

Chapter – 1 Graphics Systems

1.1 Application areas of Graphics System

Computers have become a powerful tool for the rapid and economical production of pictures. There is virtually no area in which graphical displays cannot be used to some advantage, and so it is not surprising to find the use of computer graphics so widespread. Although early applications in engineering and science had to rely on expensive and cumbersome equipment, advances in computer technology have made interactive computer graphics a practical tool. Today, we find computer graphics used routinely in such diverse areas as science, engineering, medicine, business, industry, government, art, entertainment, advertising, education, and training. Figure 1-1 summarizes the many applications of graphics in simulations, education, and graph presentations. Before we get into the details of how to do computer graphics, we first take a short tour through a gallery of graphics applications.

1.1.1 Presentation Graphics

One of the major application areas is presentation graphics, used to produce illustrations for reports or to generate 35-mm slides or transparencies for use with projectors. It is used to produce illustrations for reports or to generate slide for with projections. Examples of presentation graphics are bar charts, line graphs, surface graphs, pie charts and displays showing relationships between parameters. 3-D graphics can provide more attraction to the presentation. Presentation graphics is commonly used to summarize financial, statistical, mathematical, scientific, and economic data for research reports, managerial reports, consumer information bulletins, and other types of reports. Workstation devices and service bureaus exist for converting screen displays into 35-mm slides or overhead transparencies for use in presentations. Typical examples of presentation graphics are bar charts, line graphs, surface graphs, pie charts, and other displays showing relationships between multiple parameters.

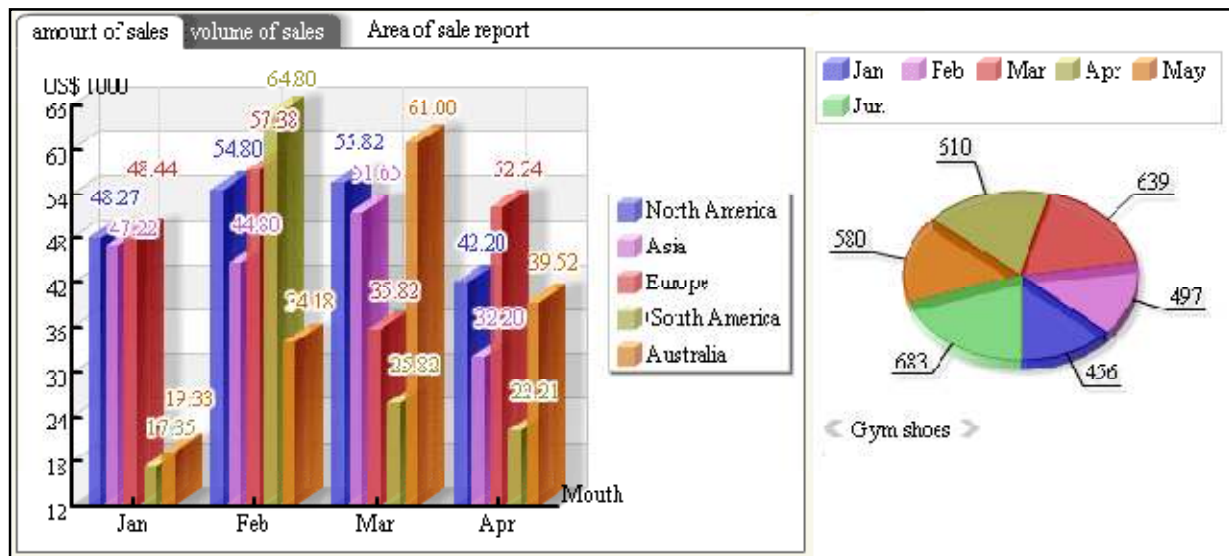


Fig: 1.1 Chart of sale of shoes in 5 continents

Figure 1.1 gives examples of two-dimensional graphics combined with the sale of shoes in 5 different continents for first 6 months. This illustration shows 5 color coded bar charts combined onto one graph and a pie chart with six sections.

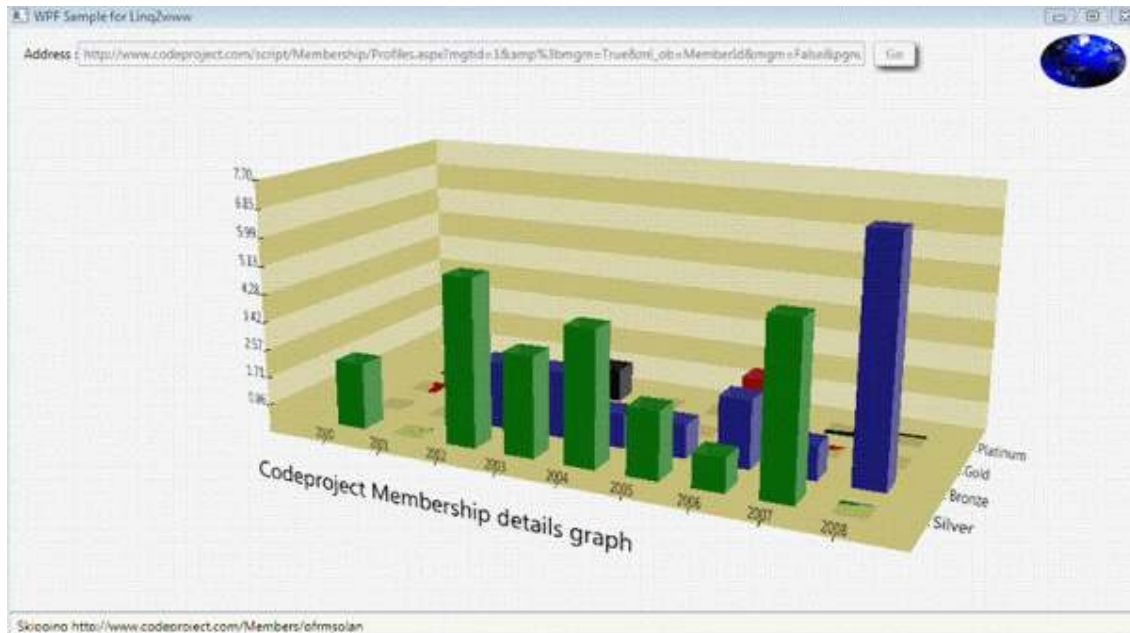


Fig: 1.2 - 3D bar chart for Code project membership details

Similar graphs and charts can be displayed in three dimensions to provide additional information. Three-dimensional graphs are sometime used simply for effect; they can provide a more dramatic or more attractive presentation of data relationships. The charts in Fig. 1.2 include a three-dimensional bar graph.

