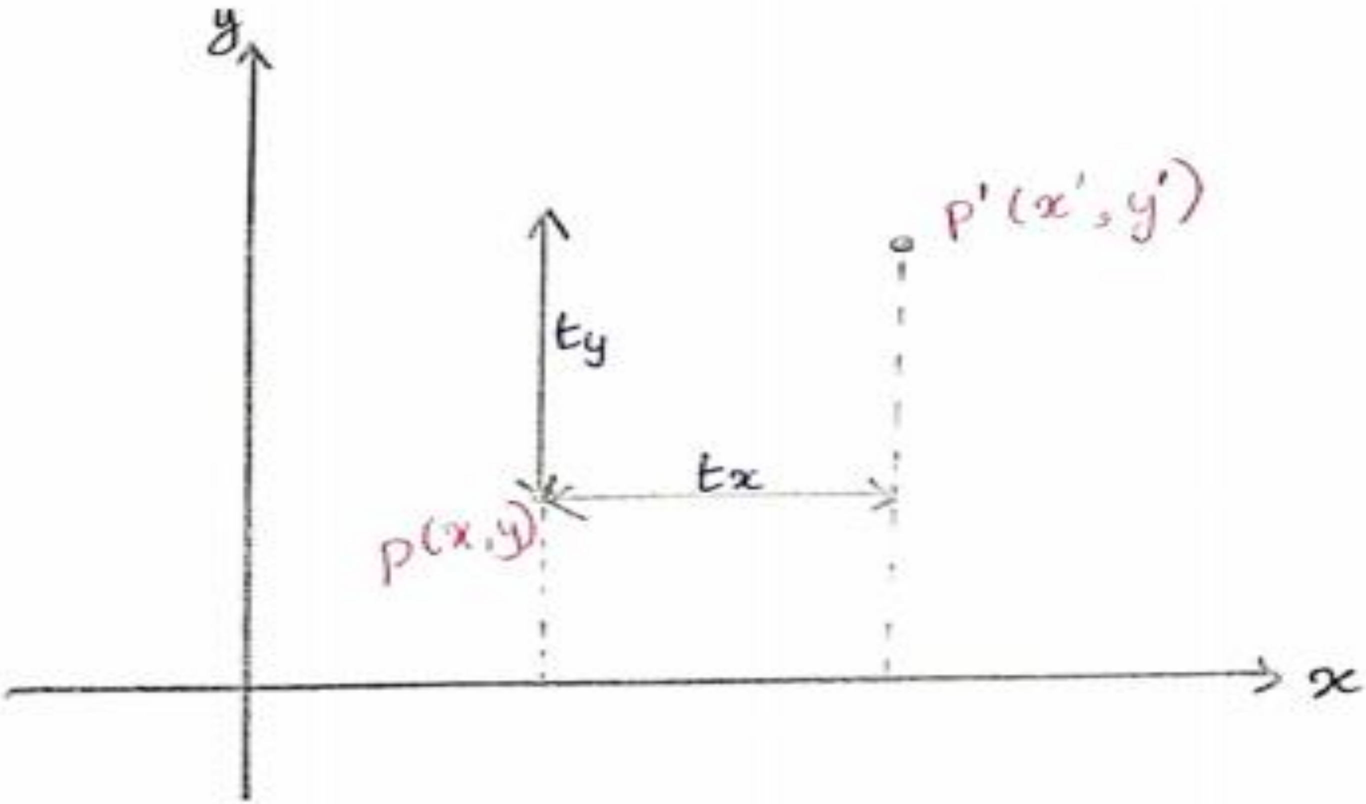
- A translation can also be represented by a pair of numbers, t=(tx,ty) where tx is the change in the x-coordinate and ty is the change in y coordinate. To translate the point p by t, we simply add to obtain the new (translated) point.

Translation

$$p' = p + t$$

$$\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} tx \\ ty \end{bmatrix} = \begin{bmatrix} x + tx \\ y + ty \end{bmatrix}$$

