Chapter 1 Introduction and application

Computer graphics is a field related to the generation of graphics using computers. It includes the creation, storage and manipulation of images of objects. These objects come from diverse fields such as physical, mathematical engineering, architectural abstract structures and natural phenomenon. Computer graphics today is largely interactive that is, the user controls the contents structure and appearance of images of the objects by using input devices such as a keyboard, mouse, or touch sensitive panel on the screen.

In 1980's personal computers with built in raster graphics displays such as the Xerox Star Apple Macintosh and the IBM PC – popularized the use of bitmap graphics for user computer interaction.

A bitmap is an ones and zeros representation of the rectangular array of points on the screen. Each point is called a pixel, short for "picture elements".

Even people who do not use computers encounter computer graphics in TV commercials and as cinematic special effects. Thus computer graphics is an integral part of all computer user interfaces, and is indispensable for visualizing 2D, 3D objects in all most all areas such as education, science, engineering, medicine, commerce the military advertising and entertainment.

Figure 1.1 Computer graphics system

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History of computer graphics:

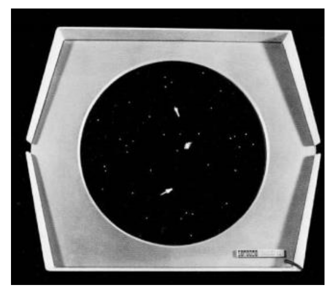
We need to take a brief look at the historical development of computer graphics to place today's system in context, crude plotting of hardcopy devices such as teletypes and line printers dates from the early days of computing.

1951

The Whirlwind computer at the Massachusetts Institute of Technology (MIT) was the first computer with a video display of real time data.

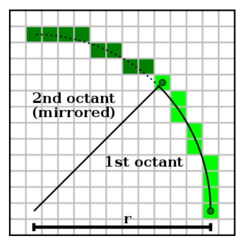
1955

The SAGE air-defense system and was the first to use command and control CRT display consoles on which operators identified targets with light pens (hand held pointing devices that sense light emitted by objects on the screen).



1961

The first video game, SpaceWar, ran using an oscilloscope as a display. Later on Ivan Sutherland writes the first computer drawing program.



1965

Jack Bresenham invents the "ideal"

Line-drawing algorithm.

That was the beginning of modern interactive graphics. In this system, keyboard and light pen were used for pointing, making choices and drawing.

At the same time, it was becoming clear to computer, automobile, and aerospace manufacturers that (CAD) and computer aided manufacturing (CAM) activities had enormous potential for automating drafting and other drawing intensive activities.

Interactive computer graphics had a limited use when it started in the early sixties but it became very common once the Apple Macintosh and IBM PC appeared in the market with affordable cost.

Applications of computer graphics:

Computers have become a powerful tool for the rapid and economical production of pictures.

Today, we find computer graphics used routinely in such diverse areas as science, engineering, medicine, business, industry, government, art, entertainment, advertising, education, and training. All of these are included in the following categories:

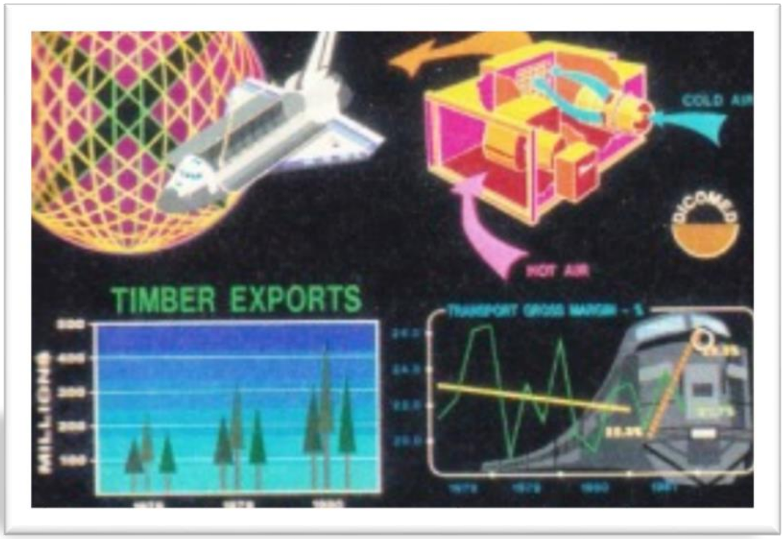


Figure 1.2 Examples of computer graphics applications.

