



# IPE-409 CAD/CAM

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# Chapter-4

## Elements of Interactive Computer Graphics

# Computer Graphics

- **Computer graphics** is the use of computers to display and manipulate information in graphical or pictorial form, either on a visual display unit or via a printer.
- Applications of computer graphics are:
  - CAD
  - Computer Art
  - Presentation
  - Entertainment
  - Education and Training
  - Visualization
  - Image processing

# Computer Graphics

- Design models are primarily geometric or graphical in nature
- Computer graphics through system's user interface help the designer
- **Computer graphics** are:
  - Passive or interactive (based on user control)
  - Vector graphics or raster graphics (based on image generation)
  - Image space graphics (Microsoft Paintbrush) or object space graphics (flight simulator)

# Computer Graphics Hardware

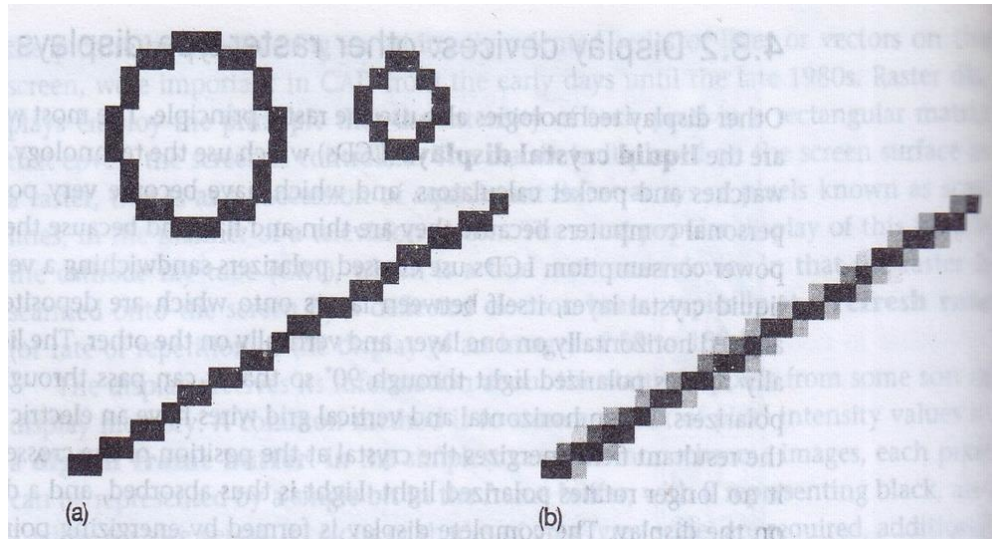
- Display devices-Raster scan, other raster type display and hardcopy devices
- Vector displays drew picture by constructing series of lines or vectors on screen and were popular until 1980s.
- Raster type displays are the most popular now. CRT, LCD, TFT are some raster type display.
- Raster type display uses succession of equidistant linear arrays of pixels.



