CAD/CAM

Module-2

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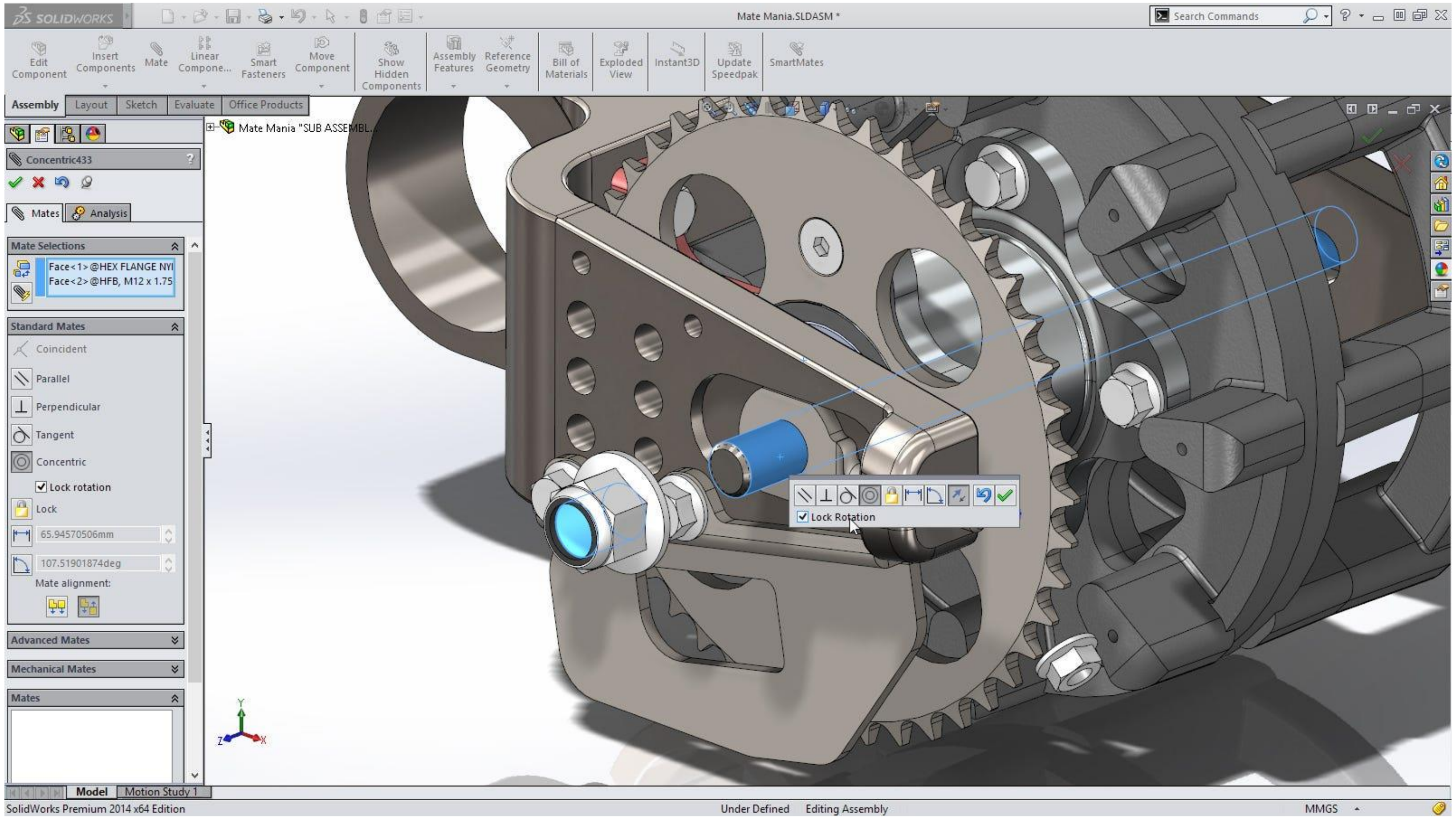
Syllabus

MODULE – II **(14 HOURS)**

Computer graphics Software and Database: Configuration, Graphics Packages, Constructing the Geometry, Transformations of geometry, Database structure and content, Wire frame versus solid modeling, Constraint– Based modeling, Geometric commands, Display control commands, Editing.

COMPUTER GRAPHICS



COMPUTER GRAPHICS

- The Graphics software is a collection of programs written to make it convenient for a user to operate the computer the computer graphic system.
- It includes programs to generate images on the CRT screen, to manipulate the images and to accomplish various types of interaction between the user and system.
- Rules that should be considered in designing graphics software:

  • Simplicity: the graphics software easy to use.

  • Consistency: The package should operate in a consistent and predictionable way to the user.

  • Completeness: There should be no inconvenient omissions set of functions.

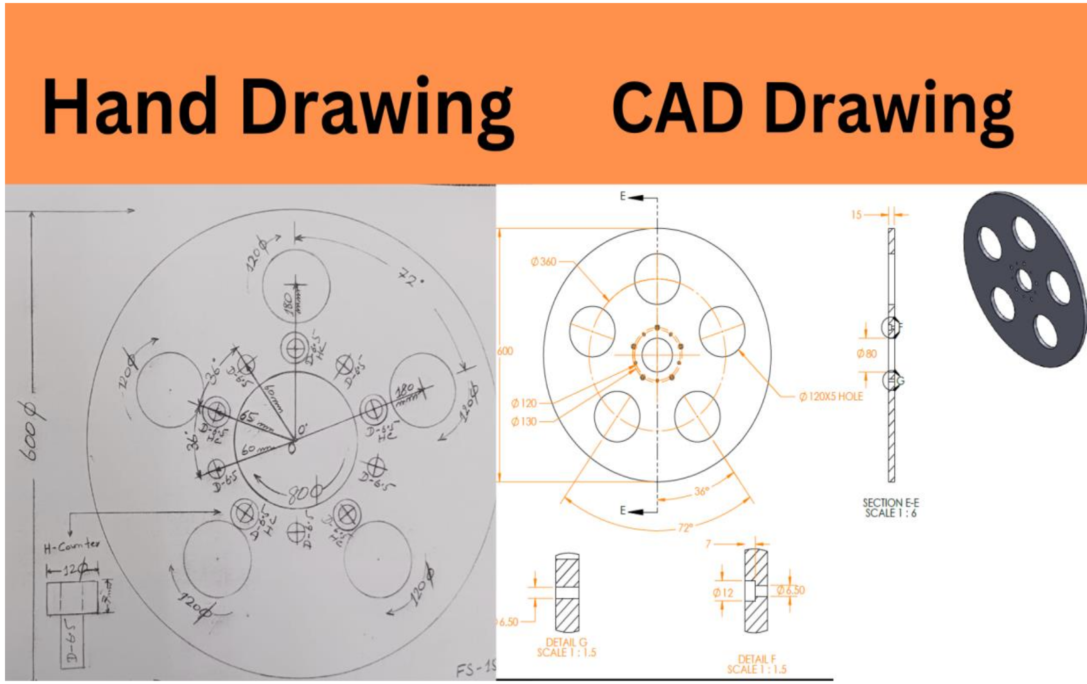
  • Robustness: the graphic system should be tolerant of minor instances of misuse by the operator.

