UNIT I

COMPUTER AIDED DESIGN

Introduction:

It involves any type of design activity which make use of computer to develop activity which make use of the computer to develop analysis or modify an engineering design known as CAD which make use of interactive computer graphics

Definition:

It is a software used to create electronic files for print, machining and other manufacturing operations , cad arrival increased the productivity of designers and improved the quality of design amongst other benefits.

There are several fundamental reasons for implementing a computer-aided design system.

1. To increase the productivity of the designer.
2. To improve the quality of design.
3. To improve communications
4. To create a database for manufacturing.

THE DESIGN PROCESS

1. Recognition of need
2. Definition of problem
3. Synthesis
4. Analysis and optimization
5. Evaluation
6. Presentation

THE APPLICATION OF COMPUTERS FOR DESIGN:

The various design-related tasks which are performed by a modem computer-aided design-system can be grouped into four functional areas:

l. Geometric modeling

2. Engineering analysis

3. Design review and evaluation

4. Automated drafting

Geometric modeling

In computer-aided design, geometric modeling is concerned with the computer-compatible mathematical description of the geometry of an object. The mathematical description allows the image of the object to be displayed and manipulated on a graphics terminal through signals from the CPU of the CAD system. The software that provides geometric modeling capabilities must be designed for efficient use both by the computer and the human designer. There are several different methods of representing the object in geometric modeling. The basic form uses wire frames to represent the object. In this form, the object is displayed by interconnecting lines as shown in Figure. Wire frame geometric modeling is classified into three types depending on the capabilities of the ICG system. The three types are:

l. 2D. Two-dimensional representation is used for a flat object.

2. 2½D. This goes somewhat beyond the 2D capability by permitting a three-dimensional object to be represented as long as it has no side-wall details.

3D. This allows for full three-dimensional modeling of a more complex geometry.

Engineering analysis:

In the formulation of nearly any engineering design project, some type of analysis is required. The analysis may involve stress-strain calculations, heat-transfer computations, or the use of differential equations to describe the dynamic behavior of the system being designed. The computer can be used to aid in this analysis work. It is often necessary that specific programs be developed internally by the engineering analysis group to solve a particular design problem. In other situations, commercially available general-purpose programs can be used to perform the engineering analysis.

Design review and evaluation

Checking the accuracy of the design can be accomplished conveniently on the graphics terminal. Semiautomatic dimensioning and tolerance routines which assign size specifications to surfaces indicated by the user help to reduce the possibility of dimensioning errors. The designer can zoom in on part design details and magnify the image on the graphics screen for close scrutiny.

Automated drafting

Automated drafting involves the creation of hard-copy engineering drawings directly from the CAD data base. In some early computer-aided design departments, automation of the drafting process represented the principal justification for investing in the CAD system. Indeed, CAD systems can increase productivity in the drafting function by roughly five times over manual drafting.

BENEFITS OF CAD:

1. Improved engineering productivity
2. Shorter lead times
3. Reduced engineering personnel requirements

4. Customer modifications are easier to make
5. Faster response to requests for quotations
6. Avoidance of subcontracting to meet schedules
7. Minimized transcription errors
8. Improved accuracy of design
9. In analysis, easier recognition of component interactions
10. Provides better functional analysis toreduce prototype testing ll. Assistance in preparation of documentation
l2. Designs have more standardization l3. Better designs provided
l4. Improved productivity in tool design l5. Better knowledge of costs provided
l6. Reduced training time for routine drafting tasks and NC part programming l7. Fewer errors in NC part programming
l8. Provides the potential for using more existing parts and tooling
l9. Helps ensure designs are appropriate to existing manufacturing techniques
20. Saves materials and machining time by optimization algorithms
21. Provides operational results on the status of work in progress
22. Makes the management of design personnel on projects more effective
23. Assistance in inspection of complicated parts
24. Better communication interfaces and greater understanding among engineers, designers, drafters, management, and different project groups.