Three major functions of presentation graphics are:

- An editor that allows text to be inserted and formatted.
- A method for inserting and manipulating graphic images.
- A slide show system to display the content.

The program that helps users to create presentations such as visual aids, handouts, and overhead slides to process artwork, graphics, and text and produce a series of slides which help speakers get their message across are presentation graphics software.

We may say that presentation graphics is more than just power point presentation because it includes any type of slide presentation, bar chart, pie chart, graphs and multimedia presentation. The key advantage of this software is that it helps you show abstracts of representation of work.

1.1.2 Entertainment

Using Computer Graphics, we can represent information in a better and more convincing manner. Today, computer graphics has emerged as a new form of art. The entertainment industry became an area where computer graphics has spread its wings.

Computer graphics methods are now commonly used in making motion pictures, music videos, and television shows. Sometimes the graphics scenes *are* displayed by themselves, and sometimes graphics objects *are* combined with the actors and live scenes.

Many TV series regularly employ computer graphics method. Graphics objects can be combined with a live action. More and more new experiments with computer graphics are being carried out in the entertainment industry.



Fig: 1.3 - Gery's Game



Fig: 1.4 Jurassic Park

1.1.3 Education & Training

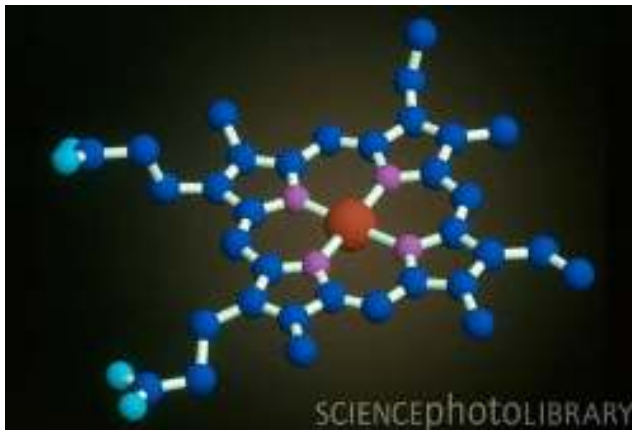


Fig: 1.5 Computer Generated Model of Hemoglobin

Computer-generated models of physical, financial, and economic systems are often used as educational aids. Fig:1.5 demonstrate such model of hemoglobin which is generated with graphics as educational aid for medical students. For some training applications, special systems are designed. Examples of such specialized systems are the simulators for practice sessions captains, aircraft pilots, heavy-equipment operators, and air traffic-control personnel. Some simulators have no video screens; for example, a flight simulator with

only a control panel for instrument flying. But most simulators provide graphics screens for visual operation. Two examples of large simulators with internal viewing systems are shown in Figs. 1.6 and 1.7.



Fig: 1.6 Driving Simulation Software



Fig: 1.7 Flight Simulation Software

1.1.4 Image Processing

Although methods used in computer graphics and Image processing overlap, the two areas are concerned with fundamentally different operations. In computer Graphics, a computer is used to create a picture. **Image processing**, on the other hand applies techniques to modify or interpret existing pictures, such as photographs and TV scans. Two principal applications of image processing are (1) Improving picture quality and (2) machine perception of visual information, as used in robotics.



Fig: 1.8 FUMA an image processing tool established by PhenixVision for various digital radiography

To apply image processing methods, we first digitize a photograph or other picture into an image file. Then digital methods can be applied to rearrange picture parts, to enhance color separations, or to improve the quality of shading. These techniques are used extensively in commercial art applications that involve the retouching and rearranging of sections of photographs and other artwork. Similar methods are used to analyze satellite photos of the earth and photos of galaxies. Medical applications also make extensive use of image processing techniques for picture enhancements, simulations of operations, etc.

1.2 Application areas of Computer Graphics

1.2.1 Computer Graphics Files

The specific file in which an image is saved is computer graphics file. The file format is identified by the three-four letter extension at the end of the file name. Every format has its own characteristics, advantages and disadvantages. By defining the file format it may be possible to determine the number of bits per pixel and additional information.

Format Name	Extension	Graphics Type
Art Gem Project	.agp	Raster
Windows Bitmap	.bmp	Raster
Corel Draw Documents	.cdr	Vector
Graphics Interchange Format	.gif	Raster
Joint Photographic Expert Group	.jpeg, .jpg	Raster
Multiple Image Network Graphics	.mng	Raster
Pixel Coordination Format	.pcf	Raster
Portable Document Format	.pdf	Raster / Vector
Portable Grey Map Format	.pgm	Raster / Vector
Picture	.pic, .pct, .pict	Raster / Vector
Portable Network Graphics	.png	Raster
Photoshop Document	.psd	Raster / Vector
Windows Metafile	.wmf	Vector

Images that may be used by PC computers are saved in various formats. Different image file formats are capable of holding different quantities of colors. Each file format will have a reference to the number of "bits per pixel" that the format is capable of supporting.

- 1 bit per pixel refers to an image with 2 colors.
- 4 bits per pixel refers to an image with up to 16 colors.
- 8 bits per pixel refers to an image with up to 256 colors.

- 16 bits per pixel refers to an image with up to 32,768 colors.
- 24 bits per pixel refers to an image with up to 16,777,216 colors.

1.2.2 Raster Graphics and Vector Graphics

In computer graphics, a **raster graphics** image, or **bitmap**, is a dot matrix data structure representing a generally rectangular grid of pixels, or points of color, viewable via a monitor, paper, or other display medium. Raster images are stored in image files with varying formats.