  • Performance: The performance should be exploited as much as possible by software. The graphics programs should be efficient and speed of response should be fast and consistent.

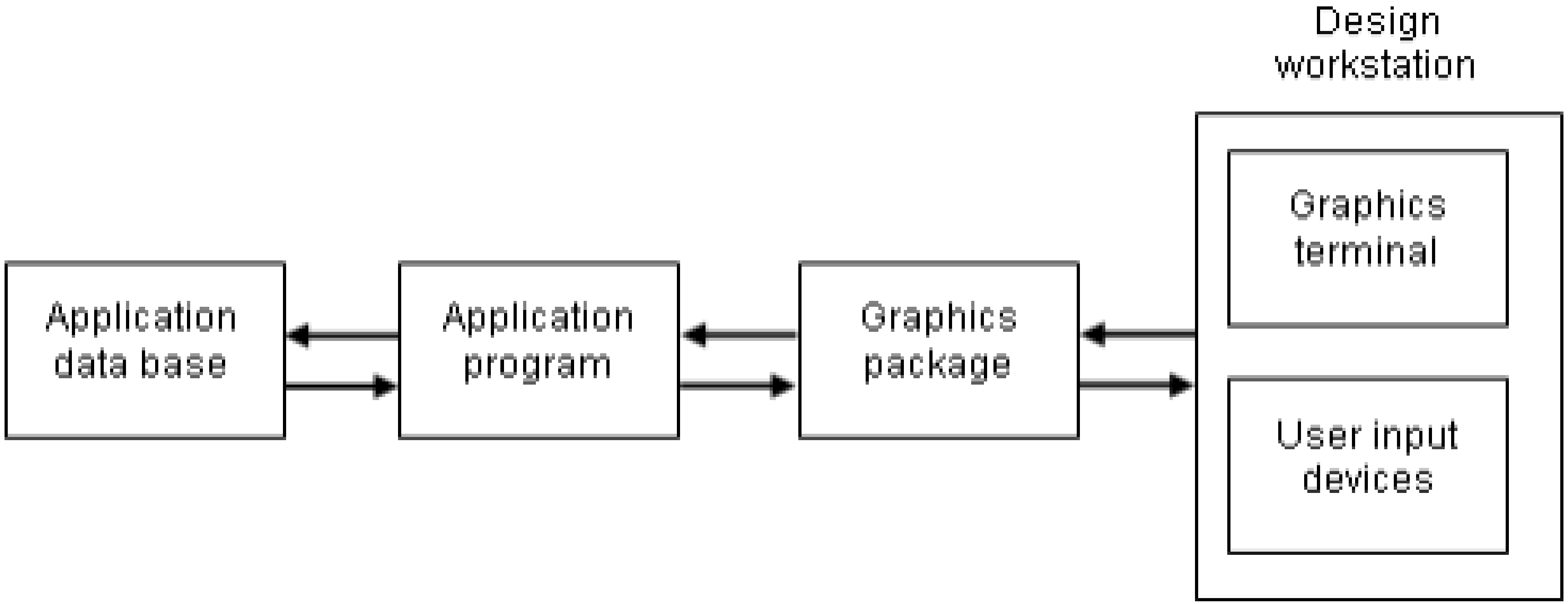
  • Economy: Graphics Programs should not be so large or expensive as to make their use prohibitive.

Use of computer graphics

- The object is represented by its geometric model in three dimensions (X, Y and Z).
- The mathematical representation reduces creation of views like orthographic, isometric, axonometric or perspective projections into simple viewingtransformations.
- Though the size of the screen is limited, there is no need to scale the drawings.
- Drawings can be made very accurate.
- The geometric models can be represented in color and can be viewed from any angle.
- Sections can be automatically created.
- The associativity ensures that any change made in one of the related views will automatically reflect in other views.
- Revision and revision control are easy.
- Drawings (geometric models) can be modified easily.
- More important than all, drawings can be reused conveniently.
- Storage and retrieval of drawings are easy.



The Software Configuration of a Graphic System



Functions of a Graphic Package

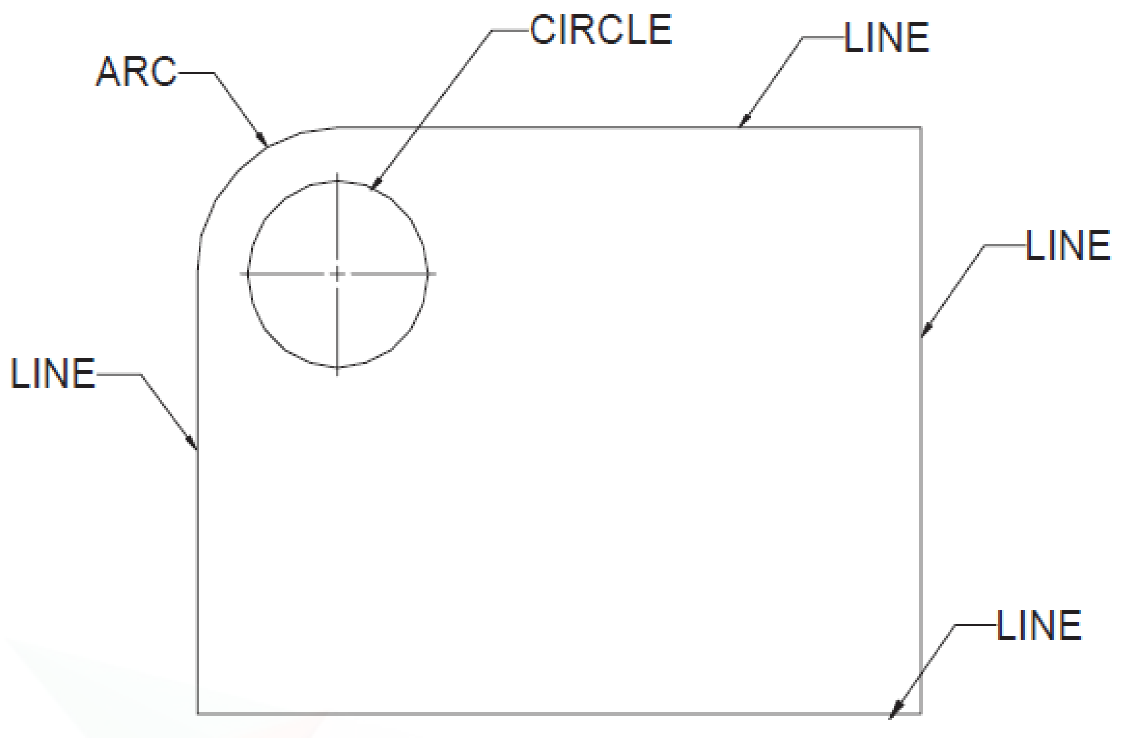
- Generation of Graphic Elements
- Transformations
- Display Control and Windowing Functions
- Segmenting functions
- User input function

GRAPHIC PRIMITIVES

A drawing is created by an assembly of points, lines, arcs, circles.