1) Translation :-



$$x' = x + t_x$$

$$y' = y + t_y$$

Translation

Matrix form,

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

$$P' = P + T$$

Example: Translation

Example :-

Polygon

$A \rightarrow (2, 5)$ $\quad t_x = 2$

$B \rightarrow (7, 10)$ $\quad t_y = 2$

$C \rightarrow (10, 2)$

$$[x' \quad y'] = [x \quad y] + [t_x \quad t_y]$$

A :-

$$x' = x + t_x = 2 + 2 = 4$$

$$y' = y + t_y = 5 + 2 = 7$$

$$\boxed{A' = (4, 7)}$$

Example: Translation

B :-

$$x' = x + t_x = 7 + 2 = 9$$

$$y' = y + t_y = 10 + 2 = 12$$

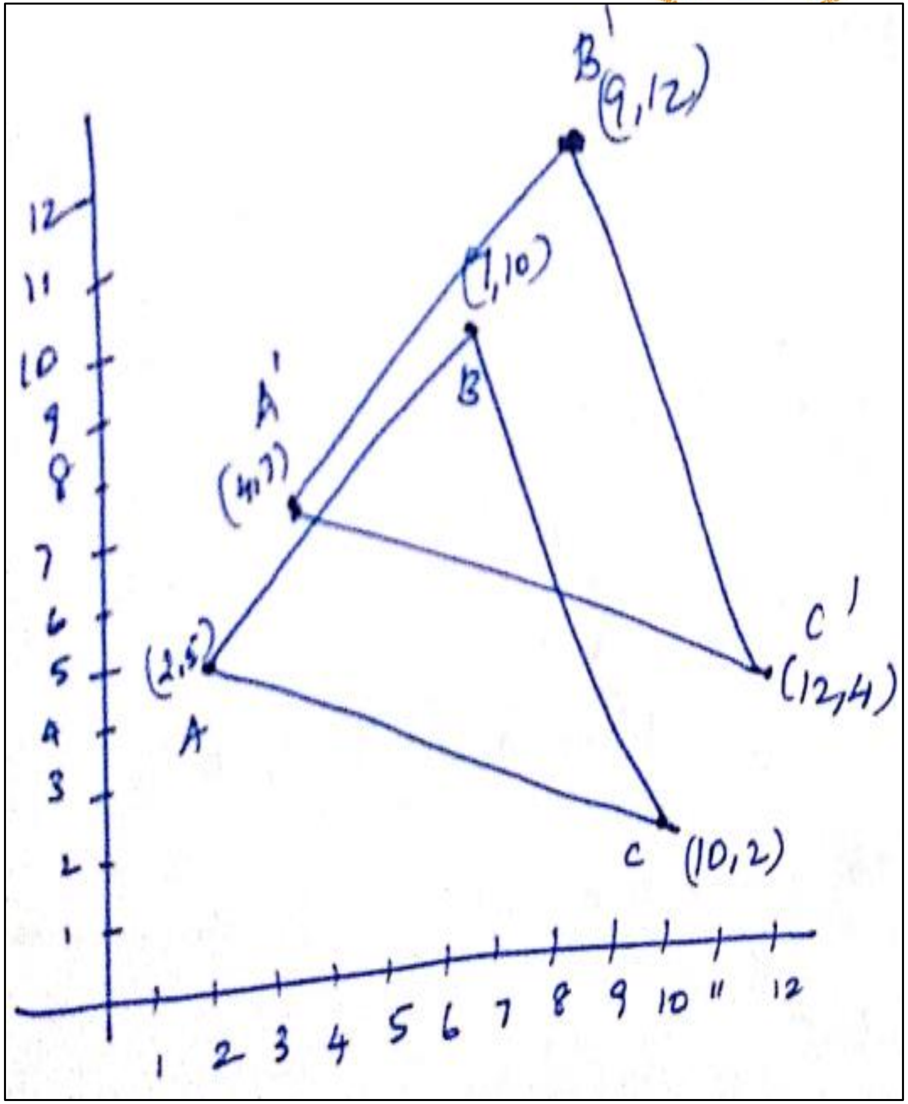
$$\boxed{B' = (9, 12)}$$

C :-

$$x' = x + t_x = 10 + 2 = 12$$

$$y' = y + t_y = 2 + 2 = 4$$

$$\boxed{C' = (12, 4)}$$

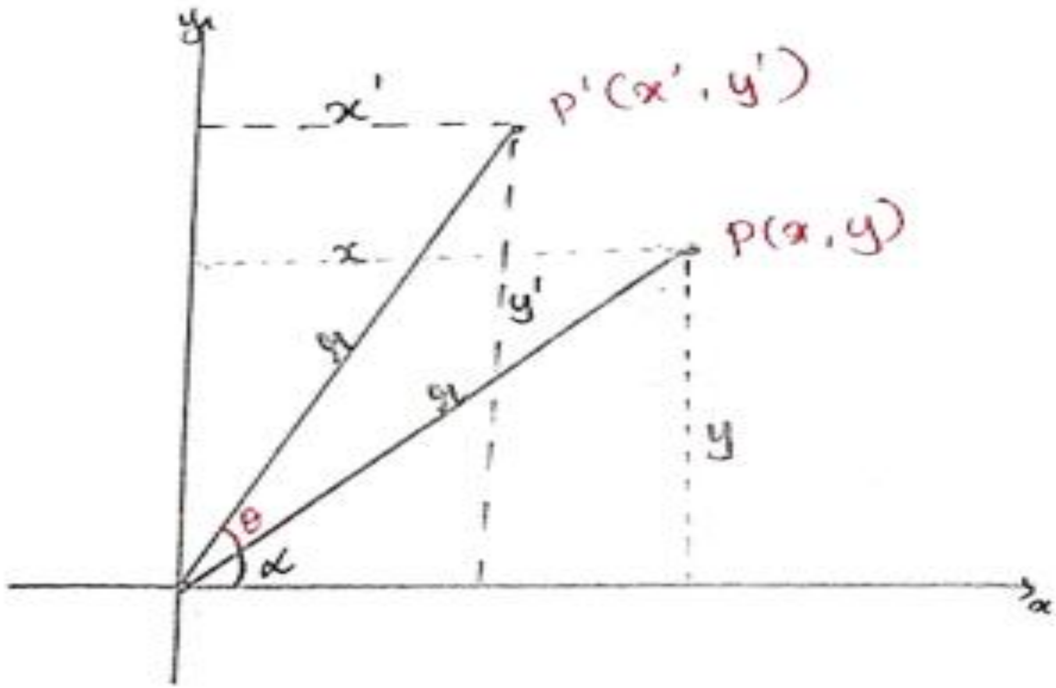


Rotation

- Rotation is applied to an object by repositioning it along a circular path in the xy plane.
- To generate a rotation, we specify
- Rotation angle θ
- Pivot point (xr , yr)
- Positive values of θ for counterclockwise rotation. Negative values of θ for clockwise rotation.

Rotation

2) Rotation :-



$$\cos\alpha = \frac{adj}{hyp} = \frac{x}{r} \Rightarrow \boxed{x = r\cos\alpha}$$

$$\sin\alpha = \frac{opp}{hyp} = \frac{y}{r} \Rightarrow \boxed{y = r\sin\alpha}$$

Rotation

x coordinate:-

$$\cos(\theta+\alpha) = \frac{x'}{r}$$

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

$[\cos(A+B) = \cos A\cos B - \sin A \sin B]$

$$x' = r(\cos\theta\cos\alpha - \sin\theta\sin\alpha)$$

$$x' = \underline{r}\cos\theta\,\underline{\cos\alpha} - \underline{r}\sin\theta\,\underline{\sin\alpha}$$

$$\Rightarrow \boxed{x' = x\cos\theta - y\sin\theta}$$

Rotation

y coordinate :-

$$\sin(\theta + \alpha) = \frac{y'}{r}$$

$\left[\sin(A+B) = \cos A \sin B + \cos B \sin A\right]$

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

$$= r(\cos\theta \sin\alpha + \cos\alpha \sin\theta)$$

$$= r\cos\theta \sin\alpha + r\cos\alpha \sin\theta)$$

$$\boxed{y' = y\cos\theta + x\sin\theta}$$

Rotation

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

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

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

$$\boxed{P' = P \cdot R}$$

Rotation

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

Trig Identity…

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

Substitute…

$x' = x \ \mathbf{cos}(\theta) - y \ \mathbf{sin}(\theta)$
$y' = x \ \mathbf{sin}(\theta) + y \ \mathbf{cos}(\theta)$