A bitmap correspond bit-for-bit with an image displayed on a screen, generally in the same format used for storage in the display's video memory, or maybe as a device-independent bitmap. A bitmap is technically characterized by the width and height of the image in pixels and by the number of bits per pixel (a color depth, which determines the number of colors it can represent).

Vector graphics is the use of geometrical primitives such as points, lines, curves, and shapes or polygon(s), which are all based on mathematical expressions, to represent images in computer graphics. Vector graphics are based on vectors (also called paths, or strokes) which lead through locations called control points. Each of these points has a definite position on the x and y axes of the work plan. Each point, as well, is a variety of database, including the location of the point in the work space and the direction of the vector (which is what defines the direction of the track). Each track can be assigned a color, a shape, a thickness and also a fill.

Difference between Raster Graphics and Vector Graphics

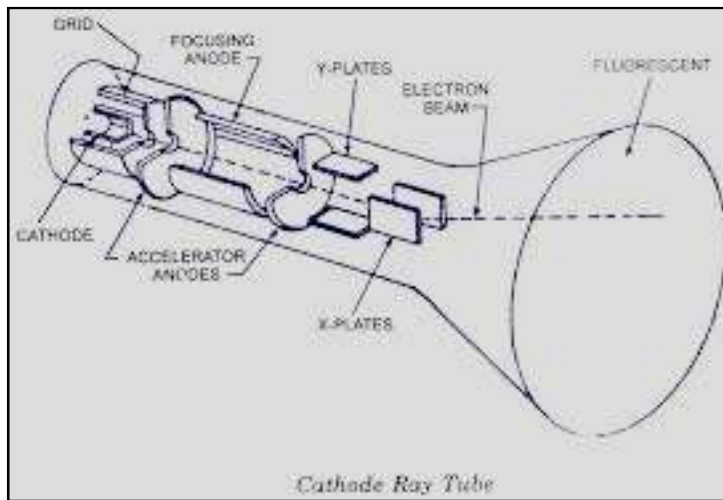
- 1) raster graphics are composed of pixels, while vector graphics are composed of paths. A raster graphic, such as a gif or jpeg, is an array of pixels of various colors, which together form an image. A vector graphic, such as an .eps file or Adobe Illustrator file, is composed of paths, or lines, that are either straight or curved.
- 2) The data file for a vector image contains the points where the paths start and end, how much the paths curve, and the colors that either border or fill the paths.
- 3) Because vector graphics are not made of pixels, the images can be scaled to be very large without losing quality. Raster graphics, on the other hand, become "blocky," since each pixel increases in size as the image is made larger. This is why logos and other designs are typically created in vector format the quality will look the same on a business card as it will on a billboard..

1.3 Video Display Devices

The primary output device in a graphics system is a video monitor. The operation of most video monitors is based on the standard cathode-ray tube (CRT) design, but several other technologies exist and solid-state monitors may eventually predominate. The monitors which are associated with a key board for manual input of characters and display the information as it is keyed in.

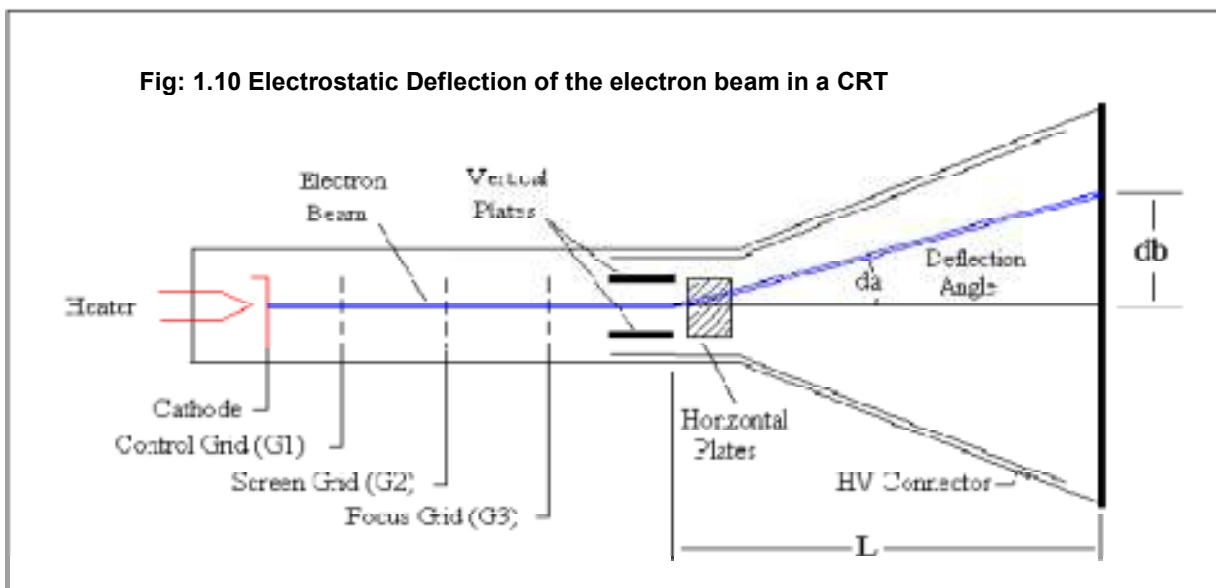
1.3.1 Refresh CRT

Figure 1.2 illustrates the basic operation of a CRT. A beam of electrons (*cathode rays*) is emitted by an electron gun. Then it passes through focusing and deflection systems that direct the beam toward specified positions on the phosphor-coated screen. The phosphor then emits a small spot of light at each position contacted by the electron beam. Because the light emitted by the phosphor fades very rapidly, some method is needed for maintaining the screen picture. One way to keep the phosphor glowing is to redraw the picture repeatedly by quickly directing the electron beam back over the same points. This type of display is called a refresh CRT.



The main components in the electron gun are metal cathodes and control grid. **Cathode** is used to emitting electrons. **Control Grid** is used to control intensity of electron beam.