HARDWARE IN COMPUTER-AIDED DESIGN

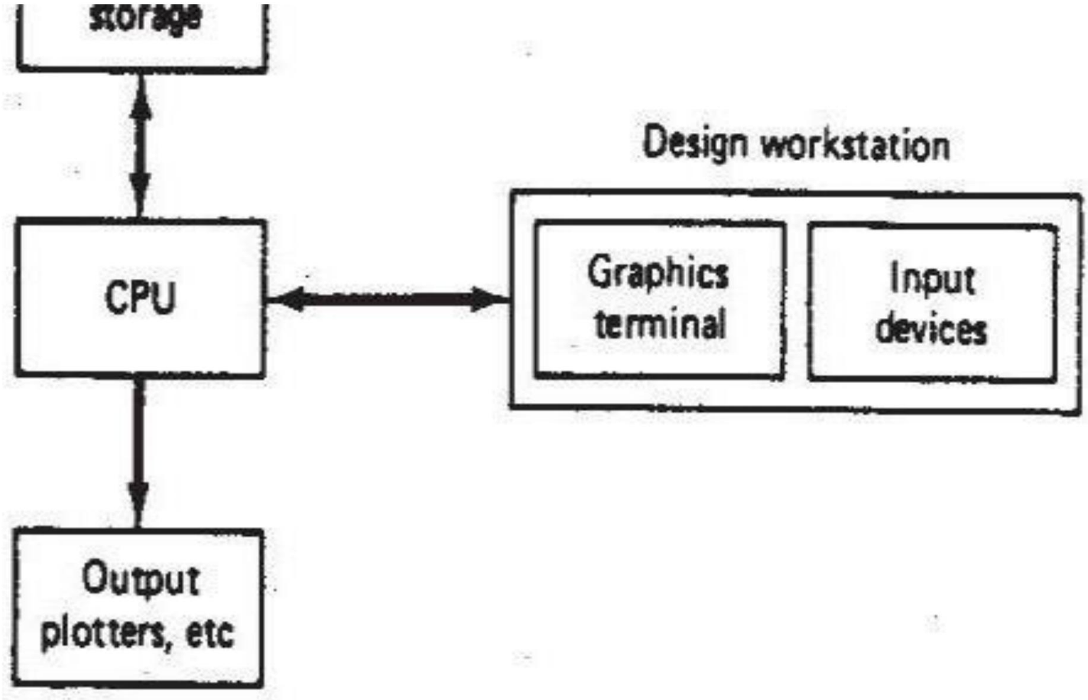
Hardware components for computer-aided design are available in a variety of sizes, configurations, and capabilities. Hence it is possible to select a CAD system that meets the particular computational and graphics requirements of the user firm. Engineering firms that are not involved in production would choose a system exclusively for drafting and design-related functions. Manufacturing firms would choose a system to be part of a company-wide CAD/CAM system.

hardware components

One or more design workstations. These would consist of: A graphics terminal Operator input devices

One or more plotters and other output devices

Central processing unit (CPU) Secondary storage

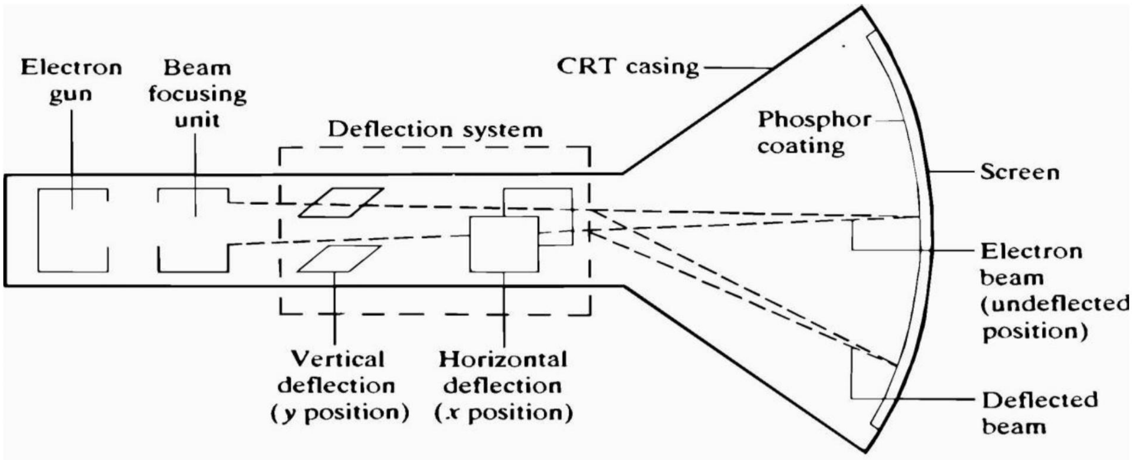


THE DESIGN WORKSTATION

The CAD workstation is the system interface with the outside world. It represents a significant factor in determining how convenient and efficient it is for a designer to use the CAD system. The workstation must accomplish five functions:

1. It must interface with the central processing unit.
2. It must generate a steady graphic image for the user.
3. It must provide digital descriptions of the graphic image.
4. It must translate computer commands into operating functions.
5. It must facilitate communication between the user and the system

A graphics terminal:
cathode ray tube (CRT)



Nearly all computer graphics terminals available today use the cathode ray tube (CRT) as the display device. Television sets use a form of the same device as the picture tube. 'The operation of the CRT is illustrated in Figure. A heated cathode emits a high-speed electron beam onto a phosphor-coated glass screen. 'The electrons energize the phosphor coating, causing it to glow at the points where the beam makes contact. By focusing the electron beam, changing its intensity, and controlling its point of contact against the phosphor coating through the use of a deflector system, the beam can be made to generate a picture on the CRT screen.
There are two basic techniques used in current computer graphics terminals for generating the image on the CRT screen. They are:
l. Stroke writing
2. Raster scan
The stroke-writing system uses an electron beam which operates like a pencil to create a line image on the CRT screen. The image is constructed out of a sequence of straight-line segments. Each line segment is drawn on the screen by directing the beam to move from one point on the screen to the next, where each point is defined by its x and y coordinates. The process is portrayed in Figure . Although the procedure results in images composed of only straight lines, smooth curves can be approximated by making the connecting line segments short enough.