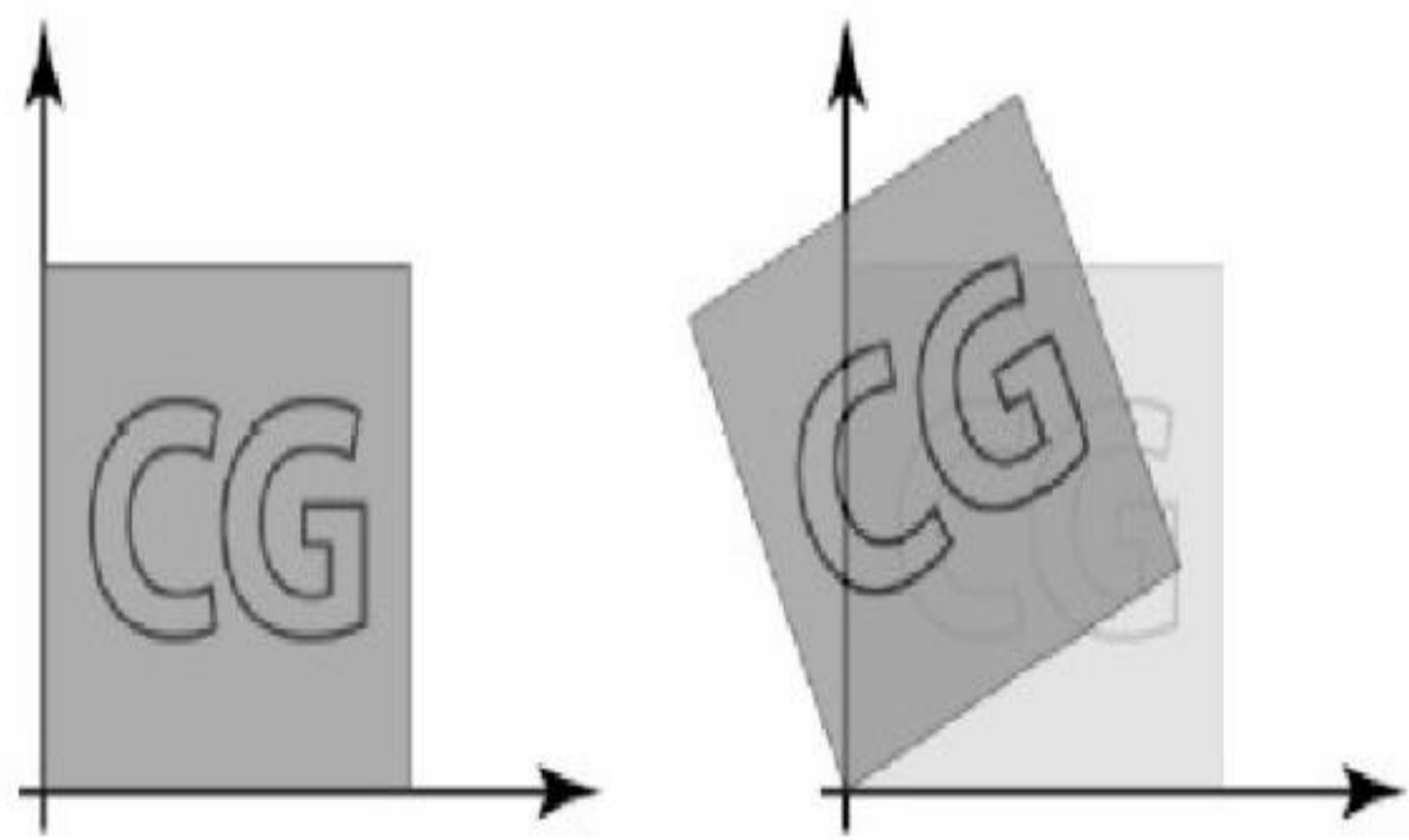
Rotation

Matrix Representation of

P'=R.P

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

Rotation



Example: Rotation

Eg: $P(4,3)$ $\theta = 90^\circ$

x y

$\sin 90^\circ = 1$

$\cos 90^\circ = 0$

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

$= 4(0) - 3(1)$

$x' = -3$

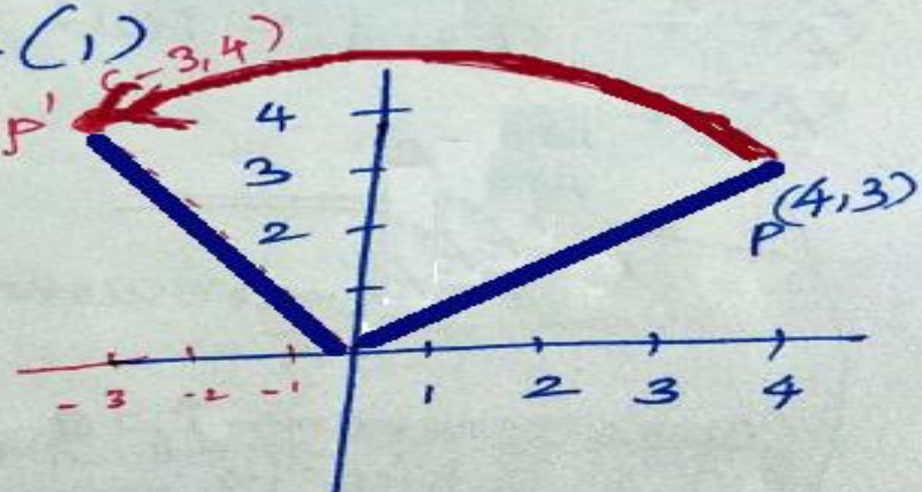
$y' = y\cos\theta + x\sin\theta$

$= 3(0) + 4(1)$

$y' = 4$

$(x, y) = (4, 3)$

$(x', y') = (-3, 4)$



Scaling

- Scaling alters the size of an object.
- Operation can be carried out by multiplying each of its components by a scalar
- Uniform scaling means this scalar is the same for all components
- Non-uniform scaling: different scalars per component
- $x' = x * sx$
- $y' = y * sy$

Scaling

3) Scaling :—

$P = (x, y)$

S_x & S_y

$P' = (x', y')$

$\boxed{x' = x . S_x}$

$\boxed{y' = y . S_y}$

$S_x > 1$ & $S_y > 1$ $\Rightarrow$ Increasing

$S_x < 1$ & $S_y < 1$ $\Rightarrow$ Decreasing

$S_x = S_y$ $\rightarrow$ Uniform Scaling

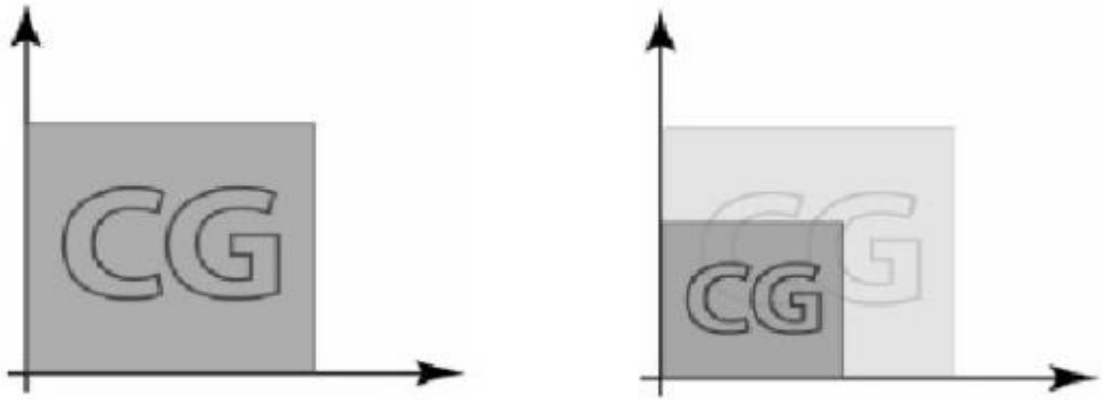
$S_x \neq S_y$ $\Rightarrow$ Non Uniform Scaling