There is a small hole at the end of control grid. If high negative voltage is applied to the grid then beam will not be able to pass through the hole. If small negative voltage is applied then number of electrons in beam will decrease so amount of light emitted will be less, because it depends on the number of electrons striking the screen. So we can control the brightness of a display by varying the voltage on the control grid.



Focusing system is used to force electron beam to converge in to small spot as it strikes the phosphor, otherwise beam will spread out. The distance to be traveled by the electron beam varies for the different points on the screen. Thus electron beam can be focused property at center of screen. As beam moves towards outer edges, images become blurred. So for that deflection system is used.(Fig: 1.10)

There are many types of phosphors in different persistence are available. i.e. how long they continue to emit light after CRT beam is removed.

Persistent

Is is defined as the time it takes for the light to decrease its intensity to one tenth of its original intensity. For ego if a dot emits 50 units of light and after 2 seconds, it decreases to 5 units (50/10), thus persistence is 2 sec. if persistence is lower, the refresh rate required is higher.

Flicker

When an image keeps flashing continuously on screen it is known as flicker.

Fluorescence

The glowing of phosphor when an electron strike is known as fluorescence.

Resolution

The maximum no of points that can be displayed without overlap is refers as resolution. The precise definition of resolution is: the no of points per centimeter that can be plotted horizontally and vertically. For certain higher quality systems resolution of 1280 X 1024 is used which is known as **High Definition Systems**.

Aspect Ratio

The ration of vertical points to horizontal points necessary to produce equal length lines is called aspect ratio. For eg. aspect ratio of 3/4 means vertical line plotted with 3 points on screen has same length as horizontal line plotted with 4 points.

1.3.2 Color CRT

A color CRT monitor displays color picture by using a combination of phosphors that emit different colored light. By combining the emitted light a range of colors can be generated.

Two basic methods for producing color displays are:

Beam Penetration Method

Random scan monitors use the beam penetration method for displaying color picture. In this, the inside of CRT screen is coated two layers of phosphor namely red and green. A beam of slow electrons excites only the outer red layer, while a beam of fast electrons penetrates red layer and excites the inner green layer. At intermediate beam speeds, combinations of red and green light are emitted to show two additional colors- orange and yellow.

Advantages

Less expensive

Disadvantages

Quality of images is not as good as comparable with other methods Four colors are allowed only

Shadow Mask Method

Raster scan system are use shadow mask methods to produce a much more range of colors than beam penetration method. In this, CRT has three phosphor color dots. One phosphor dot emits a red light, second emits a green light and third emits a blue light. This type of CRT has three electrons guns and a shadow mask grid as shown in figure besides:

In fig-1.11, three electrons beams are deflected and focused as a group onto the shadow mask which contains a series of holes. When three beams pass through a hole in shadow mask they activate dot triangle of 3 colors as sh. see depend on the amount of excitation of red, green and blue phosphor. A white area is a result of all three dots with equal intensity while yellow is produced with green and red dots and so on.

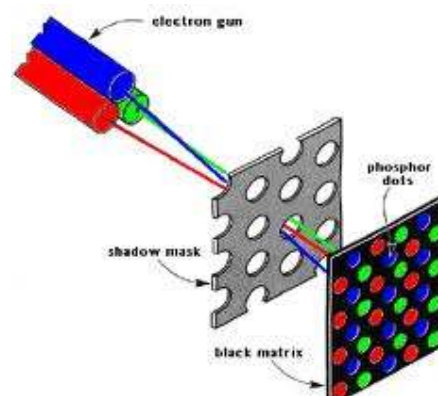


Fig: 1.10 Shadow Masking

Advantages

- Produce realistic images
- Produce different colors
- Shadows scenes

Disadvantages

- Low resolution
- Expensive
- Electron beam directed to whole screen

Full Color System

Color CRTs in graphics systems are designed as RGB monitors. These monitors use shadow mask method and take the intensity level for each gun. A RGB color system with 34 bits of storage per pixel is known as full color system or true color system.

1.3.3 LCD (Liquid Crystal Display)

A liquid crystal display is the most common display type among mobile phones because of its low power consumption and good image quality. They are generally easy to read, even under direct sunlight.

The smallest element of an image displayed on a LCD is the pixel. Each pixel normally consists of a layer of molecules aligned between two transparent electrodes, and two polarizing filters.

Three other types of LCDs are transmissive, reflective, or transfective. Transmissive displays offer nicer image quality in low or medium ambient light, while reflective ones work best in bright ambient light. Transfective displays combine the best of both.

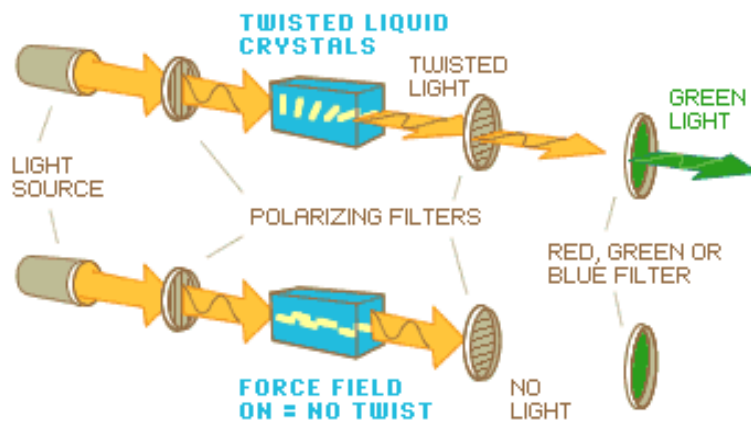


Fig: 1.11 Twisted Liquid Crystals On/Off

In the twisted nematic display, the molecules are arranged in this way. More specifically, the glass surfaces are treated such that the molecular direction is parallel to the admitting direction of each neighboring polarizer. Because these directions are crossed, the molecular direction is confined to a 90° twist from one side of the cell to the other (see figure 1.11).

