

Q: 1 Computer graphics deals with creation, manipulation and storage of different type of images and objects.

Some of the applications of computer graphics are:

1. ComputerArt:

Using computer graphics we can create fine and commercial art which include animation packages, paint packages. These packages provide facilities for designing object shapes and specifying object motion. Cartoon drawing, paintings, logo design can also be done.

2. ComputerAidedDrawing:

Designing of buildings, automobile, aircraft is done with the help of computer aided drawing, this helps in providing minute details to the drawing and producing more accurate and sharp drawings with better specifications.

3. PresentationGraphics:

For the preparation of reports or summarising the financial, statistical, mathematical, scientific, economic data for research reports, managerial reports, moreover creation of bar graphs, pie charts, time chart, can be done using the tools present in computer graphics.

4. Entertainment:

Computer graphics finds a major part of its utility in the movie industry and game industry. Used for creating motion pictures , music video, television shows, cartoon animation films. In the game industry where focus and interactivity are the key players, computer graphics helps in providing such features in the efficient way.

5. Education:

Computer generated models are extremely useful for teaching huge number of concepts and fundamentals in an easy to understand and learn manner. Using computer graphics many educational models can be created through which more interest can be generated among the students regarding the subject.

6. Training:

Specialised system for training like simulators can be used for training the candidates in a way that can be grasped in a short span of time with better understanding. Creation of training modules using computer graphics is simple and very useful.

7. **Visualisation:**

Today the need of visualise things have increased drastically, the need of visualisation can be seen in many advance technologies , data visualisation helps in finding insights of the data , to check and study the behaviour of processes around us we need appropriate visualisation which can be achieved through proper usage of computer graphics.

8. **ImageProcessing:**

Various kinds of photographs or images require editing in order to be used in different places. Processing of existing images into refined ones for better interpretation is one of the many applications of computer graphics.

9. **MachineDrawing:**

Computer graphics is very frequently used for designing, modifying and creation of various parts of machine and the whole machine itself, the main reason behind using computer graphics for this purpose is the precision and clarity we get from such drawing is ultimate and extremely desired for the safe manufacturing of machine using these drawings.

10. **GraphicalUserInterface:**

The use of pictures, images, icons, pop-up menus, graphical objects helps in creating a user friendly environment where working is easy and pleasant, using computer graphics we can create such an atmosphere where everything can be automated and anyone can get the desired action performed in an easy fashion.

Q 2: What is Interactive and Passive Graphics?

There are two types of graphics that are used nowadays, interactive and passive. The main difference between interactive and passive graphics is what they do when the user does something. In passive graphics, the graphic does not do anything special when the user tries to interact with it. In interactive graphics, the graphics responds to what the user does to it. It can be as simple as changing colors when the user moves his mouse over it, or it can be a full-on graphic animation when the user clicks on it.

Interactive graphics give a new level of interactivity to a webpage. You can greatly reduce the number of loads that the user experiences and brings a more app-like feel to webpage.

Choosing between interactive graphics and passive graphics depends on whether you are aiming for simplicity or features. Interactive graphics are more entertaining than passive graphics but is also more

difficult to deal with. Some sites choose a compromise by creating two versions for their site; one with interactive graphics, and another with passive graphics. The version with interactive graphics is the default one but users can opt for the one with passive graphics if he wants to.

Summary:

1. Interactive graphics respond to what the user does while passive graphics don't.
2. Interactive graphics are often more bandwidth hungry than passive graphics.
3. Interactive graphics are more prone to problems than passive graphics.

Q: 3. Display Devices in Computer Graphics:

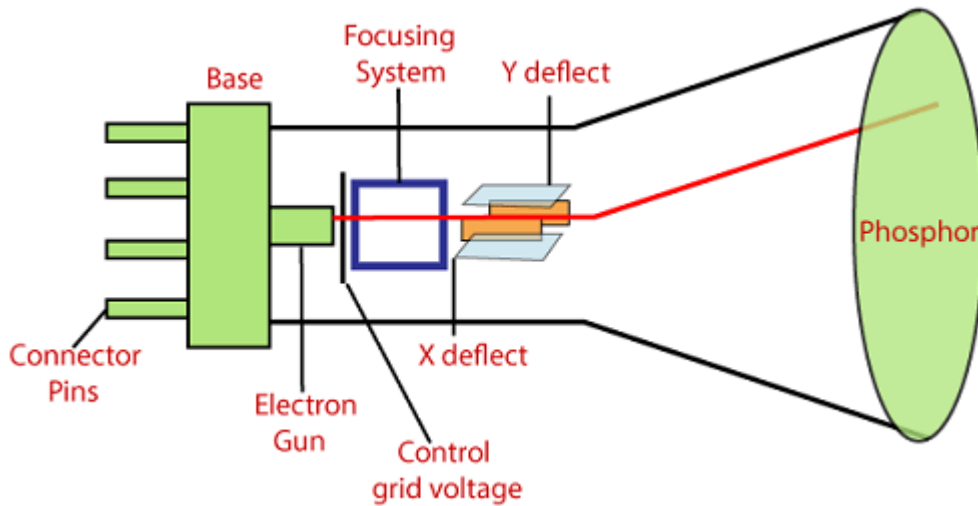
The display device is an output device used to represent the information in the form of images (visual form). Display systems are mostly called a **video monitor** or **Video display unit (VDU)**.

Display devices are designed to model, display, view, or display information. The purpose of display technology is to simplify information sharing.

Today, the demand for high-quality displays is increasing.