OPERATOR INPUT DEVICES

Operator input devices are provided at the graphics workstation to facilitate convenient communication between the user and the system. Workstations generally have several types of input devices to allow the operator to select the various preprogrammed input functions. These functions permit the operator to create or modify an image on the CRT screen or to enter alphanumeric data into the system. This results in a complete part on the CRT screen as well as complete geometric description of the part m the CAD data base.

Different CAG system vendors offer different types of operator input devices. These devices can be divided into three general categories:

l. Cursor control devices

2. Digitizers

2. Alphanumeric and other keyboard terminals

THE CENTRAL PROCESSING UNIT

The CPU operates as the central "brain" of the computer-aided design system. It is typically a minicomputer. It executes all the mathematical computations needed to accomplish graphics and other functions, and it directs the various activities within the system.

The graphics software is the collection of programs written to make it convenient for a user to operate the computer graphics system. It includes Programmes to generate images on the CRT screen, to manipulate the images, and to accomplish various types of interaction between the user and the system. In addition to the graphics software, there may be additional programs for implementing certain specialized functions related to CAD/CAM. These include design analysis programs(e.g., finite-element analysis and kinematic simulation) and Manufacturing planning programs (e.g., automated process planning and numerical control part programming). This chapter deals mainly with the graphics software.

FUNCTIONS OF A GRAPHICS PACKAGE

To fulfill its role in the software configuration, the graphics package must perform a variety of different functions. these functions can be grouped into function sets. Each set accomplishes a certain kind of interaction between the user and the system. Some of the common function sets are:

Generation of graphic elements Transformations

Display control and windowing functions Segmenting functions

User input functions

2 D TRANSFORMATIONS:

Transformations play an important role in computer graphics to reposition the graphics on the screen and change their size or orientation. To perform a sequence of transformation such as translation followed by rotation and scaling, we need to follow a sequential process

-Translate the coordinates,

-Rotate the translated coordinates, and then

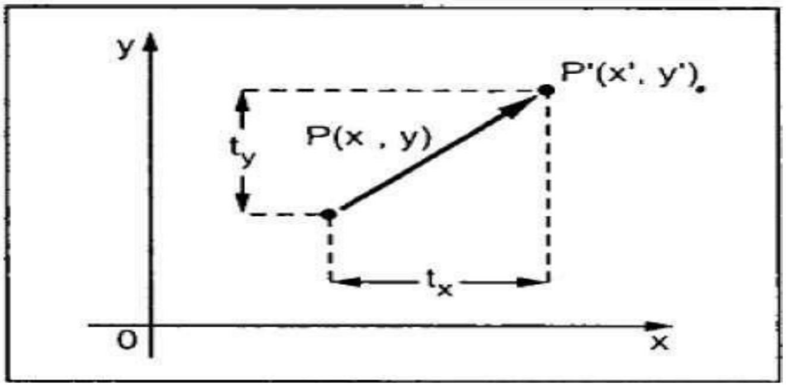
-Scale the rotated coordinates to complete the composite transformation.

-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 have to add an extra dummy coordinate W.

- represent the point by 3 numbers instead of 2 numbers, which is called Homogenous Coordinate system. In this system, we can represent all the transformation equations in matrix multiplication. Any Cartesian point P(X, Y) can be converted to homogenous coordinates by P' (Xh, Yh, h).

Translation

A translation moves an object to a different position on the screen. You can translate a point in 2D by adding translation coordinate (t_x, t_y) to the original coordinate (X, Y) to get the new coordinate (X', Y').



From the above figure, you can write that –

$$X' = X + t_x$$

$$Y' = Y + t_y$$

The pair (t_x, t_y) is called the translation vector or shift vector. The above equations can also be represented using the column vectors.

$$P = \frac{[X]}{[Y]} \quad p' = \frac{[X']}{[Y']} \quad T = \frac{[t_x]}{[t_y]}$$