In this case, what happens is that the light vibration follows this twist from one polarizer to the other, so that all light in fact passes the cell, without being absorbed, in spite of the fact that the polarizers are crossed. Hence, the cell appears bright.

When the light passing through the material is twisted to pass through polarizer and if the voltage turns off then the light is not twisted. This type of device is known as **passive matrix LCD**.

There is a transistor used for each to control the voltage at each pixel locations and to prevent charge from gradually leaking out of the liquid crystal cells. These are known as **active matrix LCD**.

1.4 Random Scan Display

Random scan system uses an electron beam which operates like a pencil to create a line image on the CRT. 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 screen to the next, where each point is defined by its x and y coordinates. After drawing the picture, the system cycles back to the first line and design all the lines of the picture 30 to 60 time each second. When operated as a random-scan display unit, a CRT has the electron beam directed only to the parts of the screen where a picture is to be drawn. Random-scan monitors draw a picture one line at a time and for this reason are also referred to as **vector displays (or stroke-writing or calligraphic displays)**. A pen plotter operates in a similar way and is an example of a random-scan, hard-copy device (Fig: 1.12). **Refresh rate on a random-scan system** depends on the number of lines to be displayed. Picture definition is now stored as a set of line-drawing commands in an area of memory referred to as the refresh display file. Random scan systems are designed for line drawing applications and can-not display realistic shaded scenes. Since picture definition is stored as a set of line-drawing instructions and not as a set of intensity values for all screen points, vector displays generally have higher resolution than raster systems. Also, vector displays produce smooth line drawings because the CRT beam directly follows the line path.

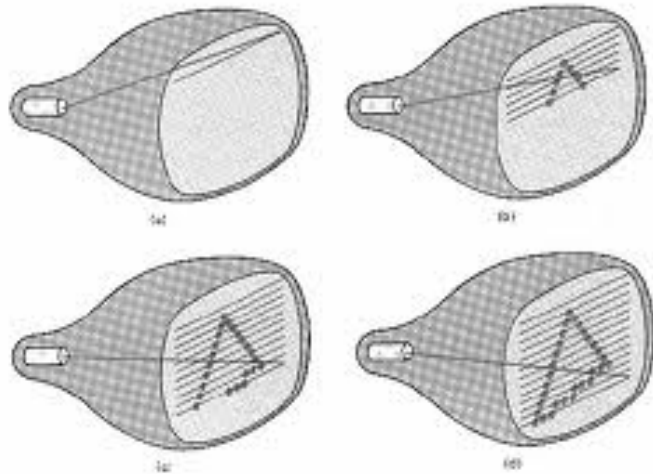


Fig: 1.12 Random scan system draws the component lines of an object in any order specified.

1.5 Raster Scan Display

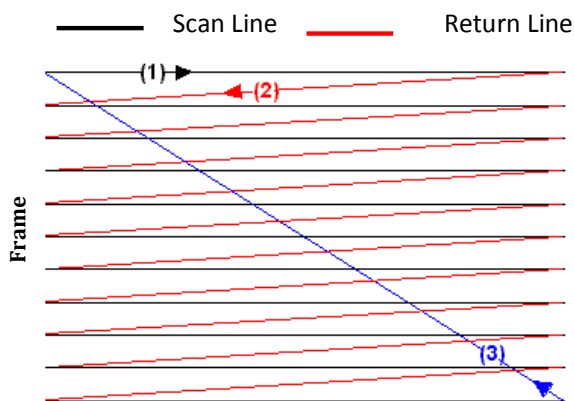


Fig: 1.13 - Raster Scanning
intensity is turned on or off to create pattern. This scanning is also known as **non interlaced scanning**.

Picture definition is stored in memory are called as refresh buffer or frame buffer. It has intensity values for all the screen points. These values are then retrieved and painted on screen one row at a time as shown in fig: 1.14.

Raster scanning is a technique for generating or recording a video image by means of a line-by-line sweep. Television and printers are using raster scan methods. Most common graphics monitor using CRT are raster scan displays. In them, the electron beam is swept from top to bottom, one row at a time. As electron beam moves across each row, the beam

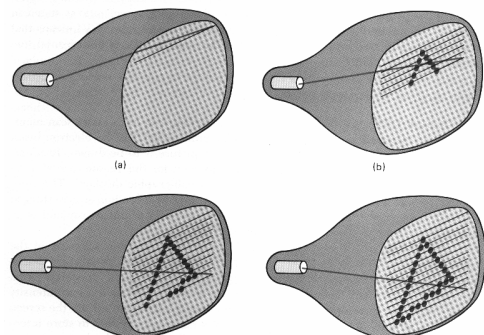


Fig: 1.14 Raster scan system displays an object as set of discrete points across each scan line

Each screen point is called as pixel or pel (Picture Element). Intensity of pixel depends on capability of raster. If there is monochromatic system then each screen point will be either on or off. So one bit per pixel is needed to store intensity of screen points. If color system is there then more number of bits per pixel will be required to store the intensity values. High quality systems can have 24 bits per pixel which will require several megabytes of frame buffer.

Bitmap

For a system having one bit per pixel, frame buffer is called as bitmap.

Pixmap

For a system having multiple bits per pixel, frame buffer is called as pixmap.

Refresh Rate

In raster scan display refreshing is done at rate of 60 to 80 frames per second or more. Refresh rates is measured in cycles per second or Hertz. Cycle corresponds to one frame. E.g. if refresh rate is 60 frames per second then it is called as 60 Hz.

Horizontal Retrace

At the end each line, the electron beam return to left side of the screen. The return to the left of the screen after refreshing each scan line is called as horizontal retrace.

Vertical Retrace

At the end of each frame, the beam returns to top left corner of the screen to start for next frame and is called as vertical retrace.

Interlacing

It is the method of incrementally displaying a visual on a CRT. On some raster scan system, interlaced refresh procedure is used. In this each frame is displayed in two passes. In the first pass, the beam sweeps across alternate scan line from top to bottom. Then after vertical retrace, the beam sweeps remaining scan lines.