The drawing entities that a user may find in a typical CAD package include :

- point
- line
- construction line, multi-line, polyline
- circle
- spline
- arc
- ellipse
- polygon
- rectangle



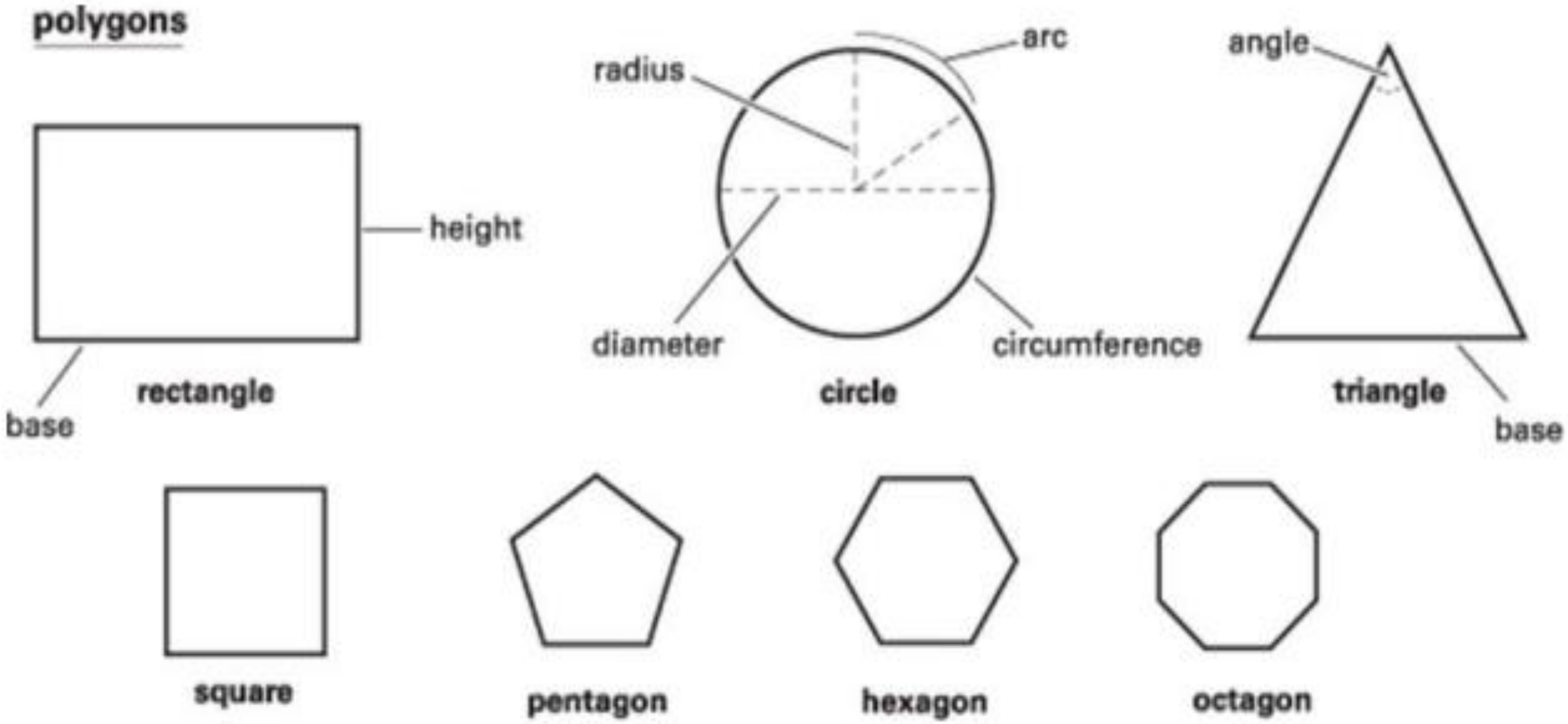
GEOMETRIC MODELLING

- Geometric modeling is an integral part of any Computer-Aided-Design (CAD) system.
- A geometric model is defined as the complete representation of graphical and non-graphical information of an object.
- The geometric models can be classified as below.