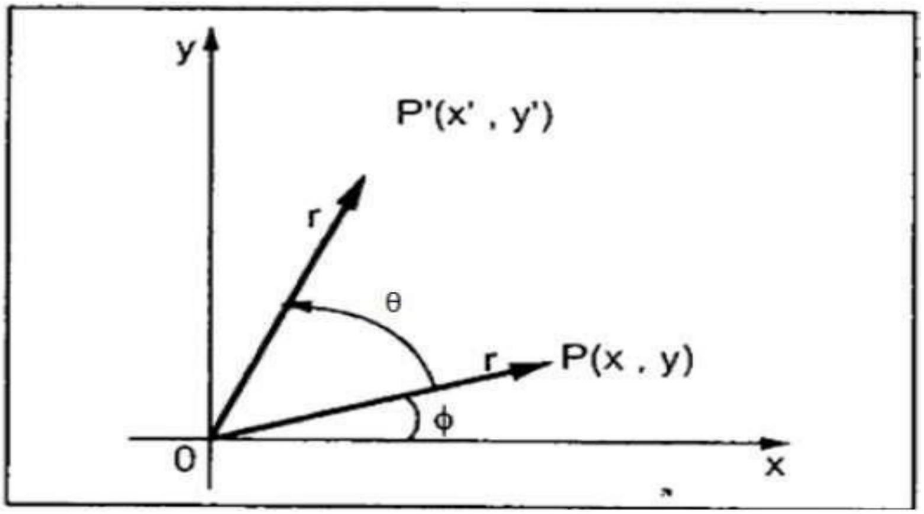
We can write it as –

$$P' = P + T$$

Rotation

In rotation, we rotate the object at particular angle θ (theta) from its origin. From the following figure, we can see that the point P(X, Y) is located at angle φ from the horizontal X coordinate with distance r from the origin.

Let us suppose you want to rotate it at the angle θ. After rotating it to a new location, you will get a new point P' (X', Y').



$$X = r\cos\phi \ldots\ldots (1)$$

$$Y = r\sin\phi \ldots\ldots (2)$$

Same way we can represent the point P′ (X′, Y′) as −

$$x' = r\cos(\phi + \theta) = r\cos\phi\cos\theta - r\sin\phi\sin\theta \ldots\ldots (3)$$

$$y' = r\sin(\phi + \theta) = r\cos\phi\sin\theta + r\sin\phi\cos\theta \ldots\ldots (4)$$

Substituting equation (1) & (2) in (3) & (4) respectively, we will get

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

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

Representing the above equation in matrix form,

$$[X'Y'] = [XY]\begin{bmatrix} cos\theta & sin\theta \\ -sin\theta & cos\theta \end{bmatrix} OR$$

P′ = P . R

Where R is the rotation matrix

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

The rotation angle can be positive and negative.

For positive rotation angle, we can use the above rotation matrix. However, for negative angle rotation, the matrix will change as shown below −

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

$$= \begin{bmatrix} cos\theta & -sin\theta \\ sin\theta & cos\theta \end{bmatrix} (\because cos(-\theta) = cos\theta \; and \; sin(-\theta) = -sin\theta)$$

Scaling

To change the size of an object, scaling transformation is used. In the scaling process, you either expand or compress the dimensions of the object. Scaling can be achieved by multiplying the original coordinates of the object with the scaling factor to get the desired result.

Let us assume that the original coordinates are (X, Y), the scaling factors are (SX, SY), and the produced coordinates are (X’, Y’). This can be mathematically represented as shown below −

X' = X . SX and Y' = Y . SY

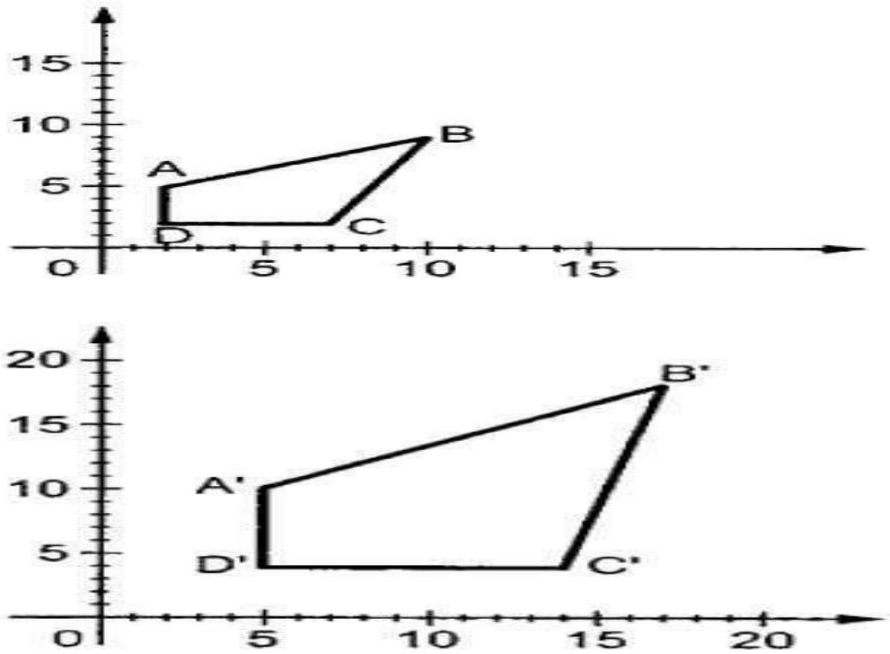
The scaling factor SX, SY scales the object in X and Y direction respectively.
The above equations can also be represented in matrix form as below −

(X′Y′)=(XY)[Sx00Sy](X′Y′)=(XY)[Sx00Sy]

