Introduction of Transformations

Computer Graphics provide the facility of viewing object from different angles. The architect can study building from different angles i.e.

1. Front Evaluation
2. Side elevation
3. Top plan

A Cartographer can change the size of charts and topographical maps. So if graphics images are coded as numbers, the numbers can be stored in memory. These numbers are modified by mathematical operations called as Transformation.

The purpose of using computers for drawing is to provide facility to user to view the object from different angles, enlarging or reducing the scale or shape of object called as Transformation.

Two essential aspects of transformation are given below:

1. Each transformation is a single entity. It can be denoted by a unique name or symbol.
2. It is possible to combine two transformations, after connecting a single transformation is obtained, e.g., A is a transformation for translation. The B transformation performs scaling. The combination of two is C=AB. So C is obtained by concatenation property.

There are two complementary points of view for describing object transformation.

1. Geometric Transformation: The object itself is transformed relative to the coordinate system or background. The mathematical statement of this viewpoint is defined by geometric transformations applied to each point of the object.
2. Coordinate Transformation: The object is held stationary while the coordinate system is transformed relative to the object. This effect is attained through the application of coordinate transformations.

An example that helps to distinguish these two viewpoints:

The movement of an automobile against a scenic background we can simulate this by

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### Types of Transformations:

1. [Translation](https://www.javatpoint.com/computer-graphics-translation)
2. [Scaling](https://www.javatpoint.com/computer-graphics-scaling)
3. [Rotating](https://www.javatpoint.com/computer-graphics-rotation)
4. [Reflection](https://www.javatpoint.com/computer-graphics-reflection)
5. [Shearing](https://www.javatpoint.com/computer-graphics-shearing)

# Translation

It is the straight line movement of an object from one position to another is called Translation. Here the object is positioned from one coordinate location to another.

## Translation of point:

To translate a point from coordinate position (x, y) to another (x1 y1), we add algebraically the translation distances Tx and Ty to original coordinate.

x1=x+Tx

y1=y+Ty

The translation pair (Tx,Ty) is called as shift vector.

Translation is a movement of objects without deformation. Every position or point is translated by the same amount. When the straight line is translated, then it will be drawn using endpoints.

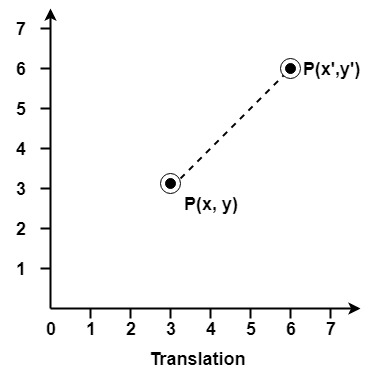
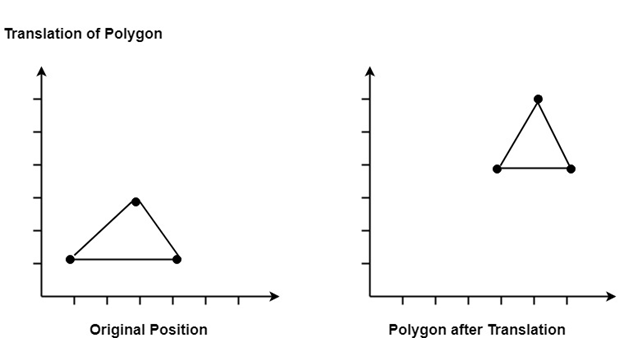
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For translating polygon, each vertex of the polygon is converted to a new position. Similarly, curved objects are translated. To change the position of the circle or ellipse its center coordinates are transformed, then the object is drawn using new coordinates.

Let P is a point with coordinates (x, y). It will be translated as (x1 y1).

## Matrix for Translation:

Translation

# Scaling:

It is used to alter or change the size of objects. The change is done using scaling factors. There are two scaling factors, i.e. Sx in x direction Sy in y-direction. If the original position is x and y. Scaling factors are Sx and Sy then the value of coordinates after scaling will be x1 and y1.

If the picture to be enlarged to twice its original size then Sx = Sy =2. If Sxand Sy are not equal then scaling will occur but it will elongate or distort the picture.