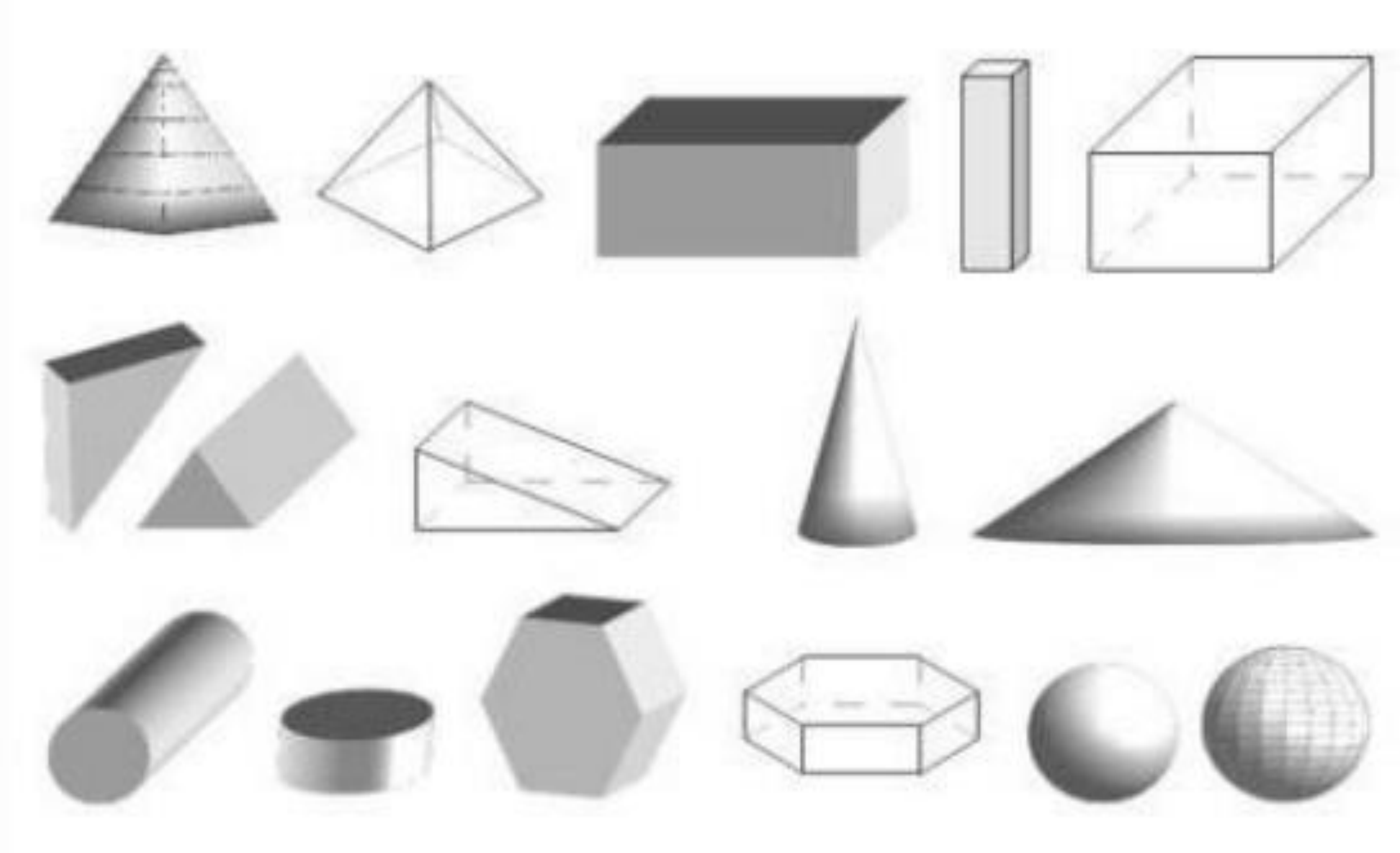
  Two dimensional (2D) models

  Three dimensional (3D)models.

Two-dimensional (2D) models

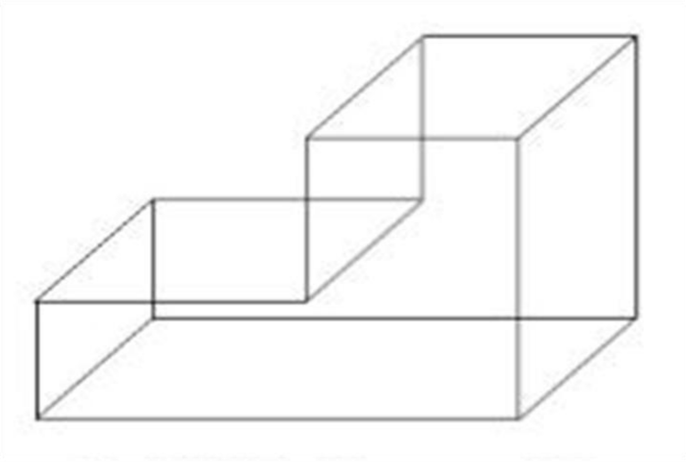


Three-dimensional (3D) models



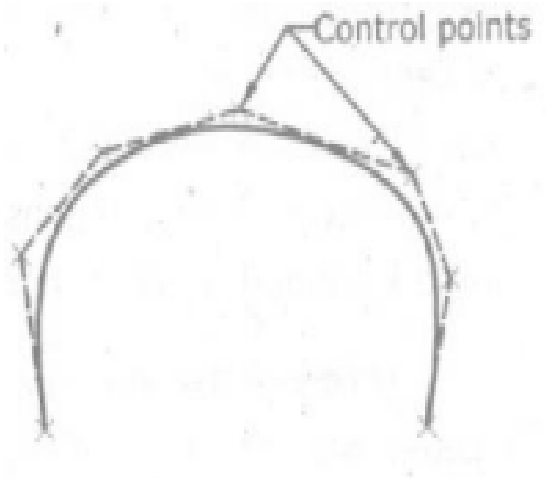
Wireframe model or line model

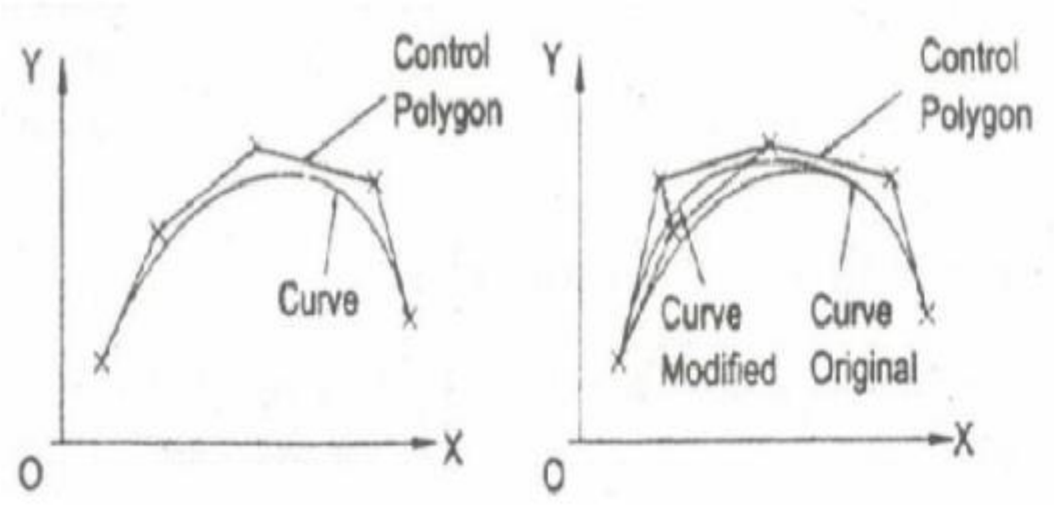
- Wireframe model is the simplest geometric model that can be used to represent an object mathematically in the computer. It is also called as line model or edge representation of the object.
- Typically, a wire frame model consists of points, lines, arcs, circles, conics, and curves.
- The word ‘wireframe’ is related to the fact that one may imagine a wire that is bent to follow the object edge to generate the model.



For constructing wireframe models the following entities are used:

- Cubic splines
- Bezier curves
- B-splines





Merits and Demerits of wireframe modelling

Merits

- It is easy to construct.
- It needs less memory space.
- It takes less manipulation time.
- It does not require any extensive training for users.
- It is best suitable for manipulations as orthographic, isometric and perspective views.