OR

P’ = P . S

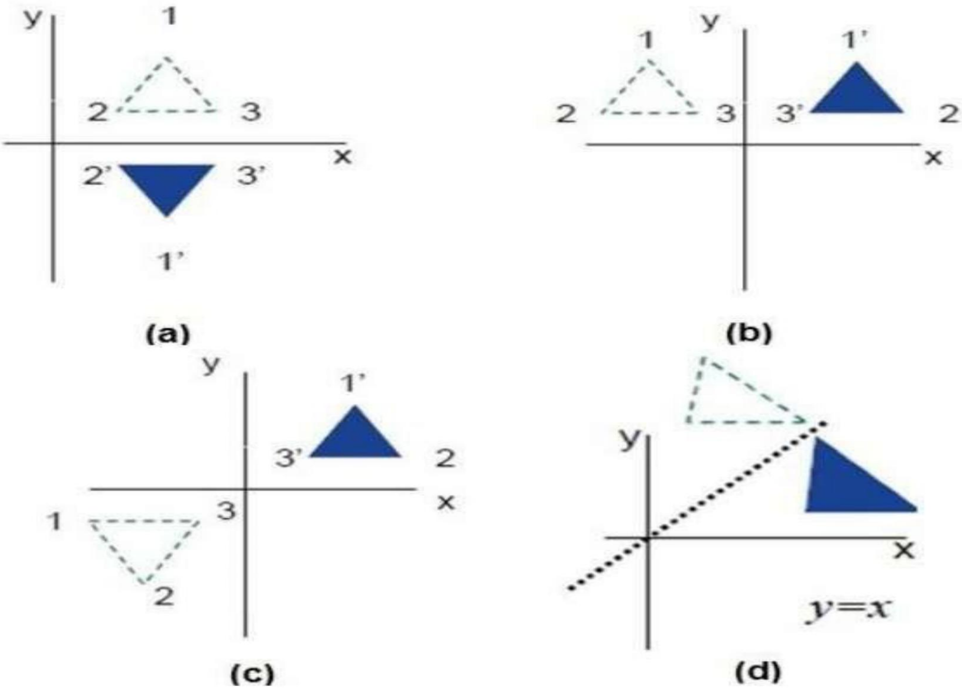
Where S is the scaling matrix. The scaling process is shown in the following figure.



Reflection

Reflection is the mirror image of original object. In other words, we can say that it is a rotation operation with 180°. In reflection transformation, the size of the object does not change.

The following figures show reflections with respect to X and Y axes, and about the origin respectively.

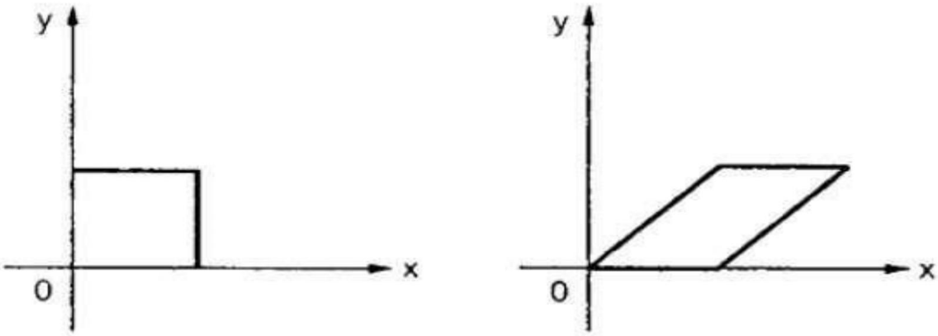


Shear

A transformation that slants the shape of an object is called the shear transformation. There are two shear transformations **X-Shear** and **Y-Shear**. One shifts X coordinates values and other shifts Y coordinate values. However; in both the cases only one coordinate changes its coordinates and other preserves its values. Shearing is also termed as **Skewing**.

X-Shear

The X-Shear preserves the Y coordinate and changes are made to X coordinates, which causes the vertical lines to tilt right or left as shown in below figure.



(a) Original object (b) Object after x shear

The transformation matrix for X-Shear can be represented as −

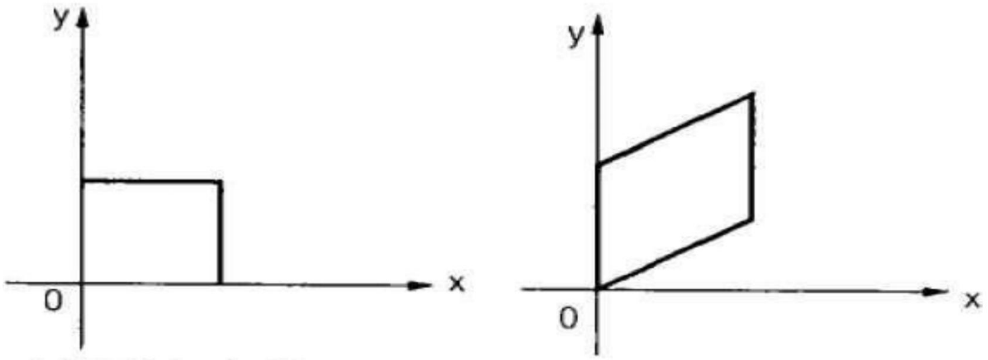
$$X_{sh} = \begin{bmatrix} 1 & shx & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$Y' = Y + Sh_y . X$$

$$X' = X$$

Y-Shear

The Y-Shear preserves the X coordinates and changes the Y coordinates which causes the horizontal lines to transform into lines which slopes up or down as shown in the following figure.