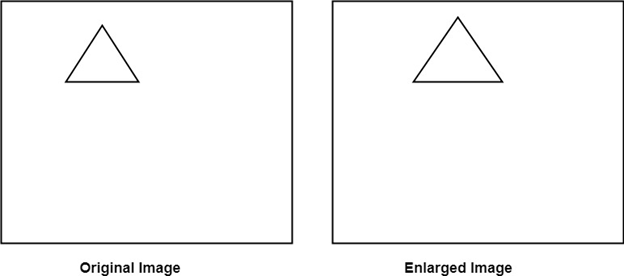
If scaling factors are less than one, then the size of the object will be reduced. If scaling factors are higher than one, then the size of the object will be enlarged.

If Sxand Syare equal it is also called as Uniform Scaling. If not equal then called as Differential Scaling. If scaling factors with values less than one will move the object closer to coordinate origin, while a value higher than one will move coordinate position farther from origin.

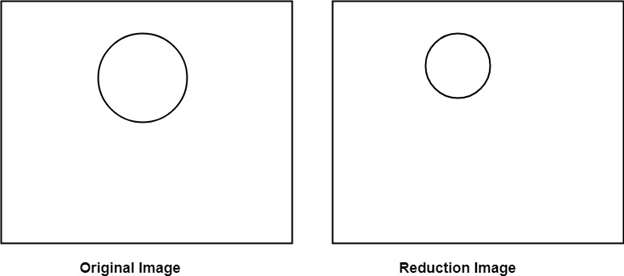
**Enlargement: If T1=Scaling,If (x1 y1)is original position and T1is translation vector then (x2 y2) are coordinated after scaling**

**Scaling**

**The image will be enlarged two times**

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**Reduction: If T1=Scaling. If (x1 y1) is original position and T1 is translation vector, then (x2 y2) are coordinates after scaling**

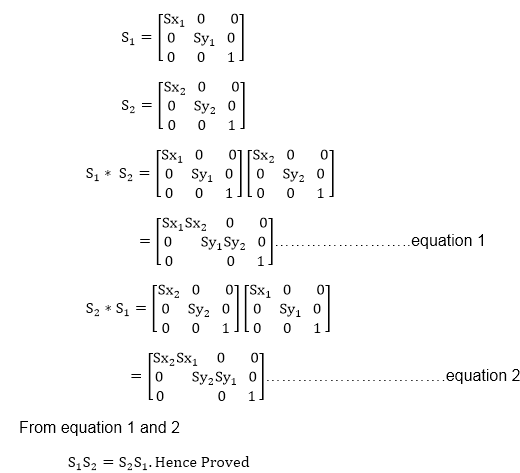
**Scaling  
**

## Matrix for Scaling:

**Scaling**

**Example: Prove that 2D Scaling transformations are commutative i.e, S1 S2=S2 S1.**

**Solution: S1 and S2 are scaling matrices**

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# Rotation:

It is a process of changing the angle of the object. Rotation can be clockwise or anticlockwise. For rotation, we have to specify the angle of rotation and rotation point. Rotation point is also called a pivot point. It is print about which object is rotated.

## Types of Rotation:

1. Anticlockwise
2. Counterclockwise

The positive value of the pivot point (rotation angle) rotates an object in a counter-clockwise (anti-clockwise) direction.

The negative value of the pivot point (rotation angle) rotates an object in a clockwise direction.

When the object is rotated, then every point of the object is rotated by the same angle.

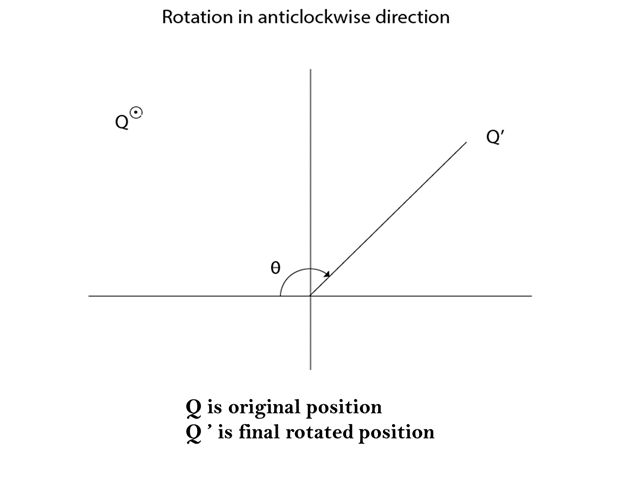
**Straight Line:** Straight Line is rotated by the endpoints with the same angle and redrawing the line between new endpoints.