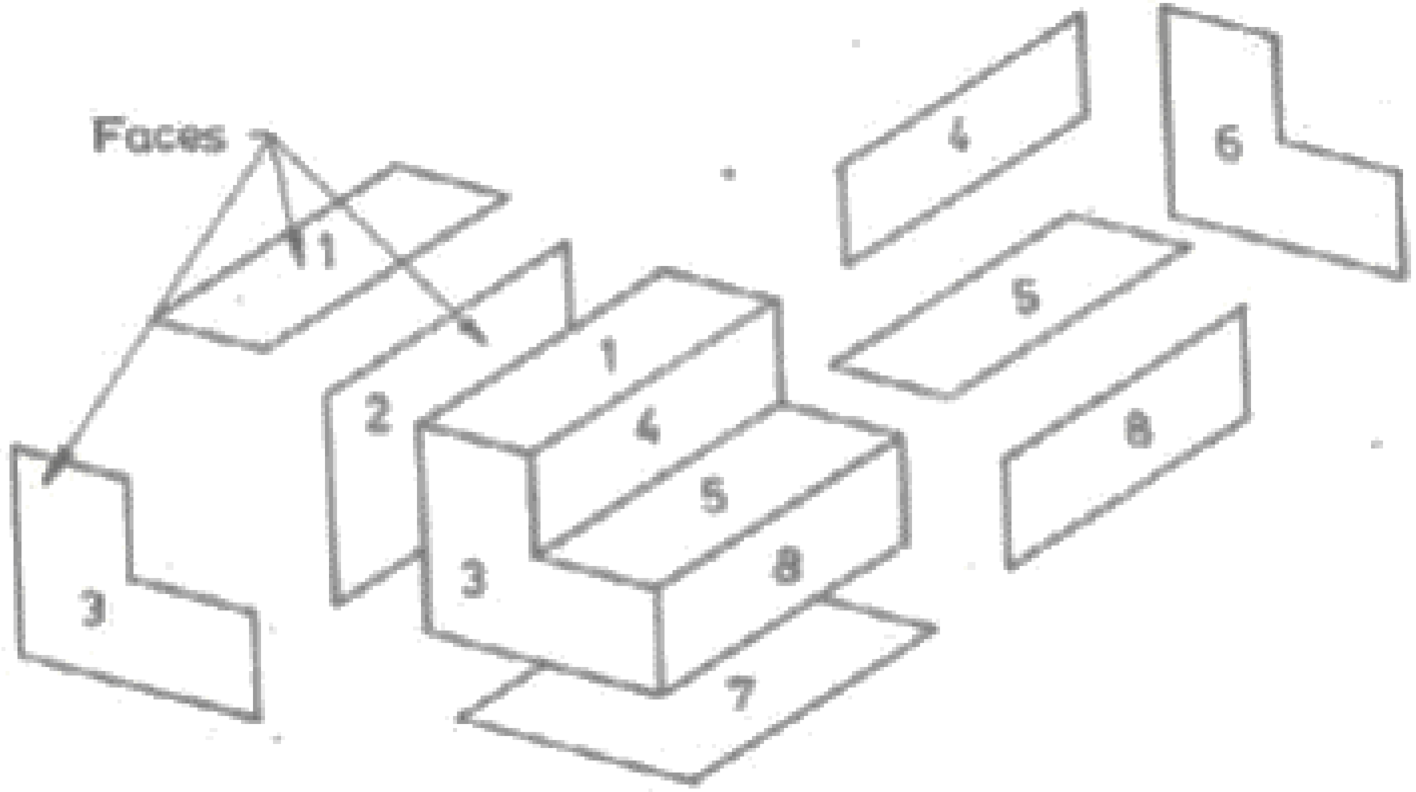
Demerits

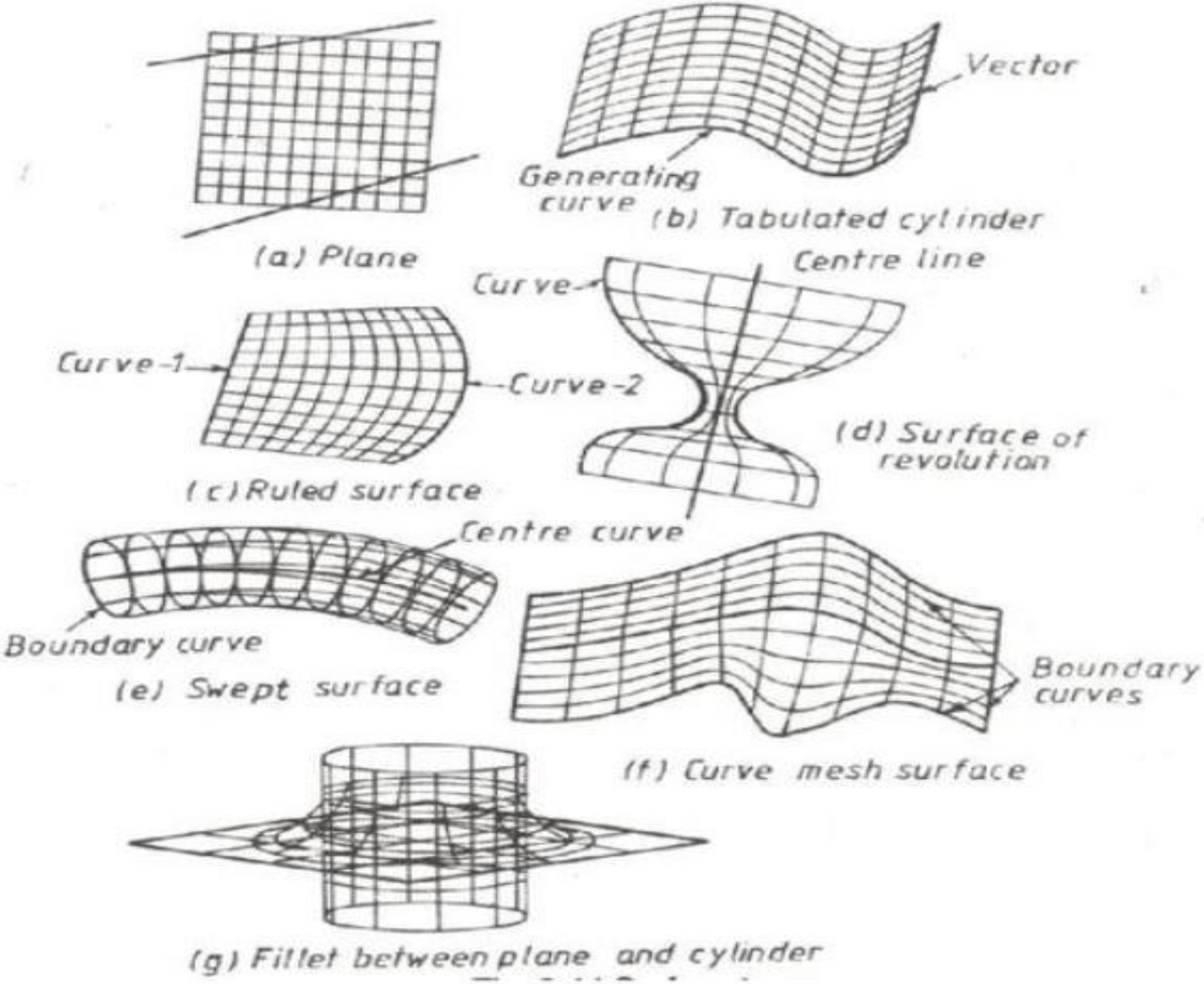
- There is more doubt in identifying the surfaces.
- The images of wireframe model cause confusion to the viewer.
- It is not possible to calculate mass properties.
- It is not useful for NC tool path generation, cross sectioning, interference detection, etc.
- It is not suitable for representing complex solids.
- Hidden line removal is a time consuming task.
- Both topological and geometrical data are required for wireframe modeling.

Surface modelling

- A surface model of an object is more complete and less confusing representation thanits wireframe model.
- A surface model can be built by defining the surface on the wireframe model.
- Modeling of curves and surfaces are essential to describe objects in several areas of mechanical design such as
    - Body panel of automobiles
    - Aircraft structural members
    - Marine vehicles
    - Consumer products, etc.