- **Computer-aided drafting and design:**

  A major use of computer graphics is in design processes, particularly for engineering and architectural systems, but almost all products are now computer designed. Generally referred to as CAD, computer-aided design methods are now routinely used in the design of buildings, automobiles, aircraft, watercraft, spacecraft, computers, textiles, and many, many other products.

  CAD (Computer Aided Design) system generate accurately, scaled mathematical models based on user input. Individual models are then integrated as components of an assembly to create the final product through which exact fit of the parts can be checked. Color-coded wireframe displays of body designs for an aircraft.

  Animations are often used in CAD applications. Real-time animations using wireframe displays on a video monitor are useful for testing performance of a vehicle or system.

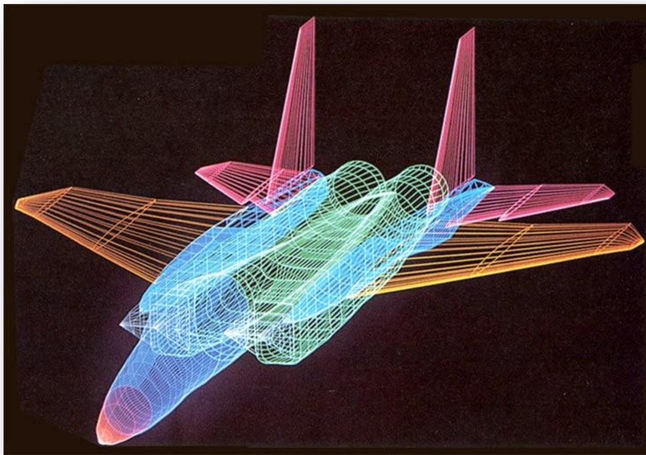


Figure 1.2 color-coded, wire-frame outlines of body designs for a aircraft.

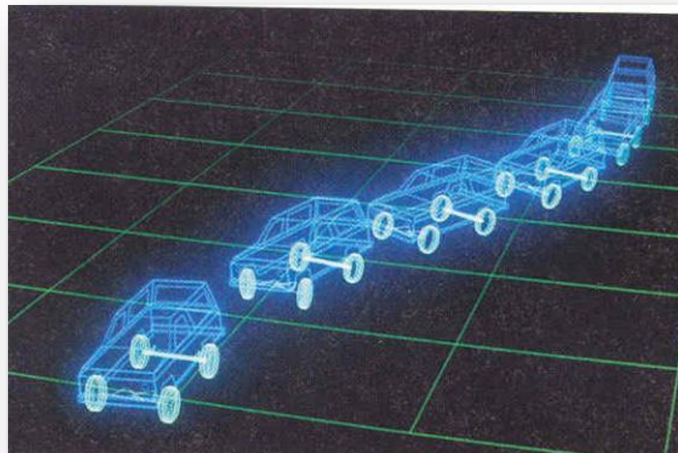


Figure 1.3 Simulation of vehicle performance during lane changes.

- **Virtual-reality environment:**

  A more recent application of computer graphics is in the creation of virtual- reality environments in which a user can interact with the objects in a three-dimensional scene. Specialized hardware devices provide three dimensional viewing effects and allow the user to “pick up” objects in a scene.

  Animation in virtual-reality environments are often used to train heavy-equipment operators or to analyze the effectiveness of various cabin configurations and control placements.

Figure 1.4 Operating tractor in virtual reality.

- **Data Visualizations:**

  Producing graphical representations for scientific, engineering, and medical diagram sets and processes is another fairly new application of computer graphics which is generally to as scientific visualization. And the tern business visualization is used in connection with data sets related to commerce, industry and other nonscientific areas.

  There are many different kinds of data sets, and effective visualization schemes depend on the characteristics of the data.

Figure 1.5 Visualization of a protein structure

Figure 1.6 Visualization of population over earth surface

- **Education and Training:**

Computer-generated models of physical, financial, and economic systems are often used as educational aids. Models of physical systems, physiological systems, population trends, or equipment, such as the color coded diagram can help trainees to understand the operation of the system.

For some training applications, special systems are designed. Examples of such specialized systems are the simulators for practice sessions or training of ship captains, aircraft pilots, heavy-equipment operators, and air traffic control personnel.