**Polygon:** Polygon is rotated by shifting every vertex using the same rotational angle.

**Curved Lines:** Curved Lines are rotated by repositioning of all points and drawing of the curve at new positions.

**Circle:** It can be obtained by center position by the specified angle.

**Ellipse:** Its rotation can be obtained by rotating major and minor axis of an ellipse by the desired angle.

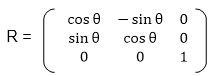


Rotation

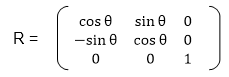
Matrix for rotation is an anticlockwise direction.

Rotation

Matrix for homogeneous co-ordinate rotation (clockwise)



Matrix for homogeneous co-ordinate rotation (anticlockwise)



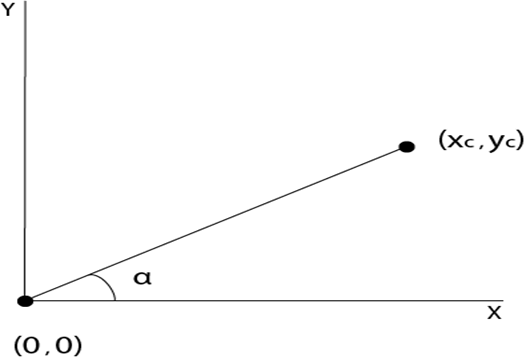
**Rotation about an arbitrary point:** If we want to rotate an object or point about an arbitrary point, first of all, we translate the point about which we want to rotate to the origin. Then rotate point or object about the origin, and at the end, we again translate it to the original place. We get rotation about an arbitrary point.

**Example:** The point (x, y) is to be rotated

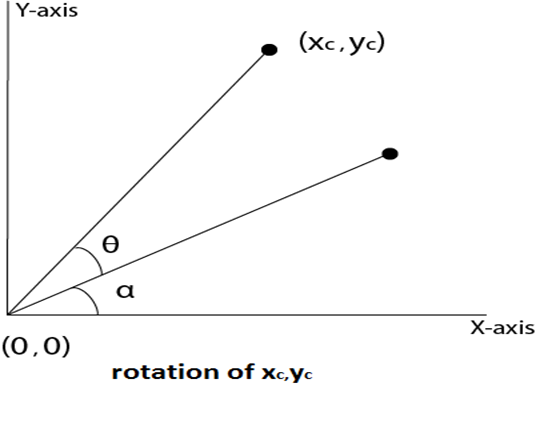
The (xc yc) is a point about which counterclockwise rotation is done

**Step1:** Translate point (xc yc) to origin

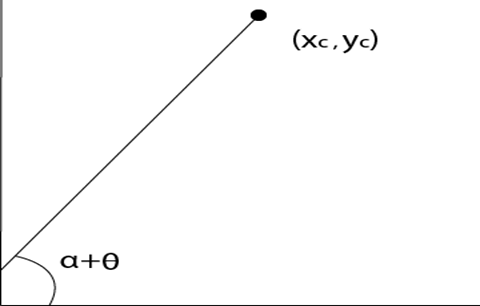
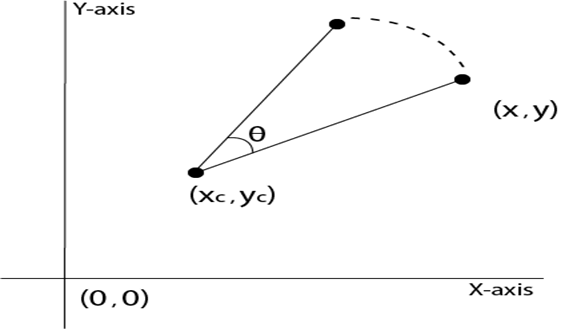
**Step1:** Translate point (xc yc) to origin