Difference between Raster Scan and Random Scan Displays

	Vector / Random Scan Display	Raster Scan Display
1	In vector scan display the beam is moved between the end points of the graphics primitives.	In raster scan display the beam is moved all over the screen one scan line at a time, from top to bottom and then back to top.
2	Vector display flickers when the number of primitives in the buffer becomes too large.	In raster display, the refresh process is independent of the complexity of the image.
3	Scan conversion is not required.	Graphics primitives are specified in terms of their endpoints and must be scan converted into their corresponding pixels in the frame buffer.
4	Scan conversion hardware is not required.	Because each primitive must be scan converted, real time dynamics is far more computational and requires separate scan conversion hardware.
5	Raster display has ability to display areas filled with solid colors or patterns.	Raster display can display mathematically smooth lines, polygons, and boundaries of curved primitives only by approximating them with pixels

		on the raster grid.
6	Cost is more.	Cost is low.
7	Vector display draws continuous and smooth lines.	Vector display only draws line characters.

1.6 Direct View Storage Tube

A direct view storage tube stores the picture information as a charge distribution just behind the phosphor-coated screen. Two electron guns are used in this system as shown in the following figure 1.15. They are: **Primary Gun** and **Flood Gun**

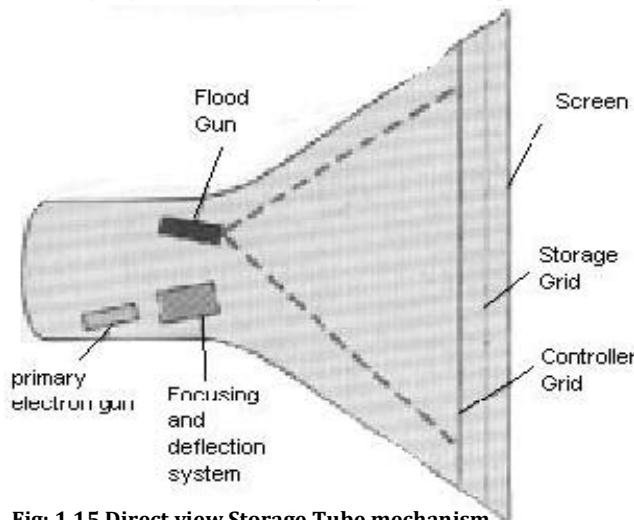


Fig: 1.15 Direct view Storage Tube mechanism

Primary gun is used to store the picture pattern whereas **flood gun** maintains the picture display.

DVST has advantage that no refresh is required so very complex pictures can be displayed at very high resolutions without flicker. Whereas, it has disadvantage that ordinarily no colors can be displayed and that selected parts of a picture cannot be erased. To eliminate a picture section, the entire screen must be erased and the modified picture redrawn. The erasing and redrawing process can take several seconds for a complex picture.

1.7 Introduction to Graphics Standard

With the increasing use of computer graphics in various fields, people around the world introduced more and more new software and graphics programs. This created a serious problem of portability of images and application developed by such systems has come. A program or an application developed on one platform could not be used on the other with the same efficiency and effect. ANSI (American National Standard Institute) and ISO (International Standard Organization) initiated and defined graphics standards to achieve the following objectives:

1. To provide portability to graphics applications.
2. To give better understanding of graphics primitives and methods to the application developers.
3. To provide standard guidelines to graphics hardware manufacturers.

1.7.1 Graphics Kernel System

The Graphical Kernel System (GKS) was the first ISO standard for low-level computer graphics, introduced in 1977. GKS provides a set of drawing features for two-dimensional vector graphics suitable for charting and similar duties. The calls are designed to be portable across different programming languages, graphics devices and hardware, so that applications written to use GKS will be readily portable to many platforms and devices.

GKS was fairly common on computer workstations in the 1980s and early 1990s, and formed the basis of Digital Research's GSX and GEM products; the latter was

common on the Atari ST and was occasionally seen on PCs particularly in conjunction with Ventura Publisher. It was little used outside these markets and is essentially obsolete today except insofar as it is the underlying API defining the Computer Graphics Metafile.

GKS was ANSI standard ANSI X3.124 and ISO standard ISO/IEC 7942. The language bindings are ISO standard ISO 8651. GKS-3D (Graphical Kernel System for Three Dimensions) functional definition is ISO standard ISO 8805 and the C bindings are ISO 8806.^[1]

The functionality of GKS is wrapped up as a data model standard in ISO 10303-46.

1.7.2 *Programmers Hierarchical Interactive GS (PHIGS)*

PHIGS (Programmer's Hierarchical Interactive Graphics System) is an API standard for rendering 3D computer graphics, at one time considered to be the 3D graphics standard for the 1990s. Instead a combination of features and power led to the rise of OpenGL, which became the most popular professional 3D API of the 1990s. PHIGS is still widely used in the computer games and film industries.

PHIGS was available as a standalone implementation (examples: Digital Equipment Corporation's DEC PHIGS, IBM's graPHIGS, Sun's SunPHIGS) and also used with the X Window system, supported via PEX, the "PHIGS Extension to X". PEX consisted of an extension to X, adding commands that would be forwarded from the X server to the PEX system for rendering. Workstations were placed in windows typically, but could also be forwarded to take over the whole screen, or to various printer-output devices.

PHIGS was designed in the 1980s, inheriting many of its ideas from the Graphical Kernel System of the late 1970s, and became an ANSI (ANSI X3.144-1988), FIPS (FIPS 153) and then ISO standard (ISO/IEC 9592 and ISO/IEC 9593) by 1989. Due to its early gestation, the standard supports only the most basic 3D graphics, including basic geometry and meshes, and only the basic Gouraud, "Dot", and Phong shading for rendering scenes. Features considered "standard" today, notably texture mapping, were not supported, nor were many machines of the era physically capable of it (at least in real time).

PHIGS originally lacked the capability to render illuminated scenes and was superseded by PHIGS+. PHIGS+ works in essentially the same manner but added methods for lighting a 3D scene and was often referred to as PHIGS PLUS.