# Computer Graphics Hardware

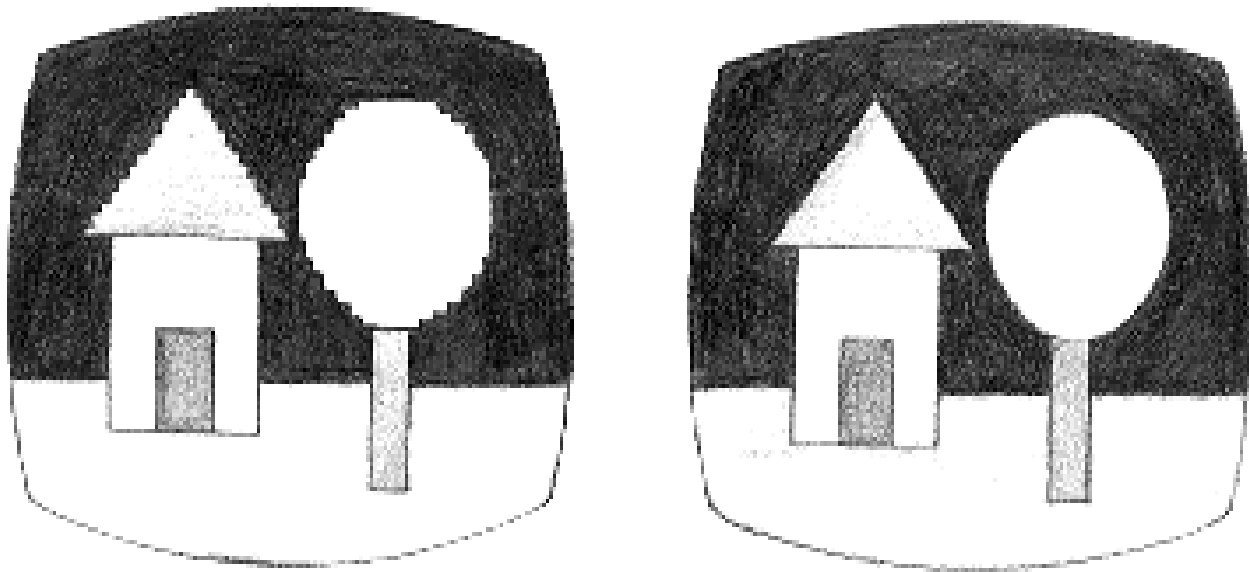
- Drawbacks of raster display:
  - Poor resolution
  - Line/Curves are not smooth
  - **Staircasing effect** is the stair-stepped appearance of diagonal lines when there are not enough pixels in the image or on screen to represent them realistically.
- How to eliminate/overcome these drawbacks

- **Antialiasing**



# Computer Graphics Hardware

- **Antialiasing:** The pixels that surround the edges of the line are changed to varying shades of gray or color in order to blend the sharp edge into the background.



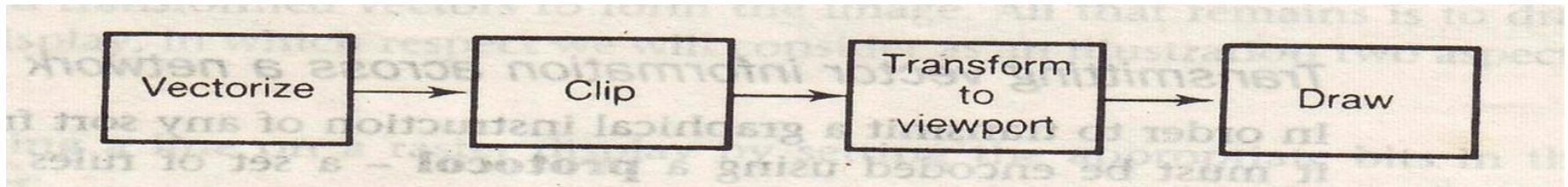
A low-resolution image showing the stair-stepping is on the left. The higher-resolution version is on the right.