(a) Original object (b) Object after y shear

The Y-Shear can be represented in matrix from as −

$$Y_{sh} \begin{bmatrix} 1 & 0 & 0 \\ shy & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$X' = X + Sh_x . Y$$

$$Y' = Y$$

Composite Transformation:

If a transformation of the plane T1 is followed by a second plane transformation T2, then the result itself may be represented by a single transformation T which is the composition of T1 and T2 taken in that order. This is written as T = T1·T2.

Composite transformation can be achieved by concatenation of transformation matrices to obtain a combined transformation matrix.

A combined matrix − Translation, scaling, Shearing, rotation and reflection

- to rotate an object about an arbitrary point (X_p, Y_p), we have
- to carry out three steps −
  - Translate point (Xp, Yp) to the origin.
  - Rotate it about the origin.
  - Finally, translate the center of rotation back where it belonged.

Viewing transformation:

- the picture is stored in the computer memory using any convenient Cartesian co-ordinate system, referred to as World Co-Ordinate System (WCS). However, when picture is displayed on the display device it is measured in Physical Device Co-Ordinate System (PDCS) corresponding to the display device. Therefore, displaying an image of a picture involves mapping the co-ordinates of the Points and lines that form the picture into the appropriate physical device co-ordinate where the image is to be displayed. This mapping of co-ordinates is achieved with the use of co- ordinate transformation known as viewing transformation.

- The viewing transformation which maps picture co-ordinates in the WCS to display co-ordinates in PDCS is performed by the following transformations.
- Converting world co-ordinates to viewing co-ordinates.
- Normalizing viewing co-ordinates.
- Converting normalized viewing co-ordinates to device co-ordinates.

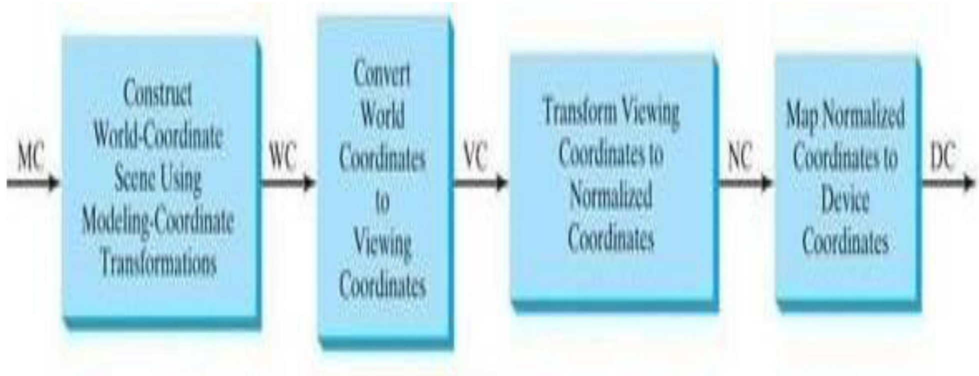


Fig. (c) Two-dimensional viewing transformation pipeline

Window and viewport:

-A world-coordinate area selected for display is called a window. In computer graphics, a window is a graphical control element

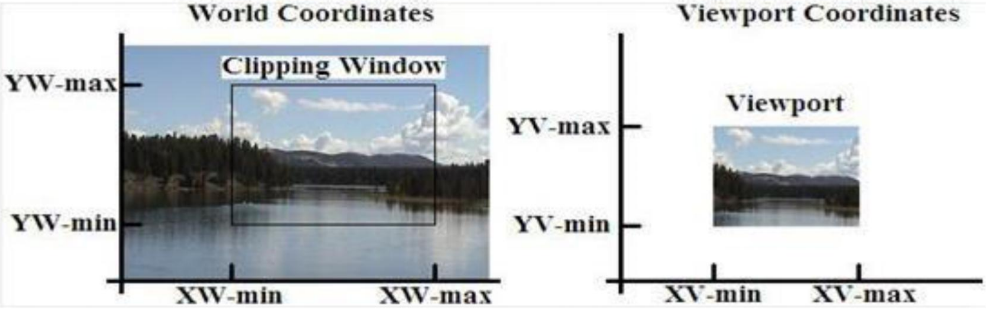
- An area on a display device to which a window is mapped is called a viewport. An area on a display device to which a window is mapped is called a viewport.