**Step2:** Rotation of (x, y) about the origin

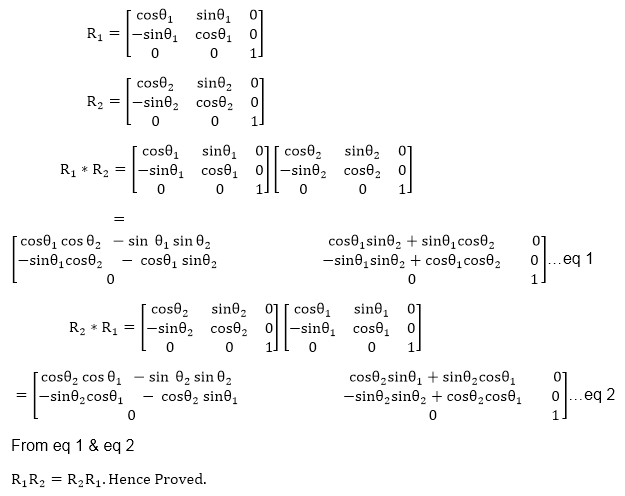


**Step3:** Translation of center of rotation back to its original position

**Example1:** Prove that 2D rotations about the origin are commutative i.e. R1 R2=R2 R1.

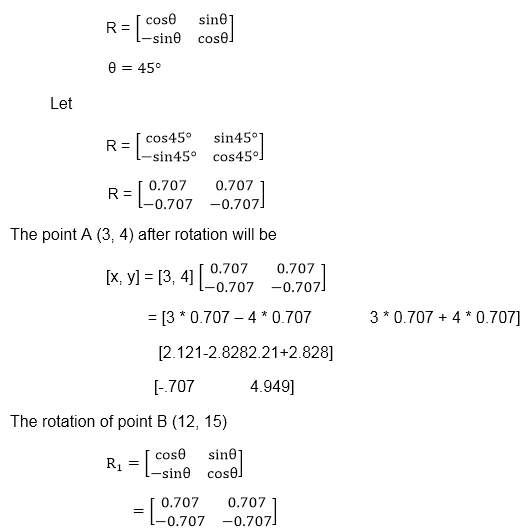
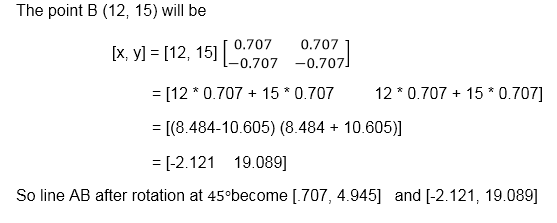
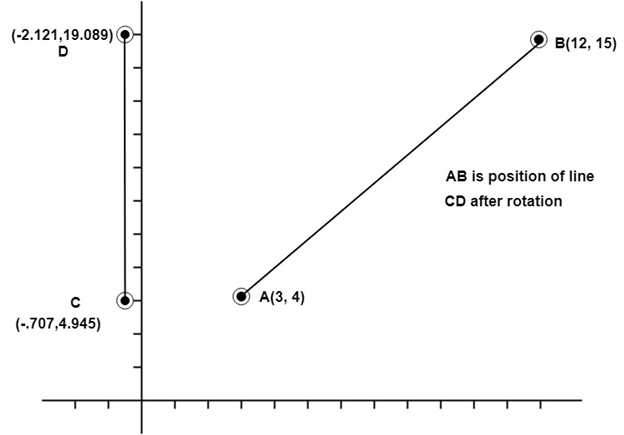
**Solution:** R1 and R2are rotation matrices



**Example2:** Rotate a line CD whose endpoints are (3, 4) and (12, 15) about origin through a 45° anticlockwise direction.