Scaling

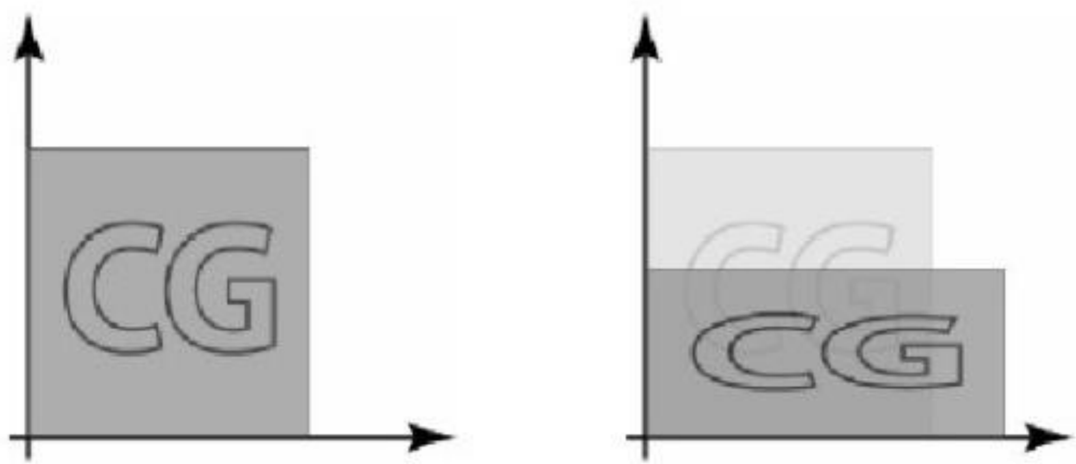
In matrix form:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} sx & 0 \\ 0 & sy \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

- Scaling
- Uniform Scaling



- Un-uniform Scaling



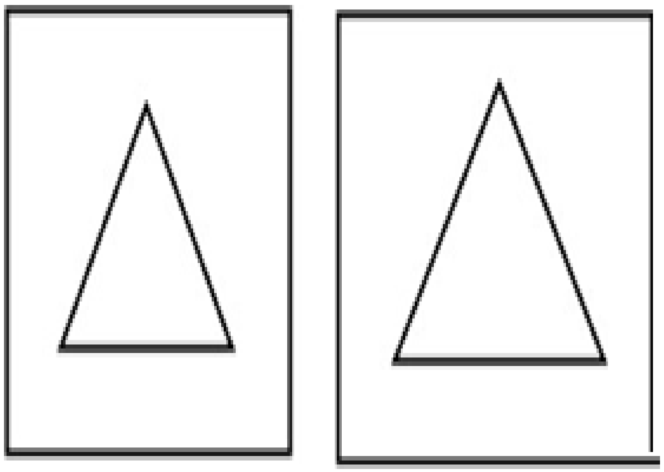
Example: Scaling

Enlargement: If $T_1 = \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix}$,If $(x_1\ y_1)$is original position ,

then $(x_2\ y_2)$ are coordinated after scaling

$$[x_2 y_2] = [\ x_1 y_1] \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix} = [2x_1 2y_1]$$

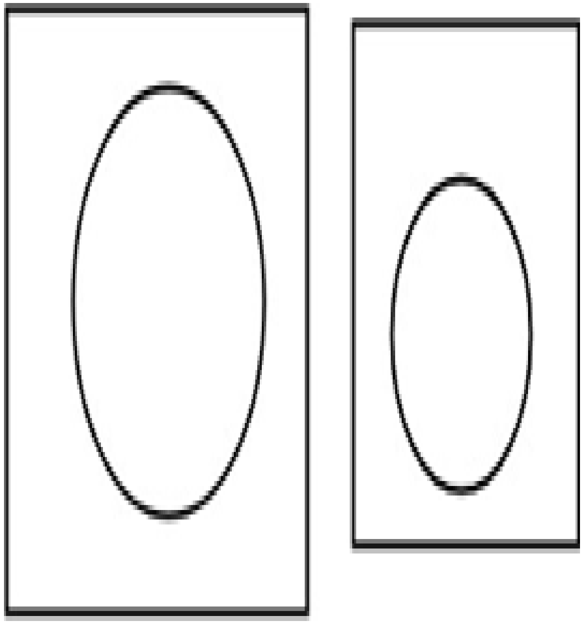
The image will be enlarged two times



Reduction: If $T_1 = \begin{bmatrix} 0.5 & 0 \\ 0 & 0.5 \end{bmatrix}$. If $(x_1\ y_1)$ is original position,