# Hard-Copy Devices

- Vector Plotters
- Raster Plotters

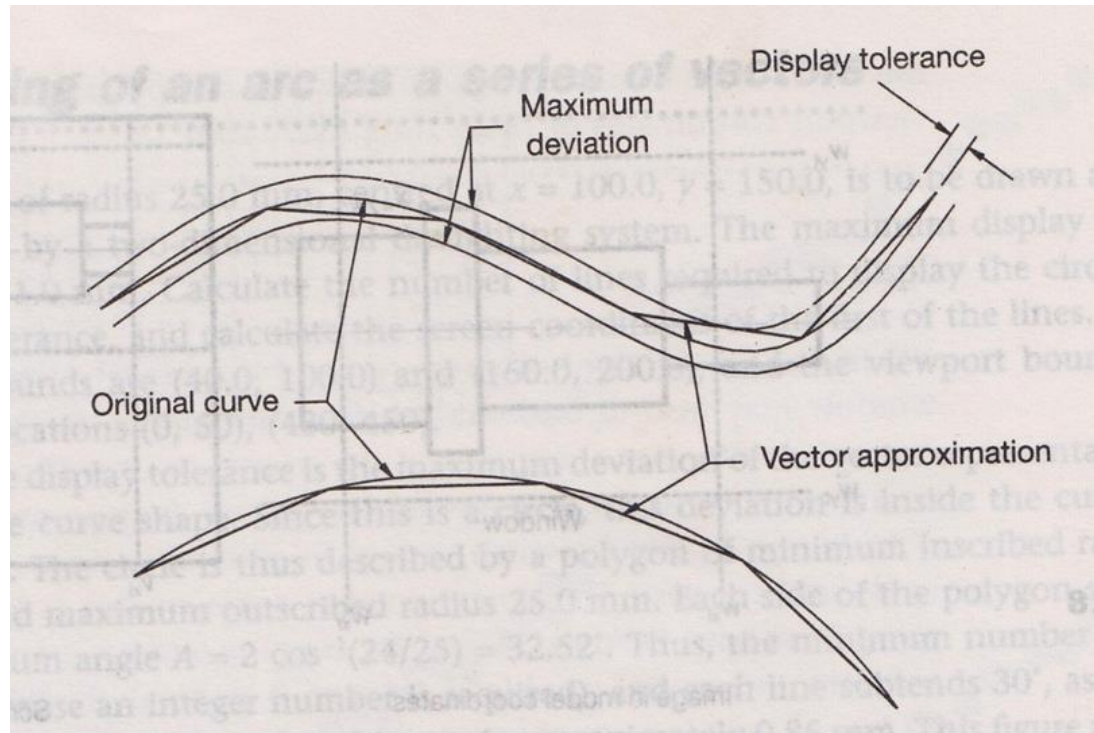
# 2D Computer Graphics

- Model is 2D or 3D, but VDU is 2D with display being defined by integer numerical coordinates.
- Computer graphics in CAD transform the design model to display in an efficient manner.
- Steps are:
  - Convert geometric representation of model in series of lines.
  - Map or transform model coordinate system to screen coordinate system.
  - Select the lines that will be visible.
  - Instruct the display device to draw the lines.