Surface modelling




(a) Plane
Vector
Generating curve
(b) Tabulated cylinder
Centre line
Curve
Curve-1
Curve-2
(c) Ruled surface
(d) Surface of revolution
Centre curve
Boundary curve
(e) Swept surface
Boundary curves
(f) Curve mesh surface
(g) Fillet between plane and cylinder

Merits

- Surface models are less confusing than wireframe model.
- They provide hidden line and surface algorithms to add realism to the displayed geometry.
- Shading algorithms are also available.

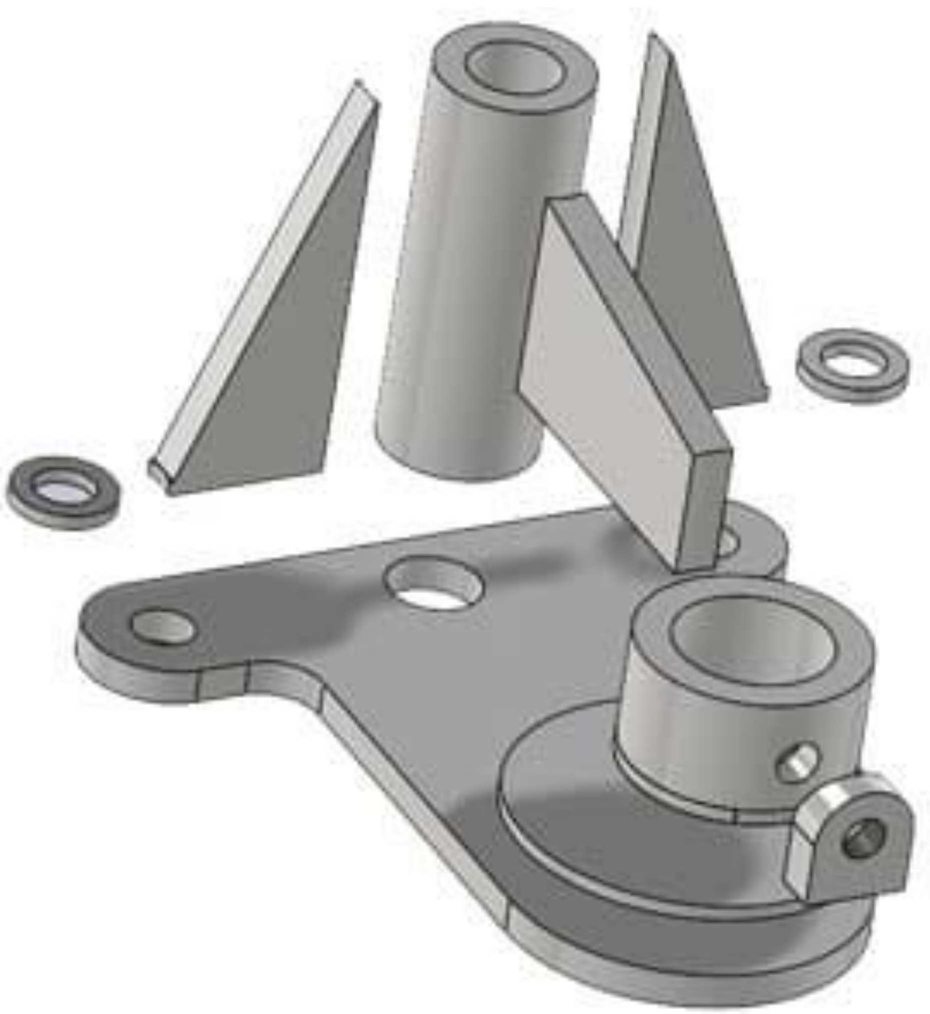
Demerits

- The interior details of the model cannot be represented.
- The designer requires more training and mathematical background.
- It takes more time to create.
- It requires more storage capacity.
- It requires more manipulation time.
- The construction is not as simple as wireframe model.

Solid modelling

- The best method for the three dimensional model construction is the solid modeling technique.
- It provides the user with complete information about the model.
- In this approach, the models are displayed as solid objects to the viewer, with very little risk of misunderstanding.
- When color is added to the image, the resulting picture becomes very realistic.
- All solid modeling systems provide facilities for creating, modifying, and inspecting models of three dimensional solid objects.

Solid modelling



Transformation

In translation, every point on an object translates exactly the same distance as shown in Figure 4.38. The effect of a translation transformation is that the original coordinate values increase or decrease by the amount of the translation along the x, and y-axes.

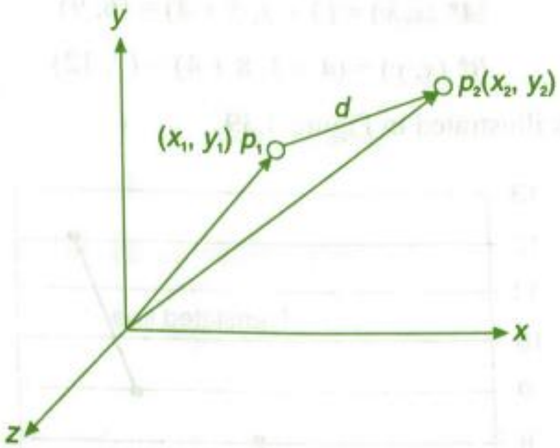


Fig. 4.38 Translation.

The point p_1 moves to p_2 by a distance d. The translation is expressed mathematically as:

$$p_2 = p_1 + d \tag{4.17}$$

This equation can be written in scalar form as follows:

$$x_2 = x_1 + d_x$$
$$y_2 = y_1 + d_y \tag{4.18}$$

In matrix form, the translation is expressed as:

$$\begin{Bmatrix} x_2 \\ y_2 \end{Bmatrix} = \begin{Bmatrix} x_1 \\ y_1 \end{Bmatrix} + \begin{Bmatrix} d_x \\ d_y \end{Bmatrix} \tag{4.19}$$

The translation matrix is given by:

$$T = \begin{Bmatrix} d_x \\ d_y \end{Bmatrix}$$

Example 4.6 If line $A(3, 5)$, $B(4, 8)$ is translated into three units along the positive x-axis and four units along the positive y-axis, find the new coordinates of the line.

Solution

Given $A(3, 5)$, $B(4, 8)$.

$$d_x = 3 \text{ and } d_y = 4$$

The new points are given by:

$$A^*(x, y) = (3 + 3, 5 + 4) = (6, 9)$$

$$B^*(x, y) = (4 + 3, 8 + 4) = (7, 12)$$

The effect of translation is illustrated in Figure 4.39.