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**Solution:** The point C (3, 4)

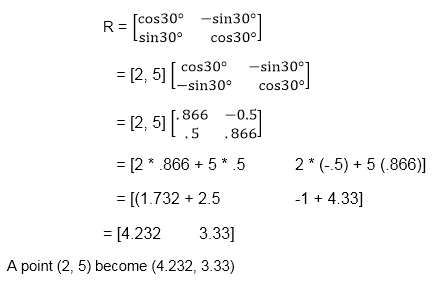
  
  


**Example3:** Rotate line AB whose endpoints are A (2, 5) and B (6, 12) about origin through a 30° clockwise direction.

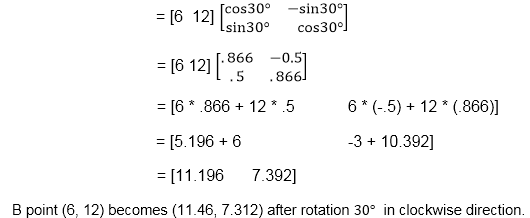
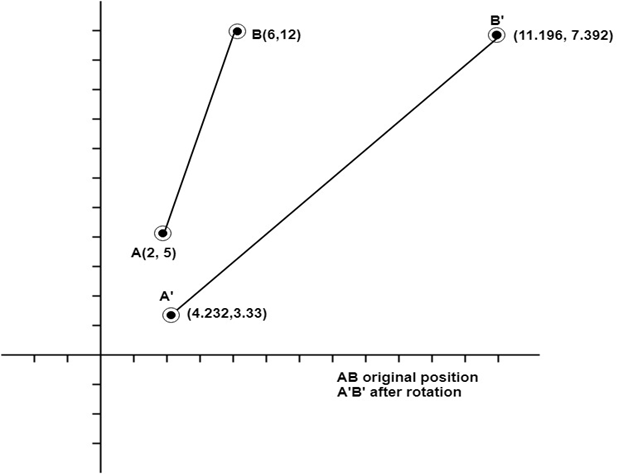
**Solution:** For rotation in the clockwise direction. The matrix is

Rotation

**Step1:** Rotation of point A (2, 5). Take angle 30°



**Step2:** Rotation of point B (6, 12)

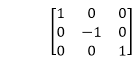
# Reflection:

It is a transformation which produces a mirror image of an object. The mirror image can be either about x-axis or y-axis. The object is rotated by180°.

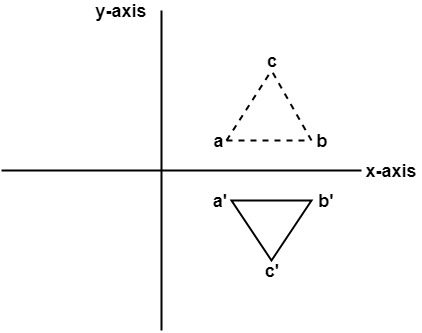
## Types of Reflection:

1. Reflection about the x-axis
2. Reflection about the y-axis
3. Reflection about an axis perpendicular to xy plane and passing through the origin
4. Reflection about line y=x

**1. Reflection about x-axis:** The object can be reflected about x-axis with the help of the following matrix



In this transformation value of x will remain same whereas the value of y will become negative. Following figures shows the reflection of the object axis. The object will lie another side of the x-axis.



**2. Reflection about y-axis:** The object can be reflected about y-axis with the help of following transformation matrix

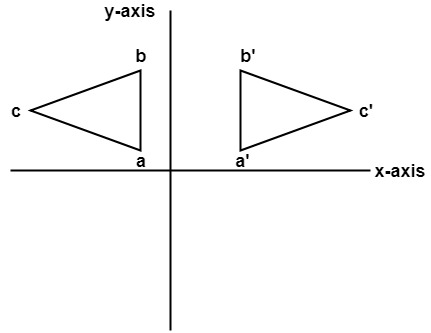
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Reflection

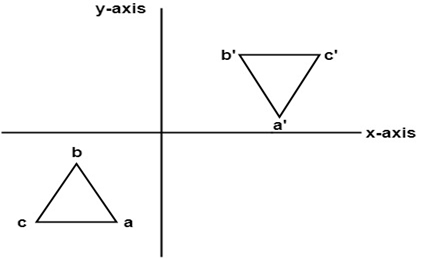
Here the values of x will be reversed, whereas the value of y will remain the same. The object will lie another side of the y-axis.