1.7.3 *OpenGL*

OpenGL (Open Graphics Library) is a standard specification defining a cross-language, cross-platform API for writing applications that produce 2D and 3D computer graphics. The interface consists of over 250 different function calls which can be used to draw complex 3D scenes from simple primitives. OpenGL was developed by Silicon Graphics Inc. (SGI) in 1992 and is widely used in CAD, virtual reality, scientific visualization, information visualization, flight simulation, and video games. OpenGL is managed by the non-profit technology consortium Khronos Group.

OpenGL is a standard that specifies a set of functions and their behavior. Basically, OpenGL was specified for C and C++, but later multi-platform bindings were developed.

OpenGL serves two main purposes, to:

1. hide complexities of interfacing with different 3D accelerators by presenting a single, uniform interface
2. hide differing capabilities of hardware platforms by requiring support of the full OpenGL feature set for all implementations (using software emulation if necessary)

In its basic operation, OpenGL accepts primitives such as points, lines and polygons, and converts them into pixels via a graphics pipeline known as the OpenGL state machine. Most OpenGL commands either issue primitives to the graphics pipeline, or configure how the pipeline processes these primitives. Prior to the introduction of OpenGL 2.0, each stage of the pipeline performed a fixed function and was configurable only within tight limits. OpenGL 2.0 offers several stages that are fully programmable using GLSL

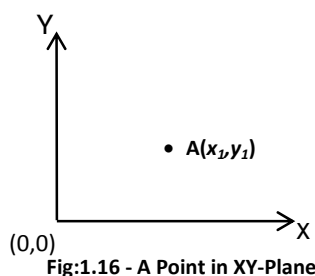
1.7.4 Computer Graphics Interface (CGI) and Computer Graphics Metafile (CGM)

CGI and CGM are used as standards for graphics devices for 2D vector graphics, raster graphics, and text, and is defined by **ISO/IEC 8632**. All graphical elements can be specified in a textual source file that can be compiled into a binary file or one of two text representations. CGM provides a means of graphics data interchange for computer representation of 2D graphical information independent from any particular application, system, platform, or device.

1.8 Concepts of Various Objects:

Point, Line, Circle, Ellipse and Polygons

By now we know that the smallest element is a point and that for a raster device, it is **pixel**. **Pixel** is the smallest addressable element of raster device. It is derived from the "Picture Element". The number of pixel of a display device determines the **resolution** of the device, and therefore higher number of pixels is preferred for graphics applications. Each of these pixels is associated with the coordinate of Cartesian plane. These coordinates identify pixel or point. To draw any image or object, some of pixels are activated by setting some intensity. In other words, the pixels turned on. For example, to draw a straight line segment the adjacent pixels between two points are turned on.



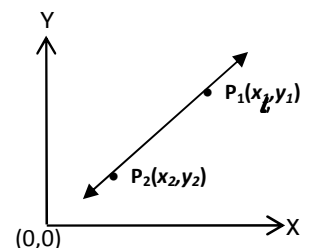
Point

As in the figure Point A has been positioned in the XY-plane and (x_1, y_1) is the position of point A. It implies that the A is located at x_1 distance in X direction and at y_1 distance in Y direction from the origin $(0,0)$. Where the (x_1, y_1) is known as the coordinates of point A.

Line

Any two points specified in the Plane will define a line, which means that for defining the line we must have to specify two points.

In the figure 2.2, two points $P_1(x_1, y_1)$ and $P_2(x_2, y_2)$ define a line l_1 . To define the line we need an equation. A random point $P(x_i, y_i)$ is said to be on the line l_1 if and only if it satisfies the equation of the line. The equation of a straight line can be derived with the help of slope concept of a straight line. The **slope** is the rate at which an



ordinate of a point on a plane changes with respect to a change in the horizontal coordinate. The notion slope is denoted by m . Thus,

$$m = \frac{\text{vertical distance between two points}}{\text{horizontal distance between two points}} \quad \therefore \quad m = \frac{y_2 - y_1}{x_2 - x_1}$$

So the slope of any line can be one of four types: the straight line 1) with positive slope, 2) with negative slope, 3) with zero slope and 4) with undefined slope.

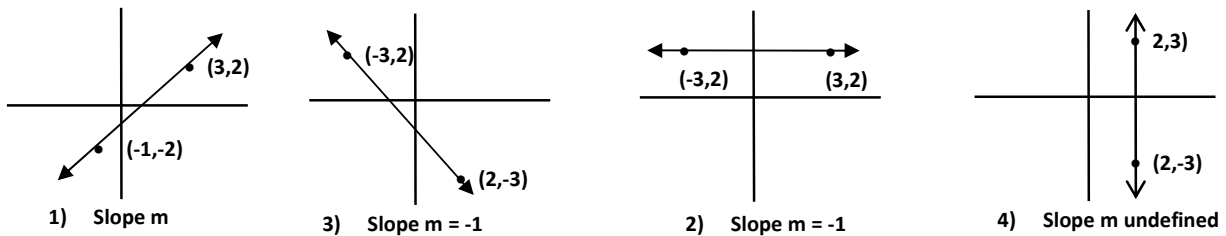


Fig:1.18 – Possible Slope values

As per previous discussion to derive a line equation the concept of slope is being used. The slope of any line between two points will remain unchanged (constant). According to this Let assume that $P_1(x_1, y_1)$ and $P_2(x_2, y_2)$ constitute a line as well as a point $P(x, y)$ is lying on the same line and the slope remain same at any point of the slope.