Window to viewport transformation:

-Window-to-Viewport transformation is the process of transforming a two- dimensional, world-coordinate scene to device coordinates.

-the clipping window is used to select the part of the scene that is to be displayed. The viewport then positions the scene on the output device.

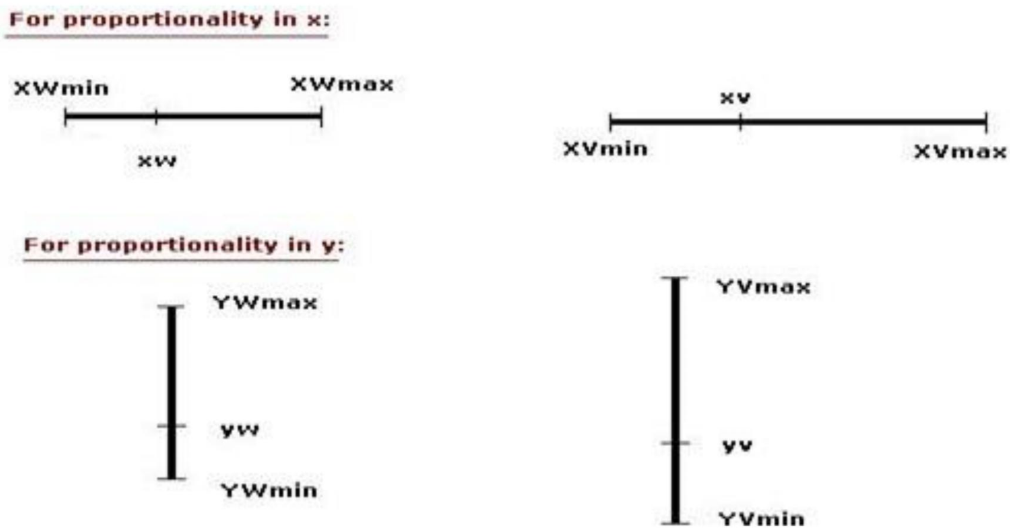
EXAMPLE :



This transformation involves developing formulas that start with a point in the world window, say (xw, yw).

The formula is used to produce a corresponding point in viewport coordinates, say (xv, yv). We would like for this mapping to be "proportional" in the sense that if xw is 30% of the way from the left edge of the world window, then xv is 30% of the way from the left edge of the viewport.

Similarly, if yw is 30% of the way from the bottom edge of the world window, then yv is 30% of the way from the bottom edge of the viewport. The picture below shows this proportionality.



1. Using this proportionality, the following ratios must be equal.

$$\frac{xv - xv_{min}}{xv_{max} - xv_{min}} = \frac{xw - xw_{min}}{xw_{max} - xw_{min}}$$

$$\frac{yv - yv_{min}}{yv_{max} - yv_{min}} = \frac{yw - yw_{min}}{yw_{max} - yw_{min}}$$

1. By solving these equations for the unknown viewport position (xv, yv), the following becomes true:

$$xv = S_x xw + t_x$$

$$yv = S_y yw + t_y$$

1. And the translation factors (Tx, Ty) would be:

$$t_x = \frac{xw_{max} xv_{min} - xw_{min} xv_{max}}{xw_{max} - xw_{min}}$$

$$t_y = \frac{yw_{max} yv_{min} - yw_{min} yv_{max}}{yw_{max} - yw_{min}}$$

A point can be translated in 3D by adding translation coordinate (t_x, t_y, t_z) to the original coordinate (X, Y, Z) to get the new coordinate (X′, Y′, Z′).

$$T = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ t_x & t_y & t_z & 1 \end{bmatrix}$$

P′ = P·T

$$[X' \; Y' \; Z' \; 1] = [X \; Y \; Z \; 1] \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ t_x & t_y & t_z & 1 \end{bmatrix}$$

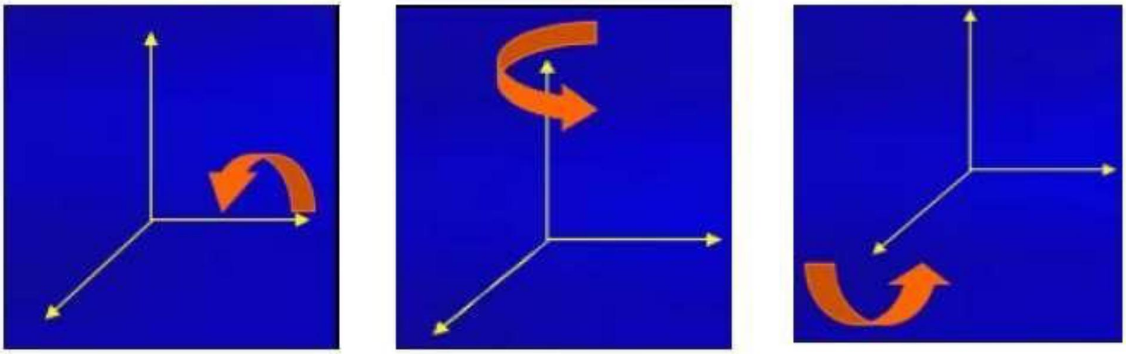
$$= [X + t_x \quad Y + t_y \quad Z + t_z \quad 1]$$