The following figure shows the reflection about the y-axis



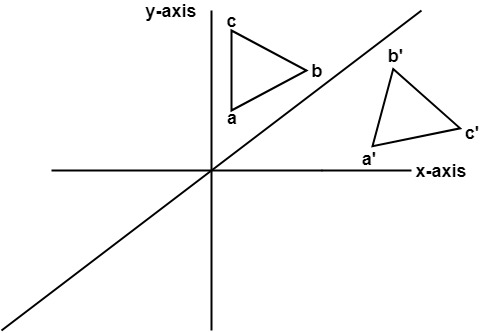
**3. Reflection about an axis perpendicular to xy plane and passing through origin:**  
In the matrix of this transformation is given below

Reflection



In this value of x and y both will be reversed. This is also called as half revolution about the origin.

**4. Reflection about line y=x:** The object may be reflected about line y = x with the help of following transformation matrix

Reflection  


First of all, the object is rotated at 45°. The direction of rotation is clockwise. After it reflection is done concerning x-axis. The last step is the rotation of y=x back to its original position that is counterclockwise at 45°.

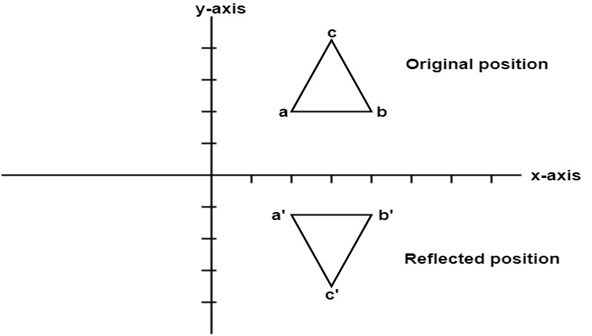
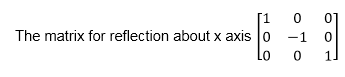
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**Example:** A triangle ABC is given. The coordinates of A, B, C are given as

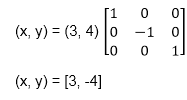
                    A (3 4)  
                    B (6 4)  
                    C (4 8)

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

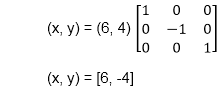
**Solution:**

The a point coordinates after reflection



The b point coordinates after reflection

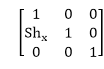
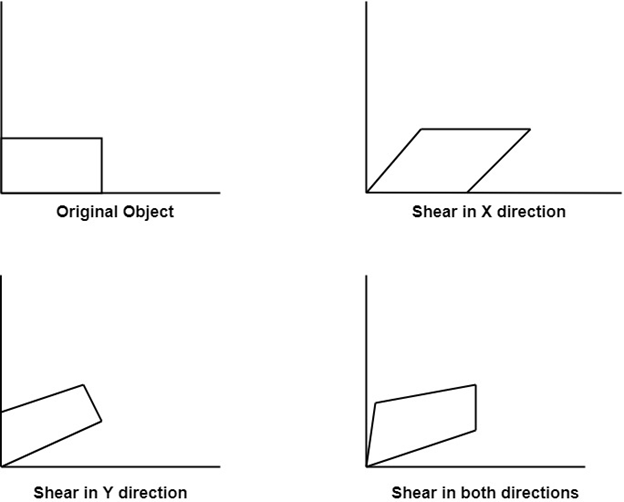


The coordinate of point c after reflection

Shearing:

It is transformation which changes the shape of object. The sliding of layers of object occur. The shear can be in one direction or in two directions.

**Shearing in the X-direction:** In this horizontal shearing sliding of layers occur. The homogeneous matrix for shearing in the x-direction is shown below:

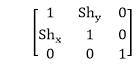
  


**Shearing in the Y-direction:** Here shearing is done by sliding along vertical or y-axis.

Shearing

**Shearing in X-Y directions:** Here layers will be slided in both x as well as y direction. The sliding will be in horizontal as well as vertical direction. The shape of the object will be distorted. The matrix of shear in both directions is given by:

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# Matrix Representation of 2D Transformation