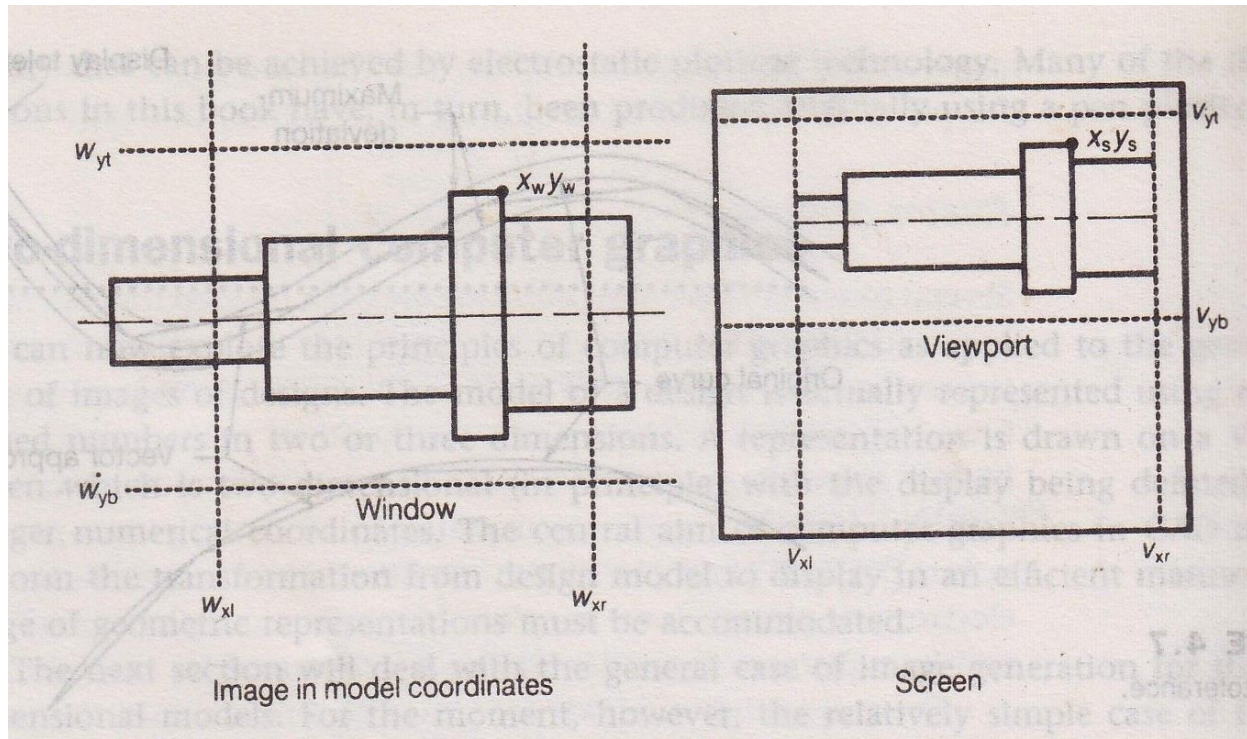


# 2D Computer Graphics

Vector generation-number of lines depends on tolerances i.e. the maximum deviation from true curve.



# Windowing transformation



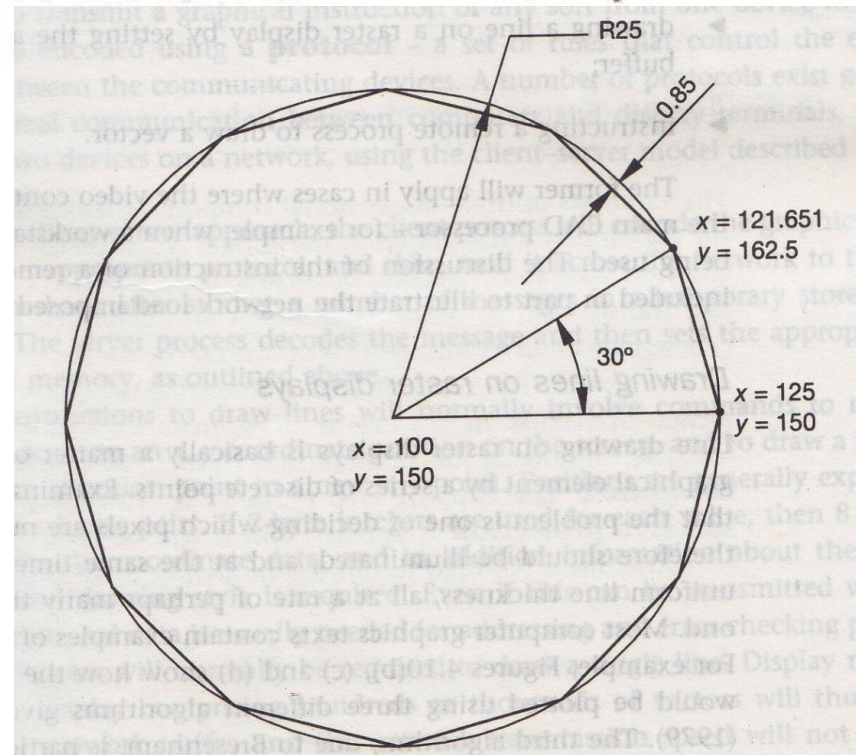
$$x_s = \frac{(v_{xr} - v_{xl})}{(w_{xr} - w_{xl})} (x_w - w_{xl}) + v_{xl}$$

$$y_s = \frac{(v_{yt} - v_{yb})}{(w_{yt} - w_{yb})} (y_w - w_{yb}) + v_{yb}$$

# Windowing transformation

## Drawing of an arc as a series of vectors

A circle of radius 25.0 mm, centred at  $x = 100.0$ ,  $y = 150.0$ , is to be drawn as a series of lines by a two-dimensional draughting system. The maximum display tolerance used is 1.0 mm. Calculate the number of lines required to display the circle within this tolerance, and calculate the screen coordinates of the first of the lines. The window bounds are (40.0, 100.0) and (160.0, 200.0), and the viewport bounds are at pixel locations (0, 50), (480, 450).