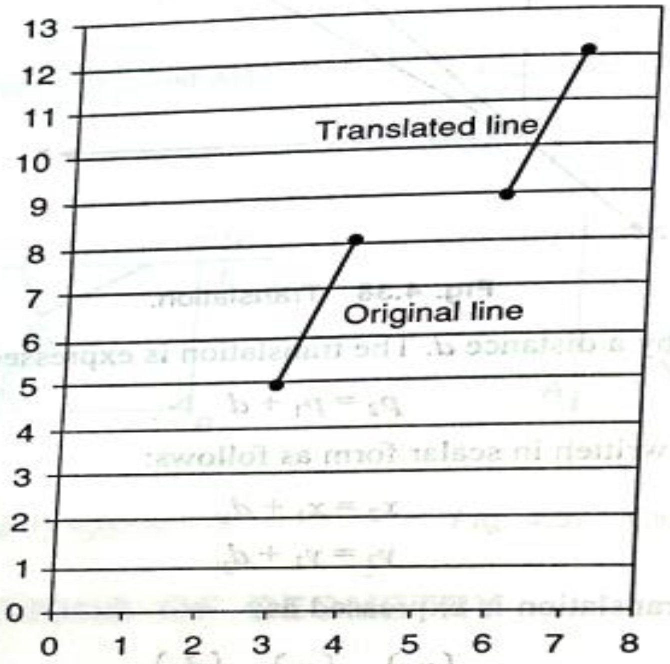


Fig. 4.39 The effect of translation of a line.

4.12.2 Scaling

In scaling transformation, the original coordinates of an object are multiplied by the given scale factor (Figure 4.40). There are two types of scaling transformations: uniform and non-uniform. In the uniform scaling, the coordinate values change uniformly along the x, and y coordinates, whereas in non-uniform scaling, the change is not necessarily the same in all the coordinate directions.

Uniform Scaling

For uniform scaling, the scaling transformation matrix is given as:

$$S = \begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} \tag{4.21}$$

Here, s is the scale factor.

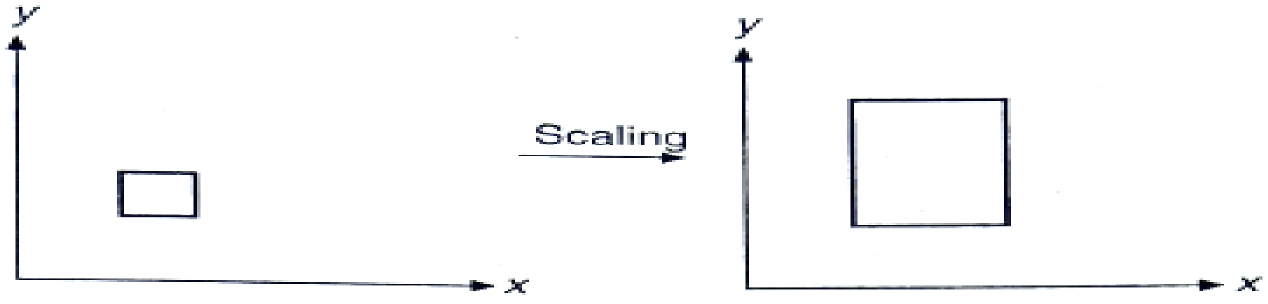


Fig. 4.40 Scaling.

Non-uniform Scaling

Matrix equation of a non-uniform scaling has the form:

$$S = \begin{bmatrix} s_x & 0 \\ 0 & s_y \end{bmatrix} \tag{4.23}$$

where s_x and s_y are the scale factors for the x and y coordinates of the object.

Example 4.7 If the triangle $A(1, 1)$, $B(2, 1)$, $C(1, 3)$ is scaled by a factor 2, find the new coordinates of the triangle.

Solution

Given: $A(1, 1)$, $B(2, 1)$, $C(1, 3)$

The uniform scale factor is 2.

The new coordinates of $A = \begin{Bmatrix} x \\ y \end{Bmatrix} = \begin{Bmatrix} 1 \\ 1 \end{Bmatrix} \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix} = \begin{Bmatrix} 2 \\ 2 \end{Bmatrix}$

The new coordinates of $B = \begin{Bmatrix} x \\ y \end{Bmatrix} = \begin{Bmatrix} 2 \\ 1 \end{Bmatrix} \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix} = \begin{Bmatrix} 4 \\ 2 \end{Bmatrix}$

The new coordinates of $C = \begin{Bmatrix} x \\ y \end{Bmatrix} = \begin{Bmatrix} 1 \\ 3 \end{Bmatrix} \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix} = \begin{Bmatrix} 2 \\ 6 \end{Bmatrix}$

The graphical representation of scaling is shown in Figure 4.41.

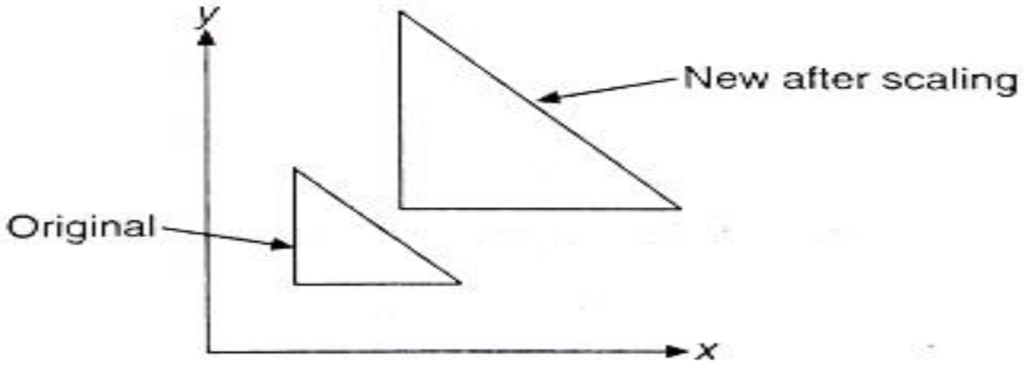


Fig. 4.41 Effect of scaling.

4.12.3 Rotation

Rotation of a point through an angle θ about x or y or z is sometimes referred to as rotation about the origin. A rotation in the counter-clockwise direction is considered as positive. The rotation of a point in space is shown in Figure 4.42.

The final position of p after rotation is shown as point p^*. The coordinates of p^* are given by:

$$x^* = r\cos(\alpha+\theta) = r\cos\alpha\cos\theta - r\sin\alpha\sin\theta$$

$$y^* = r\sin(\alpha+\theta) = r\sin\alpha\cos\theta - r\cos\alpha\sin\theta \tag{4.23}$$

where

$$x = r\cos\alpha \text{ and } y = r\sin\alpha \tag{4.24}$$

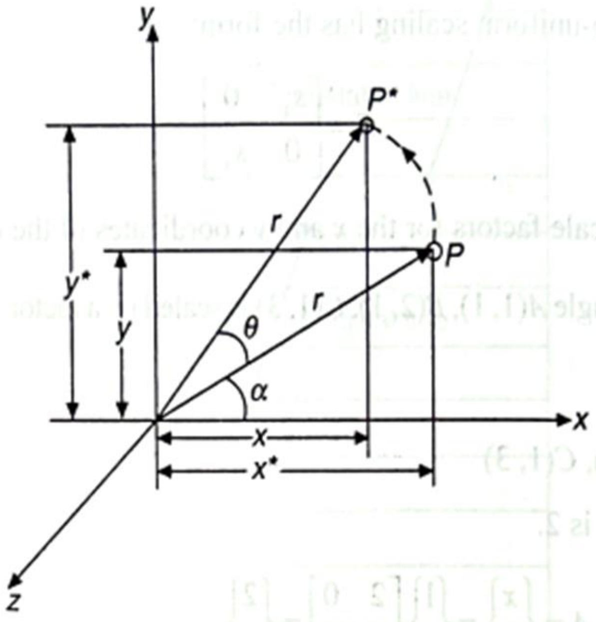


Fig. 4.42 Rotation.