then $(x_2\ y_2)$ are coordinates after scaling

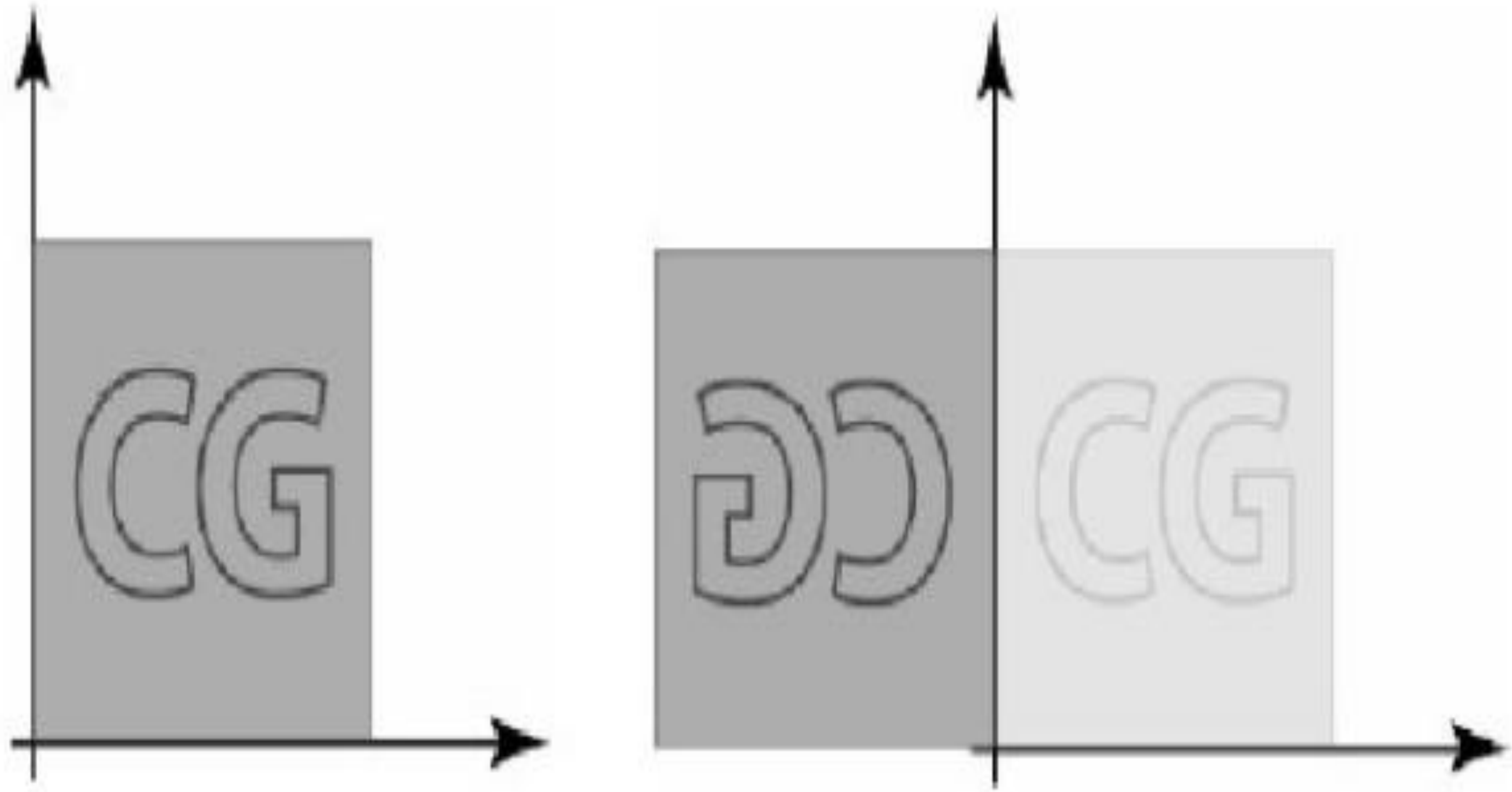
$$[x_2 y_2] = [\ x_1 y_1] \begin{bmatrix} 0.5 & 0 \\ 0 & 0.5 \end{bmatrix} = [.5x_1 .5y_1]$$



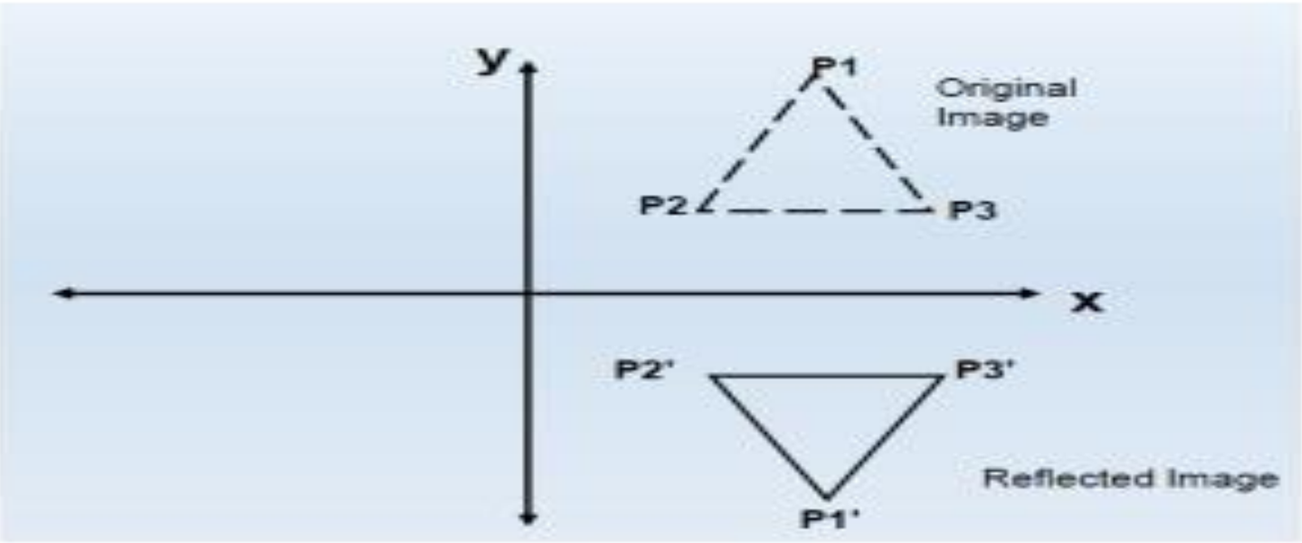
Reflection

- A reflection is a transformation that produces a mirror image of an object generated relative to an axis of reflection
- Reflection along x axis
- Reflection along y axis
- Reflection relative to an axis perpendicular to the xy plane and passing through the coordinate origin
- Reflection of an object relative to an axis perpendicular to the xy plane and passing through point P
- Reflection of an object with respect to the line y=x.

Reflection



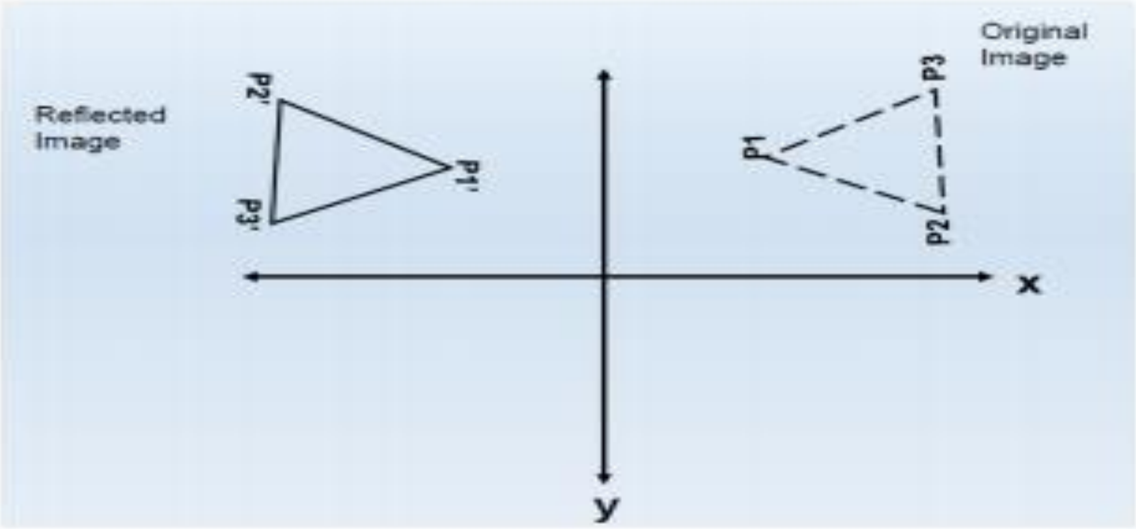
Reflection about x-axis:



$$M = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

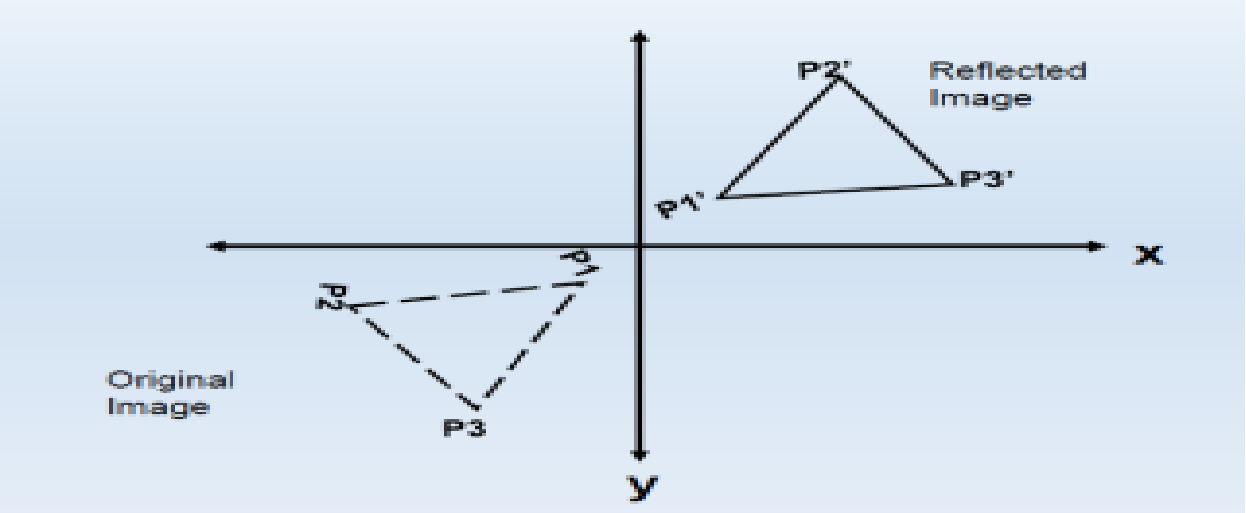
Reflection about y-axis:

Reflection about y-axis:



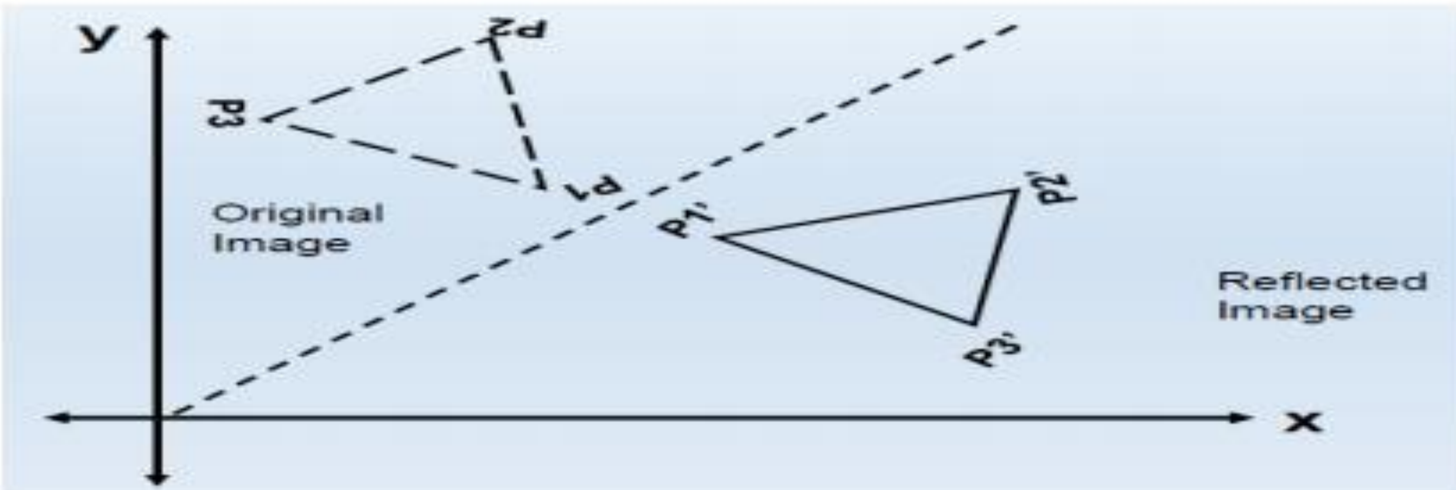
$$M = \begin{bmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Reflection relative to an axis perpendicular to the xy plane and passing through the coordinate origin:



$$M = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Reflection of an object with respect to the line y=x



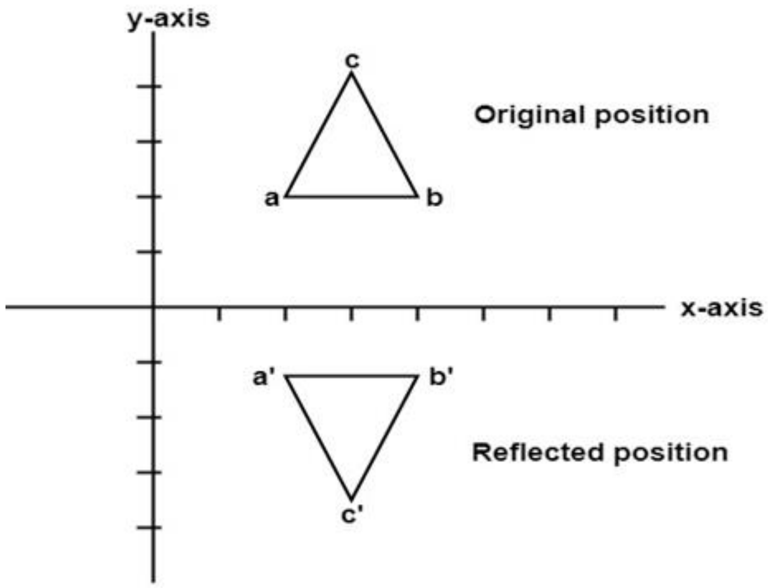
$$M = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Example: Reflection

- A triangle ABC is given. The coordinates of A, B, C are given as

  A (3 4)
  B (6 4)
  C (4 8)

  Find reflected position of triangle i.e., to the x-axis.