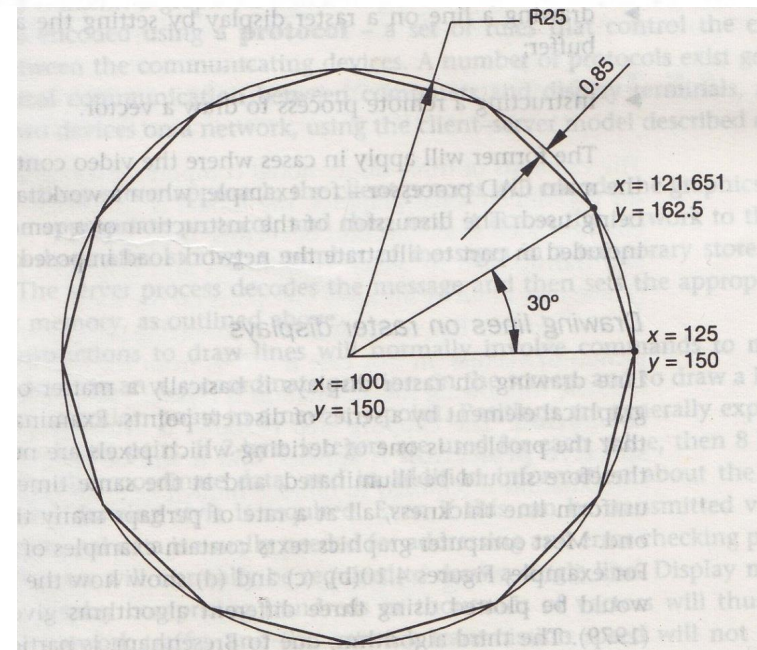
# Windowing transformation

The display tolerance is the maximum deviation of the vector representation from the true curve shape. Since this is a circle, this deviation is inside the curve for all vectors. The circle is thus described by a polygon of minimum inscribed radius 24.0 mm and maximum outscribed radius 25.0 mm. Each side of the polygon subtends a maximum angle  $A = 2 \cos^{-1}(24/25) = 32.52^\circ$ . Thus, the minimum number of lines is 12 (because an integer number is required), and each line subtends  $30^\circ$ , as shown in Figure 4.9. The tolerance in this case is approximately 0.85 mm. This figure also shows that the coordinates of the first line in the display are (125.0, 150.0), (121.651, 162.5).

The expressions for the window transformation in this case are:

$$x_s = \frac{(480 - 0)}{(160.0 - 40.0)} (x_w - 40.0) + 0$$

$$y_s = \frac{(450 - 50)}{(200.0 - 100.0)} (y_w - 100.0) + 50$$

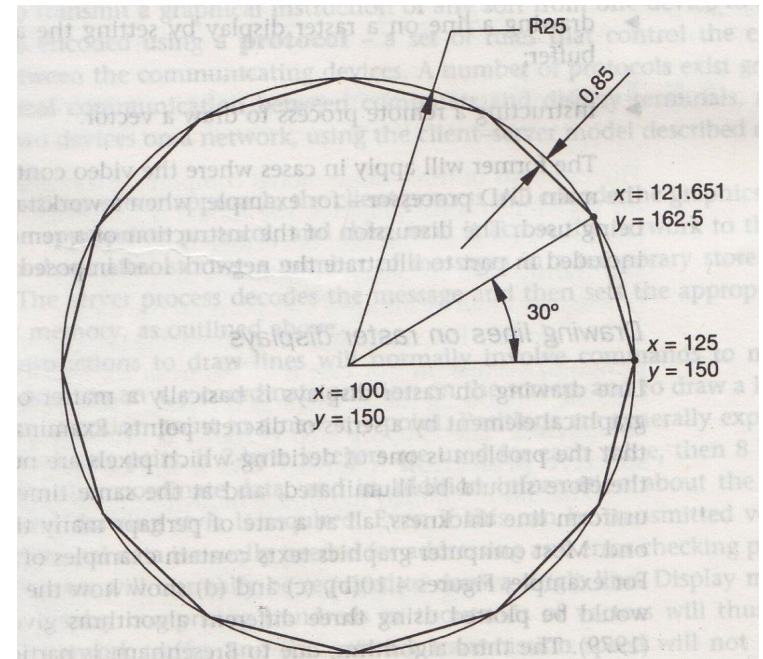


# Windowing transformation

## Drawing of an arc as a series of vectors

A circle of radius 25.0 mm, centred at  $x = 100.0$ ,  $y = 150.0$ , is to be drawn as a series of lines by a two-dimensional draughting system. The maximum display tolerance used is 1.0 mm. Calculate the number of lines required to display the circle within this tolerance, and calculate the screen coordinates of the first of the lines. The window bounds are (40.0, 100.0) and (160.0, 200.0), and the viewport bounds are at pixel locations (0, 50), (480, 450).