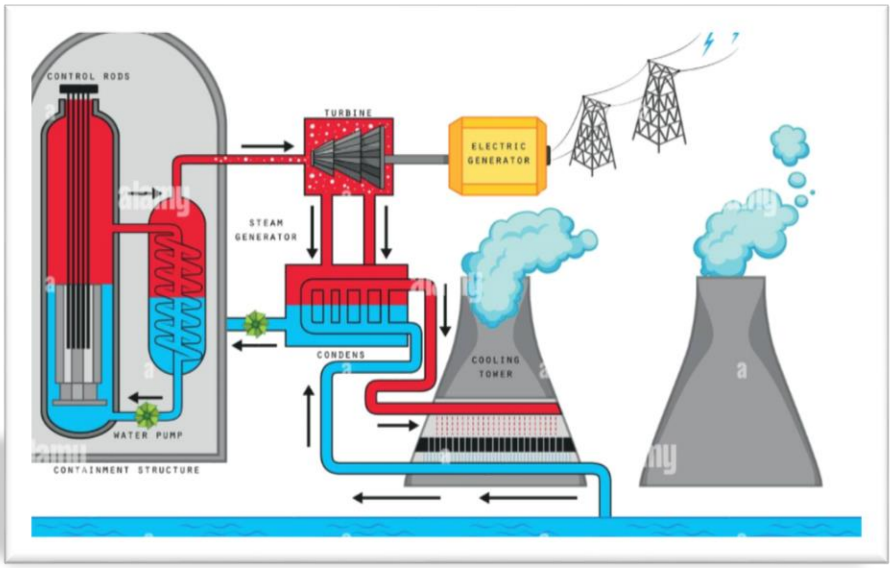


Figure 1.7 color-coded diagram used to explain the operation of a nuclear reactor.

Figure 1.7 a flight simulator.

- **Computer Art:**
  Computer graphics methods are widely used in both fine art and commercial art applications. Artists use a variety of computer methods, including special-purpose hardware, artist's paintbrush (such as Lumens), other paint packages (such as Pixel paint and Super paint), specially developed software, symbolic mathematics packages (such as Mathematics), CAD packages, desktop publishing software, and animation packages that provide facilities for designing object shapes and specifying object motions.

Figure 1.8 Computer art

- **Entertainment:**
  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 some television programs also use animation techniques to combine computer-generated figures of people, animals or cartoon characters with the lice actors in a scene or to transform an actor’s face into another shape.

Figure 1.9 a scene from the film *Avatar*.

- **Image Processing:**
  The modification or interpretation of existing pictures, such as photographs and TV scans, is called image processing. In computer graphics, a computer is used to create a picture. Image-processing techniques, on the other hand, are used to improve picture quality, analyze image, or recognize visual patterns for robotics applications.
- **Graphical User Interfaces (GUI):**
  It is common now for applications software to provide a graphical user interface. A major component of a graphical interface is a window manager that allows a user to display multiple, rectangular screen areas, called display widows.
  Using an interactive pointing device, such as a mouse, we can active a display window on some systems by positioning the screen cursor within the window display area and pressing the left mouse button.
- **Cartography:**
  Cartography is a subject which deals with the making of maps and charts. Computer graphics is used to produce both accurate and schematic representations of geographical and other natural phenomena from measurement data. Examples include geographic maps, oceanographic charts, weather maps, contour maps and population density maps Surfer is one of such graphics packages which is extensively used for cartography.

Figure 1.10 cartography of geography of Europe in 15th century

Output Device:

The primary output device in a graphical system is the video monitor. The main element of a video monitor is the Cathode Ray Tube.

Cathode Ray Tube (CRT):

An electron tube that has an electron gun, a deflection system, and a screen. This tube is used to display visual electronic signals. An electron beam is focused on a luminescent screen than varied in position and intensity to produce a visible pattern. A Cathode-ray Tube is used as computer monitors, television screens or radar displays.

The electron gun emits a beam of electrons cathode rays. The electron beam passes through focusing and deflection systems that direct it towards specified positions on the phosphor-coated screen. When the beam hits the screen, the phosphor emits a small spot of light at each position contacted by the electron beam. It redraws the picture by directing the electron beam back over the same screen points quickly.