The matrix for reflection about x axis $\begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

The a point coordinates after reflection

$$(x, y) = (3, 4) \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$(x, y) = [3, -4]$$

The b point coordinates after reflection

$$(x, y) = (6, 4) \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$(x, y) = [6, -4]$$

The coordinate of point c after reflection

$$(x, y) = (4, 8) \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

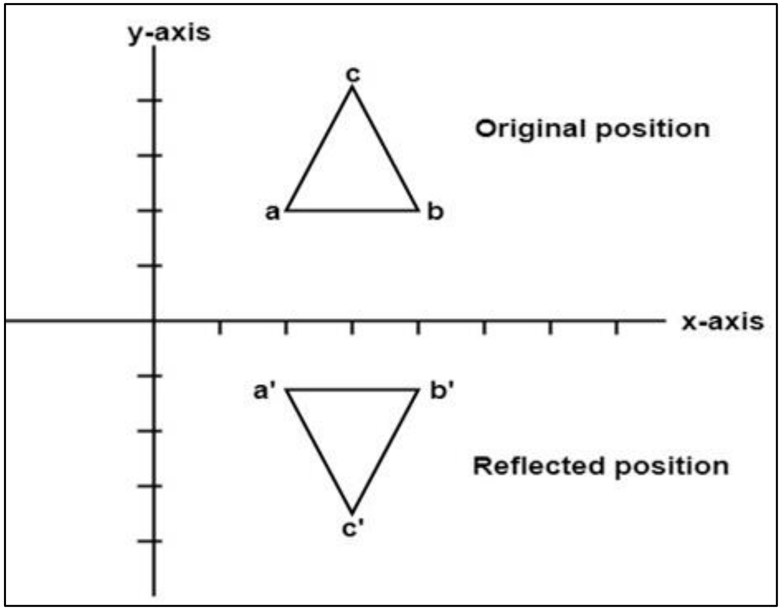
$$(x, y) = [4, -8]$$

Example: Reflection

a (3, 4) becomes a` (3, -4)

b (6, 4) becomes b` (6, -4)

c (4, 8) becomes c` (4, -8)



Shearing

- A transformation that distorts the shape of an object such that the transformed object appears as if the object were composed of internal layers that had been caused to slide over each other.

Shear relative to the x-axis

$$\begin{bmatrix} 1 & sh_x & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Shear relative to the y-axis

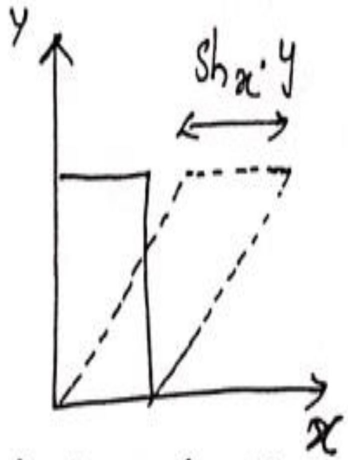
$$\begin{bmatrix} 1 & sh_y & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Shearing

Shearing

The matrix for shearing operation along x axis is,

$$\begin{bmatrix} 1 & Sh_x & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$



which transforms (x, y) to (x', y').

where $\boxed{\begin{aligned} x' &= x + sh_x \cdot y \\ y' &= y \end{aligned}}$

→ The x coordinates gets shifted horizontally by an amount sh_x.

→ Sh_x is +ve ⇒ shift the internal layers towards right

Sh_x is −ve ⇒ shift the internal layers towards left.

For the shear about y axis,

$$\begin{bmatrix} 1 & 0 & 0 \\ Sh_y & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$\boxed{\begin{aligned} y' &= y + Sh_y . x \\ x' &= x \end{aligned}}$

Example – Y_Shearing

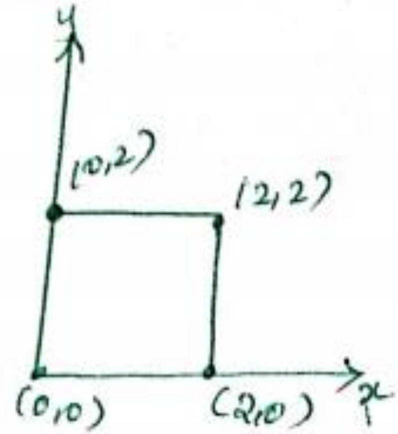
For y-shear,

$x' = x$

$y' = y + sh_y . x$

Y-shear:

Given, $Sh_y = 2$



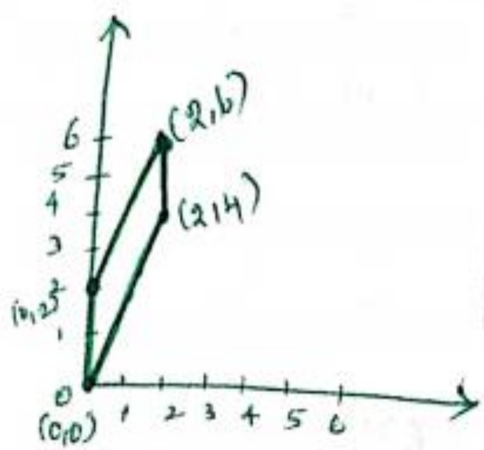
(0,0):

$x' = 0$

$y' = 0 + 2 * 0$

$= 0$

$(x', y') = (0,0)$



(0,2):

$x' = 0$

$y' = 2 + 2 * 0$

$= 2$

$(x', y') = (0,2)$

(2,0):

$x' = 2$

$y' = 0 + 2 * 2$

$= 4$

$(x', y') = (2,4)$

(2,2):

$x' = 2$

$y' = 2 + 2 * 2$

$= 6$

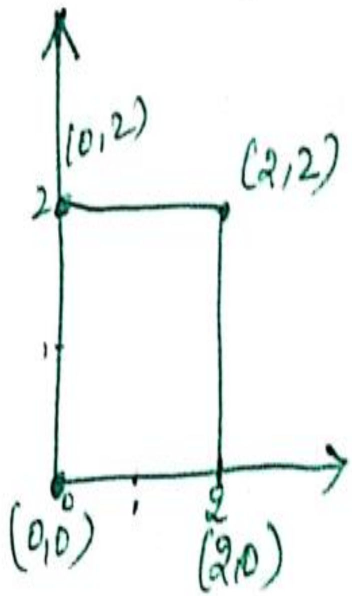
$(x', y') = (2,6)$

Example – X_Shearing

Example: Shearing

x-shear:- $x' = x + sh_x \cdot y$ $y' = y$	y-shear:- $x' = x$ $y' = y + sh_y \cdot x$

xshear: $sh_x = 2$



1) (0,0) :-

$y' = 0$

$x' = 0 + 2*0$

$= 0$

$(x', y') = (0,0)$

3) (2,0) :-

$y' = 0$

$x' = 2 + 2*0$

$= 2$

$(x', y') = (2,0)$

2) (0,2) :