Rotation

3D Transformation :3D rotation is not same as 2D rotation. In 3D rotation, we have to specify the angle of rotation along with the axis of rotation. We can perform 3D rotation about X, Y, and Z axes. They are represented in the matrix form as below –

$$R_x(\theta) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & cos\theta & -sin\theta & 0 \\ 0 & sin\theta & cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} R_y(\theta) = \begin{bmatrix} cos\theta & 0 & sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ -sin\theta & 0 & cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} R_z(\theta)$$
$$= \begin{bmatrix} cos\theta & -sin\theta & 0 & 0 \\ sin\theta & cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

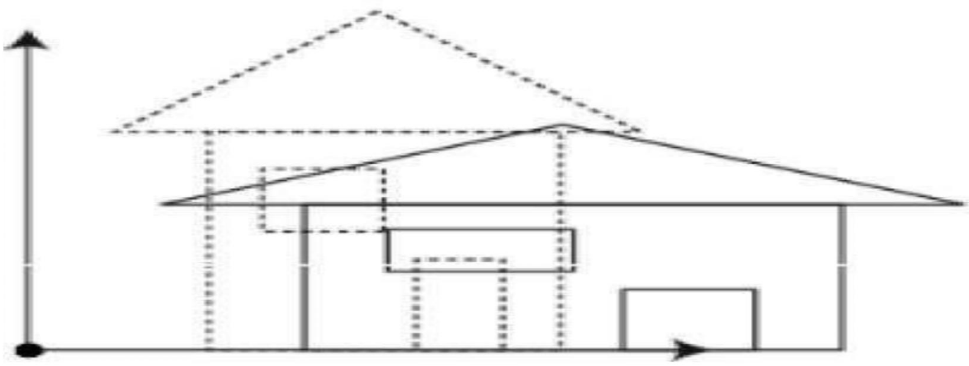
The following figure explains the rotation about various axes –



Rotation about x-axis **Rotation about y-axis** **Rotation about z-axis**

Scaling

-You can change the size of an object using scaling transformation. In the scaling process, you either expand or compress the dimensions of the object. Scaling can be achieved by multiplying the original coordinates of the object with the scaling factor to get the desired result. The following figure shows the effect of 3D scaling



In 3D scaling operation, three coordinates are used. Let us assume that the original coordinates are (X, Y, Z), scaling factors are (SX,SY,Sz)(SX,SY,Sz) respectively, and the produced coordinates are (X’, Y’, Z’). This can be mathematically represented as shown below –

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

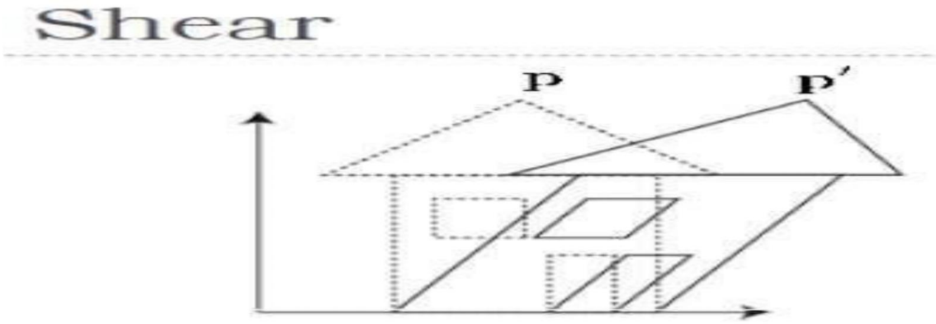
$$P' = P \cdot S$$

$$[X' \quad Y' \quad Z' \quad 1] = [X \quad Y \quad Z \quad 1] \begin{bmatrix} S_x & 0 & 0 & 0 \\ 0 & S_y & 0 & 0 \\ 0 & 0 & S_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= [X.S_x \quad Y.S_y \quad Z.S_z \quad 1]$$

Shear

A transformation that slants the shape of an object is called the shear transformation. Like in 2D shear, we can shear an object along the X- axis, Y-axis, or Z-axis in 3D.



As shown in the above figure, there is a coordinate P. You can shear it to get a new coordinate P', which can be represented in 3D matrix form as below

$$Sh = \begin{bmatrix} 1 & sh_x^y & sh_x^z & 0 \\ sh_y^x & 1 & sh_y^z & 0 \\ sh_z^x & sh_z^y & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$P' = P \cdot Sh$$

$$X' = X + Sh_x^y Y + Sh_x^z Z$$

$$Y' = Sh_y^x X + Y + sh_y^z Z$$

$$Z' = Sh_z^x X + Sh_z^y Y + Z$$