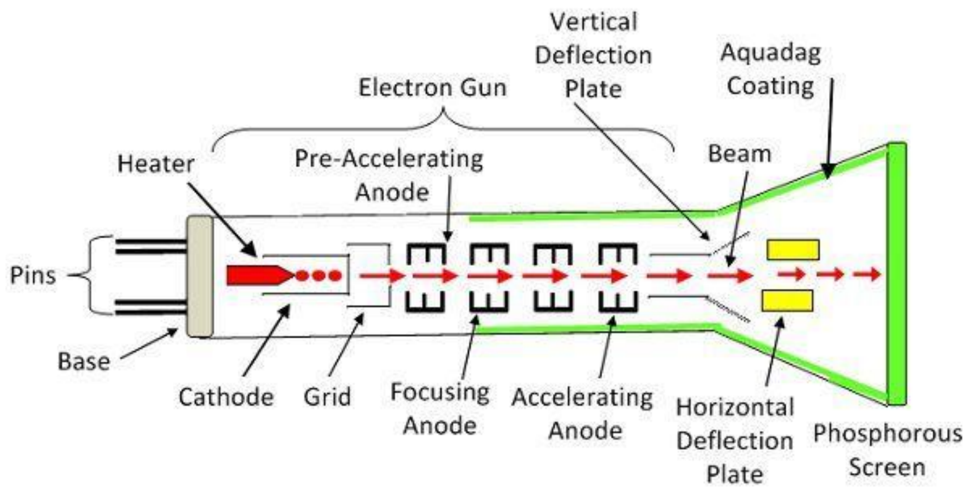


Figure 1.11 Cathode Ray Tube

Color CRTs:

Color depends on the light emitted by phosphor.

Two type:

I. Beam Penetration Method
II. Shadow Mask Method

Beam Penetration Method:

Two different layers of phosphor coating used Red (outer) and Green (inner). Display of color depends on the depth of penetration of the electron beam into the phosphor layers.

- A beam of slow electrons excites only the outer red layer.
- A beam of very fast electrons penetrates the red phosphor and excites the inner green layer.
- When quantity of red is more than green then color appears as orange.
- When quantity of green is more than red then color appears as yellow.

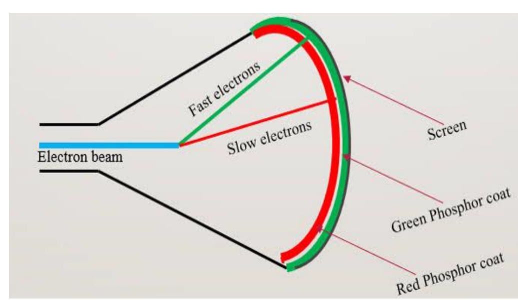


Figure 1.12 Beam penetration method

Shadow Mask Method:

- The inner side of the viewing surface of a color CRT consists of closely spaced groups of red, green and blue phosphor dots. Each group is called a triad.
- A thin metal plate perforated with many small holes is mounted close to the inner side of the viewing surface. This plate is called shadow mask.

- The shadow mask is mounted in such a way that each hole is correctly aligned with a triad in color CRT. There are three electron guns one for each dot in a triad.
- Two types:
- A Delta –Delta CRT:
- A Precision Inline CRT

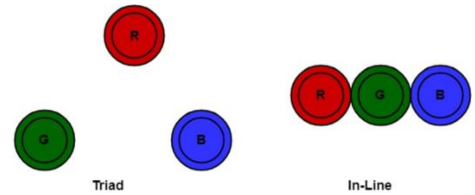


Figure 1.13 Delta and In-line arrangements of RGB electron guns of CRT

- **A Delta –Delta CRT:**
  - A triad has a triangular (delta) pattern as are the three electron guns.
  - Main drawback of this type of CRT is that a high precision display is very difficult to achieve because of technical difficulties involved in the alignment of shadow mask holes and the triad on one to one basis.

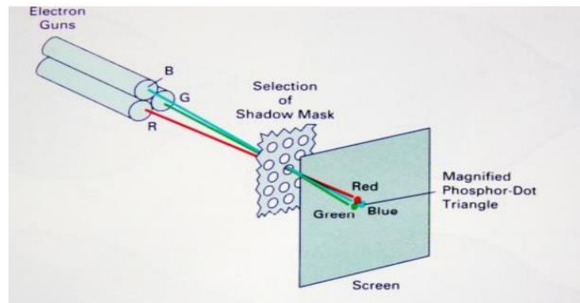


Figure 1.14 Operation of delta-delta CRT

- **A Precision Inline CRT:**
  - A triad has an in-line pattern as are the three electron guns.
  - The introduction of this type of CRT has eliminated the main drawback of a Delta-Delta CRT, but a slight reduction of image sharpness at the edges of the tube has been noticed. Normally 1000 scan lines can be achieved.