Substituting Equation 4.24 into Equation 4.25 gives:

$$x^* = x\cos\theta - y\sin\theta \text{ and } y^* = x\cos\theta + y\sin\theta \tag{4.25}$$

Rewriting Equation 4.25 in a matrix form gives:

$$\begin{Bmatrix} x^* \\ y^* \end{Bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{Bmatrix} x \\ y \end{Bmatrix} \tag{4.26}$$

Rotation about z-axis is given by:

$$R_z = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \tag{4.27}$$

Rotation about y-axis is accomplished similarly and is given by:

$$R_y = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \tag{4.28}$$

Rotation about x-axis is accomplished similarly and is given by:

$$R_x = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \tag{4.29}$$

Example 4.8 The line defined by two endpoints $A(1, 1)$ and $B(2, 4)$ is rotated by 30°. Determine the transformed line.

Solution

The rotation matrix is given by:

$$A(x^*, y^*) = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{Bmatrix} 1 \\ 1 \end{Bmatrix} = (0.37, 1.37)$$

$$B(x^*, y^*) = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{Bmatrix} 2 \\ 4 \end{Bmatrix} = (-0.27, 4.46)$$

The effect of rotation is shown in Figure 4.43

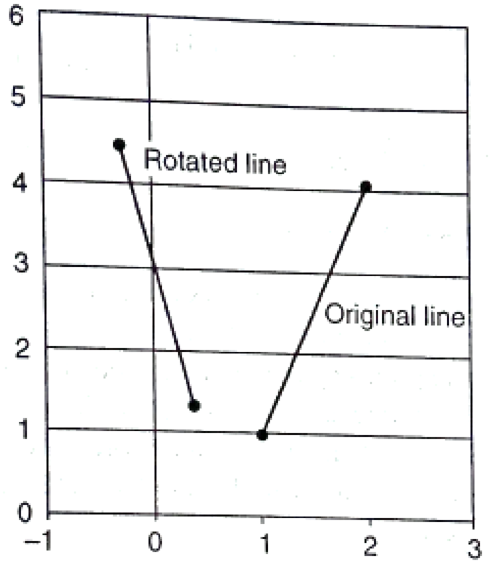


Fig. 4.43 Effect of rotation.

4.12.4 Concatenation

Most applications require the use of more than one basic transformation to achieve the desired results. In such cases, the combined transformation matrix is obtained by multiplying the respective transformation matrices. This process is called concatenation. The concatenation matrix is given by:

$$C = T_n T_{n-1} \ldots T_2 T_1 \tag{4.30}$$

Example 4.9 In the text, a point (3, 2) is to be scaled by a factor of 2 and rotated by 45°. Determine the transformed position using (i) sequential transformations and (ii) concatenated transformation matrix.

Solution

(i) Sequential transformations:

The effect of scaling is given by:

$$(x', y') = \begin{Bmatrix} 3 \\ 2 \end{Bmatrix} \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix} = (6, 4)$$

The effect of rotation is given by:

$$(x'', y'') = \begin{Bmatrix} 6 \\ 4 \end{Bmatrix} \begin{bmatrix} \cos 45 & -\sin 45 \\ \sin 45 & \cos 45 \end{bmatrix} = (7.07, 1.41)$$

(ii) Using the concatenation matrix:

The concatenation matrix is given by:

$$C = \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix} \begin{bmatrix} \cos 45 & -\sin 45 \\ \sin 45 & \cos 45 \end{bmatrix} = \begin{bmatrix} 1.414 & 1.414 \\ 1.414 & 1.414 \end{bmatrix}$$

The effect of concatenation is given by:

$$(x'', y'') = \begin{bmatrix} 3 \\ 2 \end{bmatrix} \begin{bmatrix} 1.414 & -1.414 \\ 1.414 & 1.414 \end{bmatrix} = (7.07, 1.41)$$

The same result is obtained by concatenating the two separate transformations.

4.12.7 Three-dimensional (3-D) Transformations

A three-dimensional object has a three-dimensional geometry, and therefore, it requires a three-dimensional coordinate transformation. A right-handed coordinate system is used to carry out a three-dimensional transformation. The scaling and translation transformations are essentially the same as two-dimensional transformations. However, the points matrix will have a non-zero third column. Additionally, the transformation matrices contain some non-zero values in the third row and third column, as shown below.

The translational transformation matrix in homogeneous coordinates is given by:

$$\begin{Bmatrix} x^* \\ y^* \\ z^* \\ 1 \end{Bmatrix} = \begin{bmatrix} 1 & 0 & 0 & d_x \\ 0 & 1 & 0 & d_y \\ 0 & 0 & 1 & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} x \\ y \\ z \\ 1 \end{Bmatrix} \tag{4.37}$$

The translational matrix is given by:

$$T = \begin{bmatrix} 1 & 0 & 0 & d_x \\ 0 & 1 & 0 & d_y \\ 0 & 0 & 1 & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{4.38}$$

The scaling matrix is given by:

$$S = \begin{bmatrix} s_x & 0 & 0 & 0 \\ 0 & s_y & 0 & 0 \\ 0 & 0 & s_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{4.39}$$

The rotational matrix about the z-axis is given by:

$$R_z = \begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{4.40}$$

The rotational matrix about the y-axis is given by:

$$R_y = \begin{bmatrix} \cos\theta & 0 & \sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta & 0 & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{4.41}$$

The rotational matrix about the z-axis is given by:

$$R_x = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta & 0 \\ 0 & \sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{4.42}$$

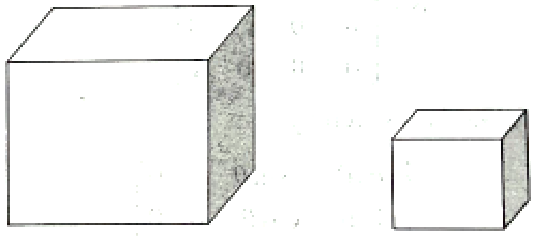
Example 4.10 The coordinates of a cube are (0, 0, 0), (2, 0, 0), (2, 2, 0), (0, 2, 0), (0, 0, 2), (2, 0, 2), (2, 2, 2), (0, 2, 2). Scale the cube uniformly by 1/2.

Solution

The effect of scaling is given by:

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

The results of scaling of the cube are shown in Figure 4.46.



(a) Original cube (b) Scaled cube

Fig. 4.46 Effect of scaling.