$y' = 2$

$x' = 0 + 2*2$

$= 4$

$(x', y') = (4,2)$

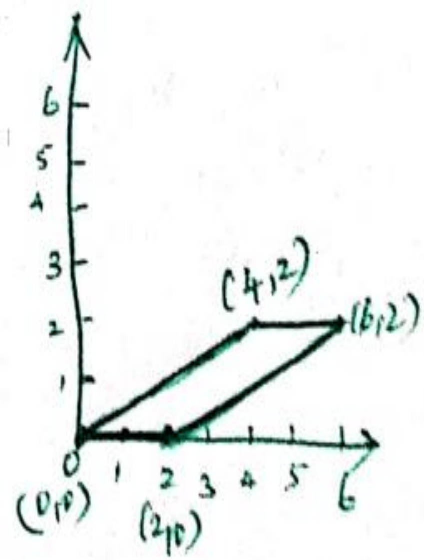
4) (2,2) :-

$y' = 2$

$x' = 2 + 2*2$

$= 6$

$(x', y') = (6,2)$



Shearing

Homogeneous Coordinates

- Expressing positions in homogeneous Coordinates allows us to represent all geometric transformation equations as matrix multiplications.
- Coordinates are represented with three-element column vectors, and transformation operations are written as 3 by 3 matrices.

Homogeneous Coordinates

- To combine these three transformations into a single transformation, homogeneous coordinates are used. In homogeneous coordinate system, two-dimensional coordinate positions (x, y) are represented by triple-coordinates.
- Homogeneous coordinates are generally used in design and construction applications. Here we perform translations, rotations, scaling to fit the picture into proper position.
- **Example of representing coordinates into a homogeneous coordinate system:** For two-dimensional geometric transformation, we can choose homogeneous parameter h to any non-zero value. For our convenience take it as one. Each two-dimensional position is then represented with homogeneous coordinates (x, y, 1).

Homogeneous Coordinate representation of 2D

For translation, we have

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

$$\mathbf{P}' = \mathbf{T}(t_x, t_y) \cdot \mathbf{P}$$

Similarly, rotation transformation equations about the coordinate origin are now written as

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

$$\mathbf{P}' = \mathbf{R}(\theta) \cdot \mathbf{P}$$

Finally, a scaling transformation relative to the coordinate origin is now expressed as the matrix multiplication

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} s_x & 0 & 0 \\ 0 & s_y & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

Matrix Representation for two-dimensional transformation in homogeneous coordinates

1. Translation

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ t_x & t_y & 1 \end{bmatrix} \text{ or } \begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{bmatrix}$$

2. Scaling

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

3. Rotation (clockwise)

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

4. Rotation (anti-clock)

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

5. Reflection against X axis $$\begin{bmatrix}1 & 0 & 0\\0 & -1 & 0\\0 & 0 & 1\end{bmatrix}$$

6. Reflection against Y axis $$\begin{bmatrix}-1 & 0 & 0\\0 & 1 & 0\\0 & 0 & 1\end{bmatrix}$$

7. Reflection against origin $$\begin{bmatrix}-1 & 0 & 0\\0 & -1 & 0\\0 & 0 & 1\end{bmatrix}$$

8. Reflection against line Y=X $$\begin{bmatrix}0 & 1 & 0\\1 & 0 & 0\\0 & 0 & 1\end{bmatrix}$$

9. Reflection against Y= −X $$\begin{bmatrix}0 & -1 & 0\\-1 & 0 & 0\\0 & 0 & 1\end{bmatrix}$$

10. Shearing in X direction $$\begin{bmatrix}1 & 0 & 0\\Sh_x & 1 & 0\\0 & 0 & 1\end{bmatrix}$$

11. Shearing in Y direction $$\begin{bmatrix}1 & Sh_y & 0\\0 & 1 & 0\\0 & 0 & 1\end{bmatrix}$$

12. Shearing in both x and y direction $$\begin{bmatrix}1 & Sh_y & 0\\Sh_x & 1 & 0\\0 & 0 & 1\end{bmatrix}$$

Composite Transformations

Translations

If two successive translation vectors (t_{x1}, t_{y1}) and (t_{x2}, t_{y2}) are applied to a coordinate position **P**, the final transformed location **P'** is calculated as

$$\mathbf{P'} = T(t_{x2}, t_{y2}) \cdot \{\mathbf{T}(t_{x1}, t_{y1}) \cdot \mathbf{P}\}$$
$$= \{\mathbf{T}(t_{x2}, t_{y2}) \cdot \mathbf{T}(t_{x1}, t_{y1})\} \cdot \mathbf{P}$$

where **P** and **P'** are represented as homogeneous-coordinate column vectors. We can verify this result by calculating the matrix product for the two associative groupings. Also, the composite transformation matrix for this sequence of translations is

$$\begin{bmatrix} 1 & 0 & t_{x2} \\ 0 & 1 & t_{y2} \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 & t_{x1} \\ 0 & 1 & t_{y1} \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & t_{x1} + t_{x2} \\ 0 & 1 & t_{y1} + t_{y2} \\ 0 & 0 & 1 \end{bmatrix}$$

or

$$\mathbf{T}(t_{x2}, t_{y2}) \cdot \mathbf{T}(t_{x1}, t_{y1}) = \mathbf{T}(t_{x1} + t_{x2}, t_{y1} + t_{y2})$$

which demonstrates that two successive translations are additive.

Composite Transformations

Rotations

Two successive rotations applied to point **P** produce the transformed position

$$\mathbf{P}' = \mathbf{R}(\theta_2) \cdot \{\mathbf{R}(\theta_1) \cdot \mathbf{P}\}$$
$$= \{\mathbf{R}(\theta_2) \cdot \mathbf{R}(\theta_1)\} \cdot \mathbf{P}$$

By multiplying the two rotation matrices, we can verify that two successive rotations are additive:

$$\mathbf{R}(\theta_2) \cdot \mathbf{R}(\theta_1) = \mathbf{R}(\theta_1 + \theta_2)$$

so that the final rotated coordinates can be calculated with the composite rotation matrix as

$$\mathbf{P}' = \mathbf{R}(\theta_1 + \theta_2) \cdot \mathbf{P}$$

Scalings

Concatenating transformation matrices for two successive scaling operations produces the following composite scaling matrix:

$$\begin{bmatrix} s_{x2} & 0 & 0 \\ 0 & s_{y2} & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} s_{x1} & 0 & 0 \\ 0 & s_{y1} & 0 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} s_{x1} \cdot s_{x2} & 0 & 0 \\ 0 & s_{y1} \cdot s_{y2} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

or

$$\mathbf{S}(s_{x2}, s_{y2}) \cdot \mathbf{S}(s_{x1}, s_{y1}) = \mathbf{S}(s_{x1} \cdot s_{x2}, s_{y1} \cdot s_{y2})$$

The resulting matrix in this case indicates that successive scaling operations are multiplicative. That is, if we were to triple the size of an object twice in succession, the final size would be nine times that of the original.

Thank you