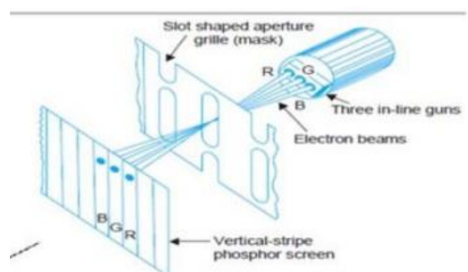


Figure 1.15 Operation of In-line CRT

Refresh rate: The refresh rate is the number of times per second the image is redrawn to give a feeling of un-flickering pictures and it is usually 50 per second. As the refresh rate decreases flicker develops because the eye can no longer integrate the individual light impulses coming from a pixel.

Horizontal scan rate: The horizontal scan rate is the number of scan lines per second. The rate is approximately the product of the refresh rate and the number of scan lines.

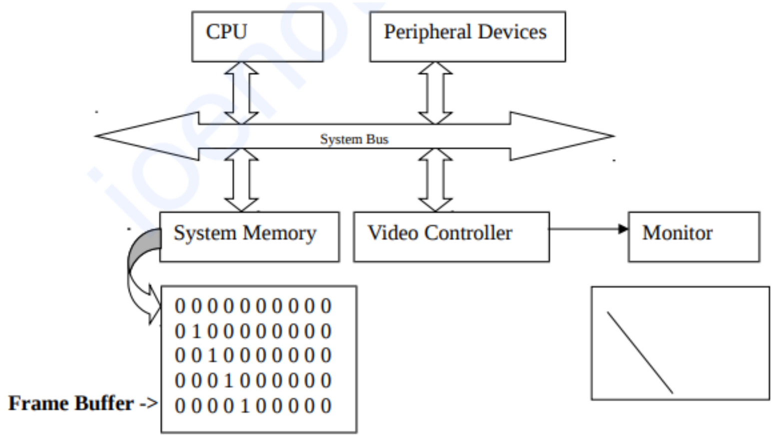
Resolution: Resolution is defined as the maximum number of points that can be displayed horizontally and vertically without overlap on a display device.

Raster-Scan Displays:

This technology based on television technology was developed in early 70s. It consists of central processing unit, a video controller, a monitor, system memory and peripheral devices such as mouse and keyboard. The application program and graphics subroutine package both reside in the system memory and execute on CPU.

When a particular command such as a line(x1, y1, x2, y2) is called by the application program the graphics subroutine package sets the appropriate pixels in the frame buffer, a portion of the system memory.

The video controller then cycles thru the frame buffer, one scan line at a time typically 50 times per second. It brings a value of each pixel contained in the buffer and uses it to control the



intensity of the CRT electron beam. So there exists a one to one relationship between the pixel in the frame buffer and that on the CRT screen.

Figure 1.16 Raster Display Technology

A pixel in a frame buffer may be represented by one bit as in monochromatic system where each pixel on CRT screen is either on '1' or off '0'.

A 640 pixels by 480 lines is an example of medium resolution raster display. In color system each of the three color red, green and blue is represented by eight bits producing 2^{24} = 16 million colors A medium resolution color display having 640 x 480 pixels will thus require (640 x 480 x 24) / 8 = 9kb of RAM.

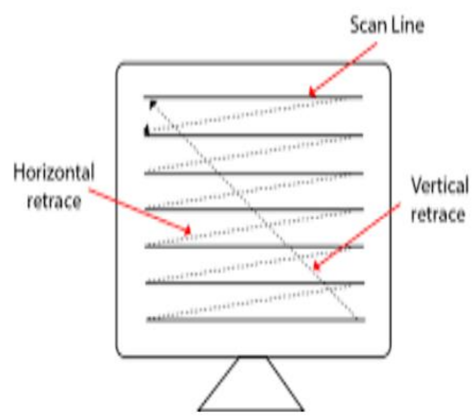


Figure 1.17 Raster Scan display

Vector Display Technology:

Vector display technology was developed in 60's and used as a common display device until 80's .It is also called random scan, a stroke, a line drawing or calligraphic display.

It consists of a central processing unit, a display processor, a monitor, system memory and peripheral devices such as mouse and keyboard. A display processor is also called a display processing unit or graphics controller .The application program and graphics subroutine package both reside in the system memory and execute on CPU.