Viewport Coordinates: (340,250), (327, 300)



# 3D Computer Graphics

**Viewing Transformation:** Rotation, scaling and translation transformation

## Rotation

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

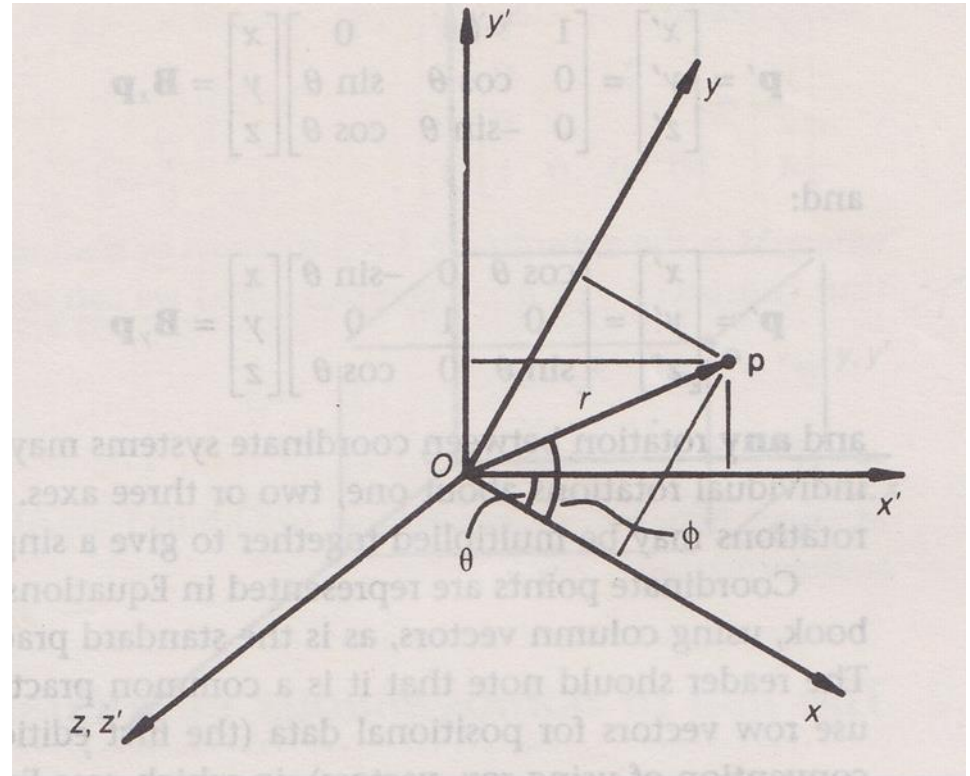
$$y' = r \sin(\phi - \theta)$$

$$z' = z$$

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

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

$$z' = z$$



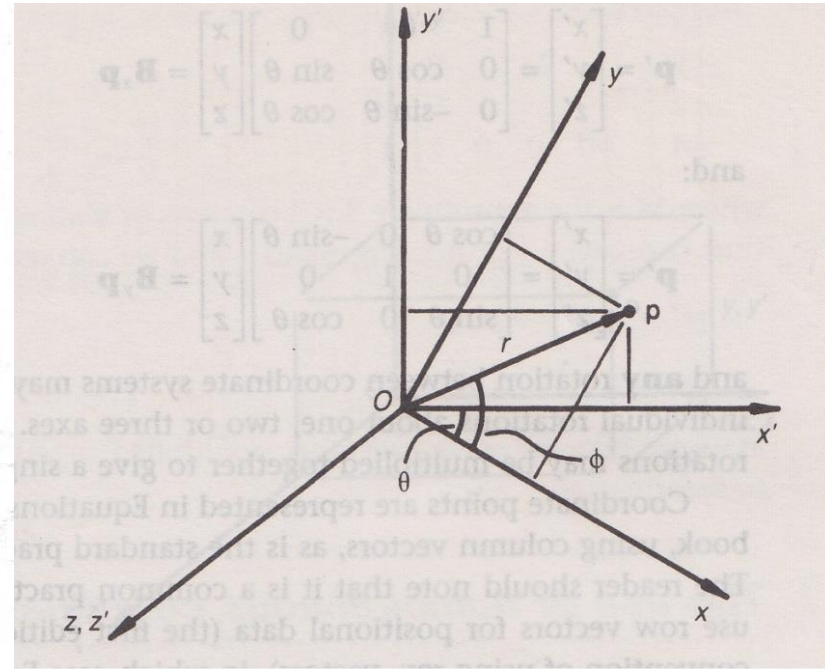
# 3D Computer Graphics

## Rotation

$$\mathbf{p}' = \begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} \cos \theta & \sin \theta & 0 \\ -\sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \mathbf{B}_z \mathbf{p}$$