So the slope can be written as follows:

$$m = \frac{y_2 - y}{x_2 - x} \quad \text{and also} \quad m = \frac{y_2 - y_1}{x_2 - x_1}$$

$$\frac{y_2 - y}{x_2 - x} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$\begin{aligned} \frac{y - y_1}{x - x_1} = m & \Rightarrow y - y_1 = m(x - x_1) \Rightarrow y = mx - mx_1 + y_1 \Rightarrow y \\ & = mx + (y_1 - mx_1) \end{aligned}$$

We can assume that $b = y_1 - mx_1$ then the equation of straight line can be given as $y = mx + b$ (1)

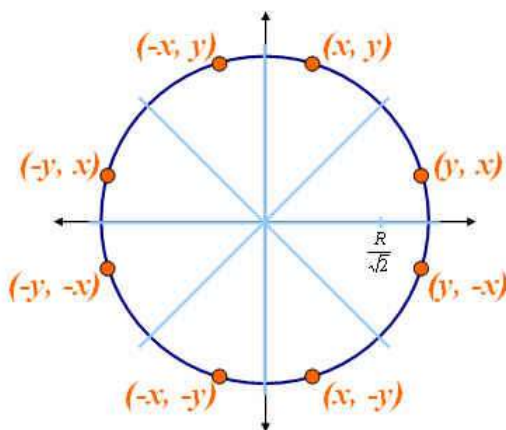


Fig. :1.19 Circle Construction

Circle

The first thing we can notice to make our circle drawing algorithm more efficient is that circles centered at (0, 0) have eight-way symmetry.

The equation for a circle is:

$$x^2 + y^2 = r^2$$

, where r is the radius of the circle

So, we can write a simple circle drawing algorithm by solving the equation for y at unit x intervals using:

$$y = \pm \sqrt{r^2 - x^2}$$

If we try to construct a circle of radius 20, the equation may seem like following:

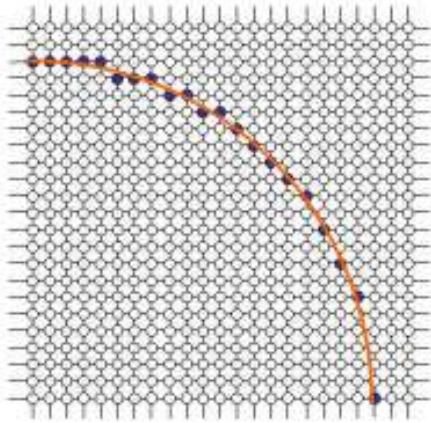


Fig. :1.20 Circle point generation

$$y_0 = \sqrt{20^2 - 0^2} \approx 20$$

$$y_1 = \sqrt{20^2 - 1^2} \approx 20$$

$$y_2 = \sqrt{20^2 - 2^2} \approx 20$$

•
•
•

$$y_{19} = \sqrt{20^2 - 19^2} \approx 6$$

$$y_{20} = \sqrt{20^2 - 20^2} \approx 0$$

However, unsurprisingly this is not a brilliant solution!

Firstly, the resulting circle has large gaps where the slope approaches the vertical.

Secondly, the calculations are not very efficient. For that mid-point circle algorithm can be applied to resolve the problem.

Mid-Point Circle (X_c , Y_c , R):

Description: Here X_c and Y_c denote the x – coordinate and y – coordinate of the center of the circle. R is the radius.

1. Set $X = 0$ and $Y = R$
2. Set $P = 1 - R$
3. Repeat While ($X < Y$)
 - a. Call Draw Circle(X_c , Y_c , X , Y)
 - b. Set $X = X + 1$
 - c. If ($P < 0$) Then

$$P = P + 2X + 6$$
 - d. else

$$\text{Set } Y = Y - 1$$

$$P = P + 2(X - Y) + 1$$
 - e. [End of If]
 - f. Call Draw Circle(X_c , Y_c , X , Y)
4. [End of While]
5. Exit

Draw Circle (X_c , Y_c , R):

1. Call PutPixel($X_c + X$, $Y_c + Y$)
2. Call PutPixel($X_c - X$, $Y_c + Y$)
3. Call PutPixel($X_c + X$, $Y_c - Y$)
4. Call PutPixel($X_c - X$, $Y_c - Y$)
5. Call PutPixel($X_c + Y$, $Y_c + X$)
6. Call PutPixel($X_c - Y$, $Y_c + X$)
7. Call PutPixel($X_c + Y$, $Y_c - X$)
8. Call PutPixel($X_c - Y$, $Y_c - X$)
9. Exit

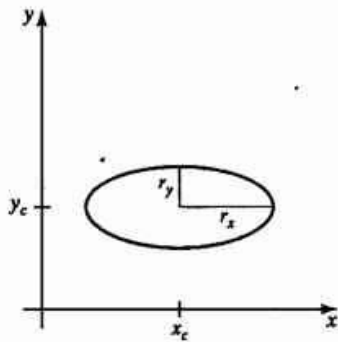
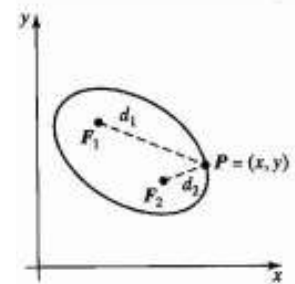
Ellipse

Ellipse is the finite or bounded case of a conic section, the geometric shape that results from cutting a circular conical or cylindrical surface with an oblique plane. It is also the locus of all points of the plane whose distances to two fixed points add to the same constant. Ellipses also arise as images of a circle or a sphere under parallel projection, and some cases of perspective projection. Indeed, circles are special cases of ellipses. An ellipse is also the closed and bounded case of an implicit curve of degree 2, and of a rational curve of degree 2. It is also the simplest Lissajous figure, formed when the horizontal and vertical motions are sinusoids with the same frequency.

The circle algorithm can be generalized to work for an ellipse but only four way symmetry can be used.

Ellipse Properties

Given two fixed positions F_1 and F_2 the sum of the two distances from these points to any point P on the ellipse ($d_1 + d_2$) is constant.



Ellipse Equation

With the major and minor axes aligned with the coordinate axes the ellipse is said to be in standard position:

$$\frac{(x - x_c)^2}{r_x^2} + \frac{(y - y_c)^2}{r_y^2} = 1$$

One Approach

Take small steps in x from x_c to $x_c + r_x$ and calculate y :

Symmetry can be used

Only one quadrant needs to be calculated since symmetry gives the three other quadrants.

$$y = r_y \sqrt{1 - \frac{(x - x_c)^2}{r_x^2}} + y_c$$