A graphics subroutine package creates a display list and stores in the system memory. A display list contains point and line plotting commands with end point coordinates as well as character plotting commands.

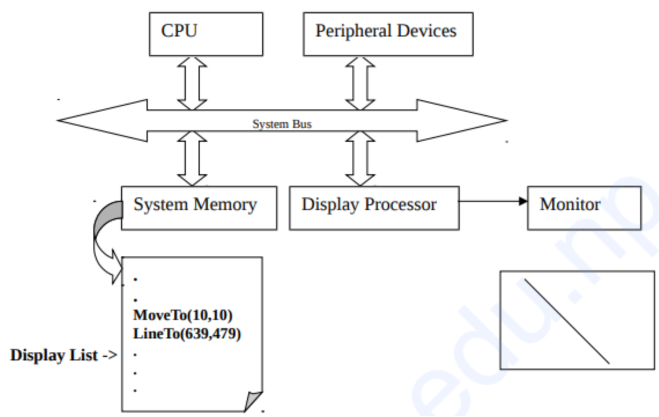


Figure 1.18 Vector Display Technology

The DPU interprets the commands in the display list and plots the respective output primitives such as point, line and characters.

As a matter of fact the DPU sends digital point coordinates to a vector generator that converts the digital coordinate values to analog.

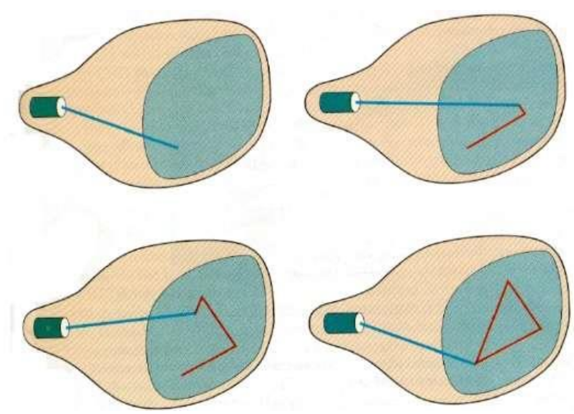


Figure 1.19 Vector scan display

Table 1.0 Difference between Raster scan system and Random scan system:

Raster scan system	Random scan system
1. The electron beam is swept across the screen, one row at a time, from top to bottom	1. The electron beam is directed only to the parts of screen where a picture is to be drawn.
2. Its resolution is poor because raster systems in contrast produces zigzag lines that are plotted as discrete point sets.	2. Its resolution is good because this system produces smooth lines drawings because CRT beam directly follows the line path.
3. Picture definition is stored as a set of intensity values for all screen points, called pixels in a refresh buffer area.	3. Picture definition is stored as a set of line drawing instructions in a display file.
4. The capability of this system to store intensity values for pixel makes it well suited for the realistic display of scenes contain shadow and color pattern.	4. These systems are designed for line-drawing and can’t display realistic shaded scenes.
5. Screen points/ pixels are used to draw an image	5. Mathematical function are used to draw an image.
6. It is used for photos. That is why Photoshop is a raster editing program	6. It is used for text, logos, and letter heads.
7. It is less expensive	7. It is costlier than raster scan system
8. It occupy more space which depends upon image quality and file extension may be .BMP, .TIF .JPG.	8. It occupy less space and file extension may be .PDF, .AI

Input Hardwares:

The Input Devices are the hardware that is used to transfer transfers input to the computer. The data can be in the form of text, graphics, sound, and text.

Mouse

A Mouse is a pointing device and used to position the pointer on the screen. It is a small palm size box. There are two or three depression switches on the top. The mouse cannot be used to enter text. Therefore, they are used in conjunction with a keyboard.

Keyboard:

The most commonly used input device is a keyboard. The data is entered by pressing the set of keys. All keys are labeled. The layout of the keyboard is like that of traditional typewriter, although there are some additional keys provided for performing additional functions.

Light pen:

It is a pencil shaped device to determine the coordinates of a point on the screen where it is activated such as pressing the button. It works by sensing the sudden small change in brightness of a point on the screen when the electron gun refreshes that spot. Light pens have the advantage of 'drawing' directly onto the screen, but this can become uncomfortable, and they are not as accurate as digitizing tablets.