$$\mathbf{p}' = \begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos \theta & \sin \theta \\ 0 & -\sin \theta & \cos \theta \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \mathbf{B}_x \mathbf{p}$$

$$\mathbf{p}' = \begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} \cos \theta & 0 & -\sin \theta \\ 0 & 1 & 0 \\ \sin \theta & 0 & \cos \theta \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \mathbf{B}_y \mathbf{p}$$



# 3D Computer Graphics

## Scaling

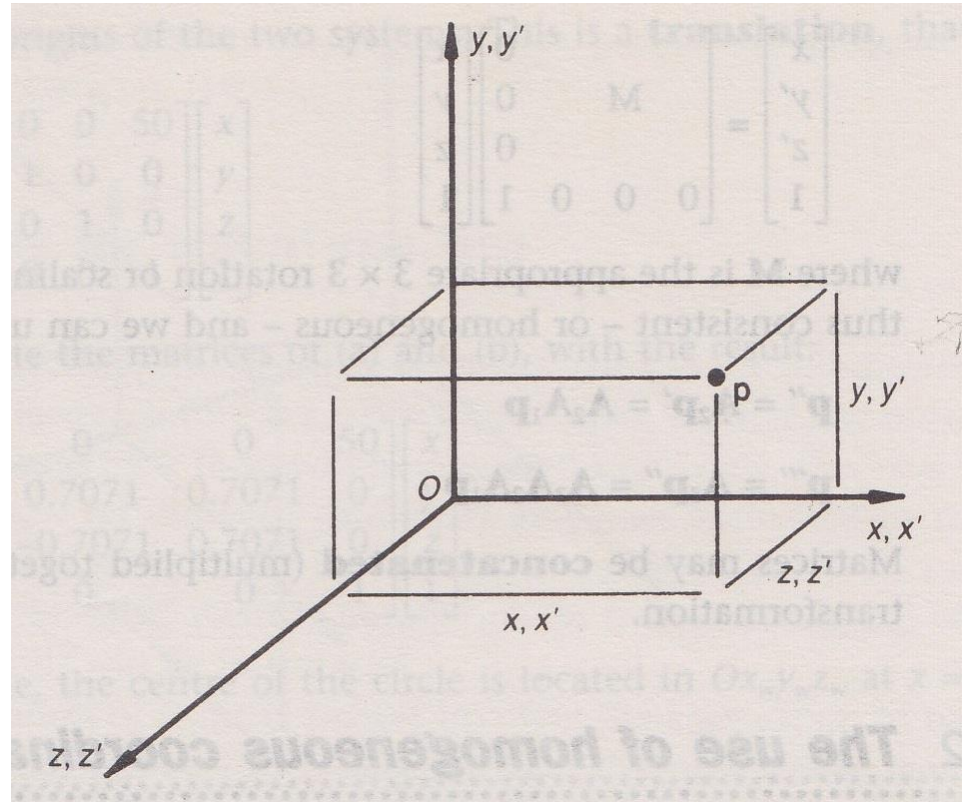
$$x' = x/S$$

$$y' = y/S$$

$$z' = z/S$$

or, in matrix form:

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} 1/S & 0 & 0 \\ 0 & 1/S & 0 \\ 0 & 0 & 1/S \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$



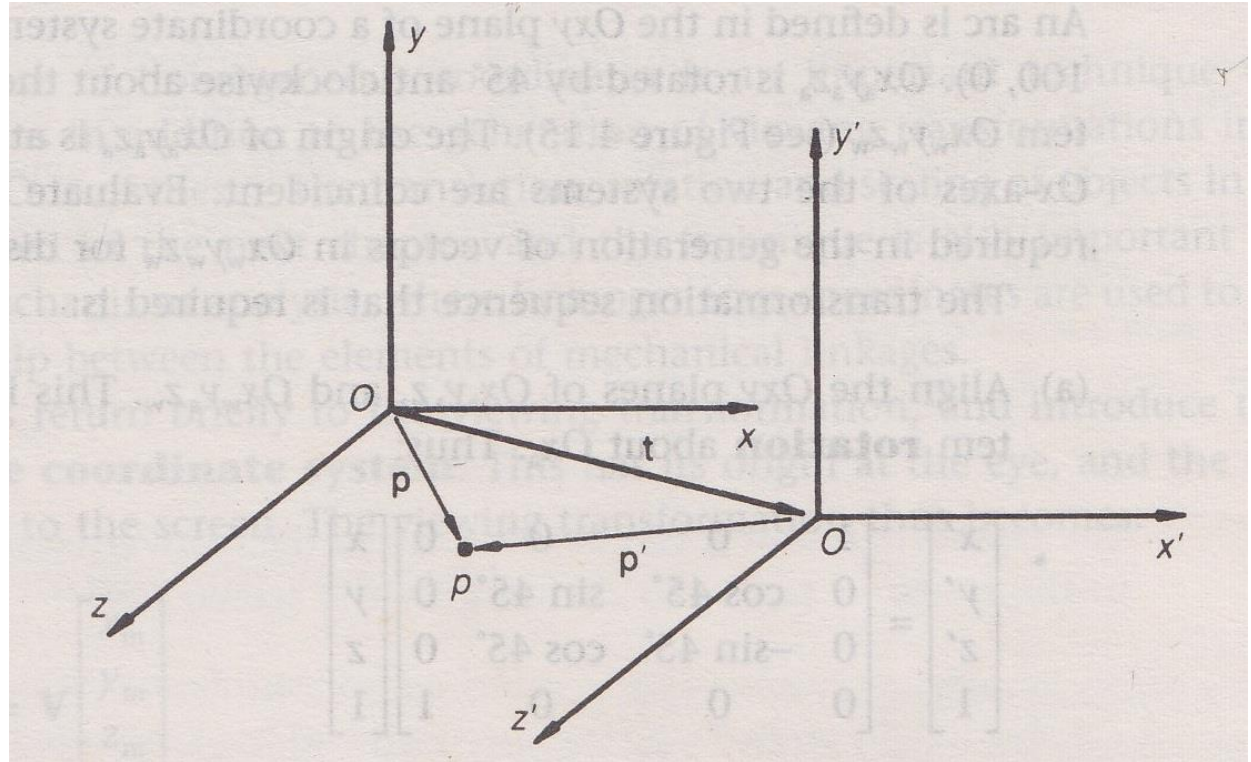
# 3D Computer Graphics

## Translation

$$x' = x - dx$$

$$y' = y - dy$$

$$z' = z - dz$$



$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & -dx \\ 0 & 1 & 0 & -dy \\ 0 & 0 & 1 & -dz \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

# 3D Computer Graphics

## Rotation and Scaling

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} & & & 0 \\ & \mathbf{M} & & 0 \\ & & & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

where  $\mathbf{M}$  is the appropriate  $3 \times 3$  rotation or scaling matrix.

# Hardware for user interaction

- Positioning Devices
- Pointing Devices

# Reference book

- CAD CAM principles, practice and manufacturing management *by Chris McMohan and Jimmie Browne*

***Thank You***