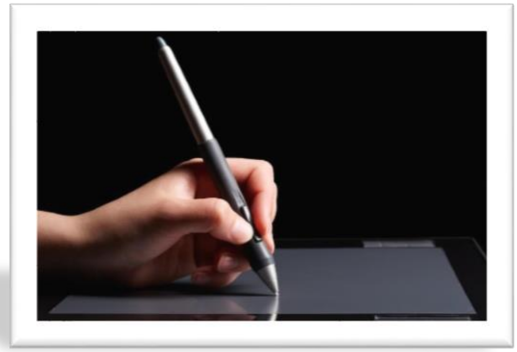


Figure 1.20 Light pen

Touch Panel:

The touch panel allows the user to point at the screen directly with a finger to move the cursor around the screen or to select the icons. When a user touches the surface, the system records the change in the electrical current that flows through the display.

Figure 1.21 Touch panel

- **Optical Touch Panel**
- **Sonic Touch Panel**
- **Electrical Touch Panel**

Tablet:

Tablet a tablet is a digitizer. In general, a digitizer is a device which is used to scan over an object and input a set of discrete coordinate positions. These positions can then be joined with straight line segments to approximate the shape of the original object. A tablet digitizes an object detecting the position of a movable stylus (a pencil shaped device) or a puck (a mouse like device with cross hairs for sighting positions) held in the user's hand.

Figure 1.21 Tablet

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Solutions

Q1. Consider raster systems with the resolutions of 640 x 480.

a) What size is frame buffer (in bytes) for this systems to store 12 bits per pixel?
Ans.
Eight bits constitute a byte, and frame-buffer sizes of the system is as follows:
640 x 480 x 12 bits / 8 = 460800 Byte = 450KB (1024 Byte = 1 KB)

b) How many pixels could be accessed per second in this system by a display controller that refreshes the screen at a rate of 60 frames per second?
Ans.
Since 60 frames are refreshed per second and each frame consists of 640 x 480 pixels, the access rate of such a system is (640 x 480) * 60 = 1.8432×10^7 pixels/second.

c) What is the access time per pixel in each system?
Ans.
We know that the access time per pixel should be 1/ (access rate). Therefore, the access time is around 54 nanoseconds/pixel.

d) How much time is spent scanning across each row of pixels during screen refresh with a refresh rate of 60 frames per second?
Ans.
Here, resolution = 640 X 480
That means system contains 480 scan lines and each scan line contains 640 pixels
Refresh rate = 60 frame/sec.
So, 1 frame takes = 1/60 sec.
Since resolution = 640 X 480
1 frame buffer consist of 480 scan lines
It means then 480 scan lines takes 1/60 sec
Therefore, 1 scan line takes: $\frac{1}{60 * 480}$ sec

Q2. Consider a raster system with the resolution of 1024 x 768 pixels and the color palette calls for 65,536 colors. What is the minimum amount of video RAM that the computer must have to support the above-mentioned resolution and number of colors?

Ans.
The color palette calls for 65,536 colors, which implies that 16 bits are being used to represent the color of each pixel on the display. The display's resolution is 1024 by 768 pixels, which implies that there is a total of 786,432 (1024 × 768) pixels on the display, and frame-buffer sizes of the system is as follows:
1024 x 768 x 16 bits / 8 = 1,572,864 Bytes = 1,536 KB = 1.5 MB

Q3. Find out the aspect ratio of the raster system using 8 x 10 inches screen and 100 pixel/inch.

Ans.

We know that,

Aspect ratio = Width / Height

= 8 x 100 / 10 x 100

= 4 / 5

Aspect ratio = 4: 5

Q4. How long would it takes to load a 640 X 480 frame buffer with 12 bit per pixels if 105 bits can be transferred per second?

Ans.

Total size of frame buffer = 640 X 480 X 12

it takes = (640 X 480 X 12) / 10^5

Chapter 1 Introduction and application

Exercise 1:

Q1. Suppose a RGB raster system is to be designed using an 8 inch by 10 inch screen with a resolution of 100 pixels per inch in each direction. How long would it take to load this raster system in frame buffer with 24 bits per pixel, if 10^5 bits can be transferred per second?

Q2. Consider a raster can system having 12 inch by 10 inch screen with a resolution of 100 pixels per inch in each direction. If the display controller of this system refreshes the screen at the rate of 50 frames per second, how many pixels could be accessed per second and what is the access time per pixel of the system?

Q3. How Many k bytes does a frame buffer needs in a 600 x 400 pixel?