There are some display devices given below:

1. Cathode-Ray Tube(CRT)
 2. Color CRT Monitor
 3. Liquid crystal display(LCD)
 4. Light Emitting Diode(LED)
 5. Direct View Storage Tubes(DVST)
 6. Plasma Display
 7. 3D Display
1. **Cathode-ray Tube (CRT):** Here, CRT stands for Cathode ray tube. It is a technology which is used in traditional computer monitor and television.
Cathode ray tube is a particular type of vacuum tube that displays images when an electron beam collides on the radiant surface.



Component of CRT:

- **Electron Gun:** The electron gun is made up of several elements, mainly a heating filament (heater) and a cathode.
The electron gun is a source of electrons focused on a narrow beam facing the CRT.
- **Focusing & Accelerating Anodes:** These anodes are used to produce a narrow and sharply focused beam of electrons.
- **Horizontal & Vertical Deflection Plates:** These plates are used to guide the path of the electron the beam. The plates produce an electromagnetic field that bends the electron beam through the area as it travels.
- **Phosphorus-coated Screen:** The phosphorus coated screen is used to produce bright spots when the high-velocity electron beam hits it.

There are two ways to represent an object on the screen:

1. **Raster Scan:** It is a scanning technique in which the electron beam moves along the screen. It moves from top to bottom, covering one line at a time.

A raster scan is based on pixel intensity control display as a rectangular box on the screen called a **raster**.

Picture description is stored in the memory area called as **Refresh buffer, or Frame Buffer**.

Frame buffer is also known as **Raster or Bitmap**. Raster scan provides the refresh rate of 60 to 80 frames per second.

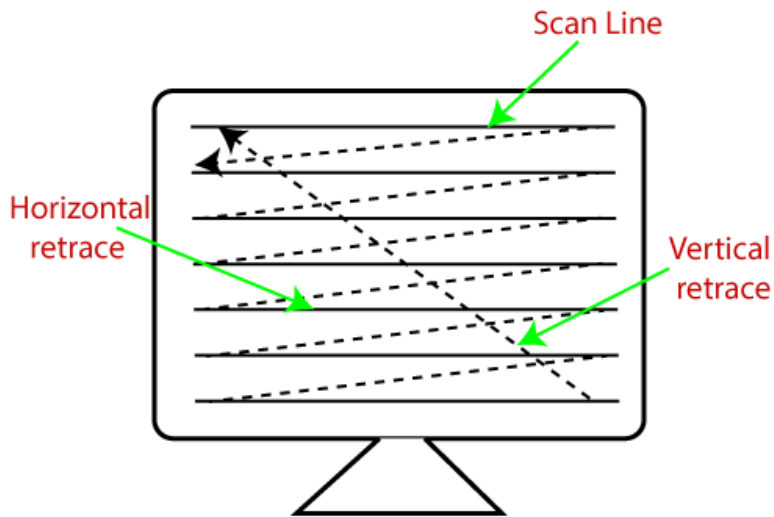
For Example: Television

The beam refreshing has two types:

1. Horizontal Retracing
2. Vertical Retracing

When the beam starts from the top left corner and reaches bottom right, and again return to the top left, it is called the **vertical retrace**.

It will call back from top to bottom more horizontally as a horizontal reversal.



Advantages:

1. Real image
2. Many colors to be produced
3. Dark scenes can be pictured

Disadvantages:

1. Less resolution
2. Display picture line by line
3. More costly

2. Random Scan (Vector scan): It is also known as stroke-writing display or calligraphic display. In this, the electron beam points only to the area in which the picture is to be drawn.

It uses an electron beam like a pencil to make a line image on the screen. The image is constructed from a sequence of straight-line segments. On the screen, each line segment is drawn by the beam to pass from one point on the screen to the other, where its x & y coordinates define each point.

After compilation of picture drawing, the system cycle back to the first line and create all the lines of picture 30 to 60 times per second.

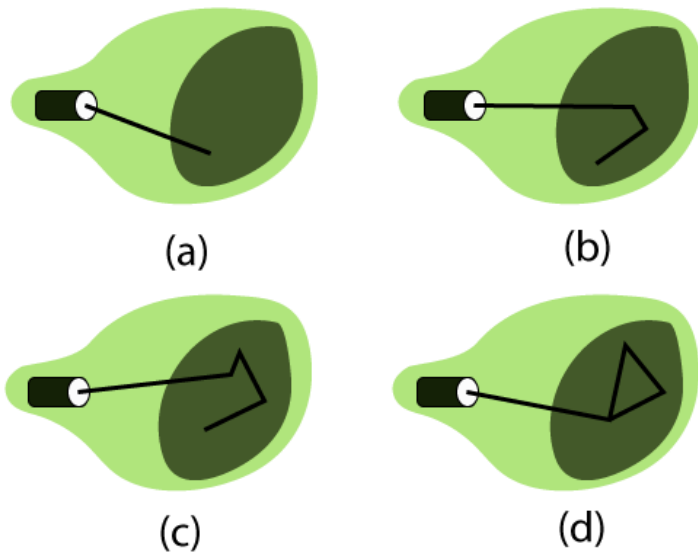


Fig: A Random Scan display draws the lines of an object in a specific order

Advantages:

1. High Resolution
2. Draw smooth line Drawing

Disadvantages:

1. It does only the wireframe.
2. It creates complex scenes due to flicker.

2. Color CRT Monitor: It is similar to a CRT monitor.

The basic idea behind the color CRT monitor is to combine three basic colors- Red, Green, and Blue. By using these three colors, we can produce

millions of different colors.

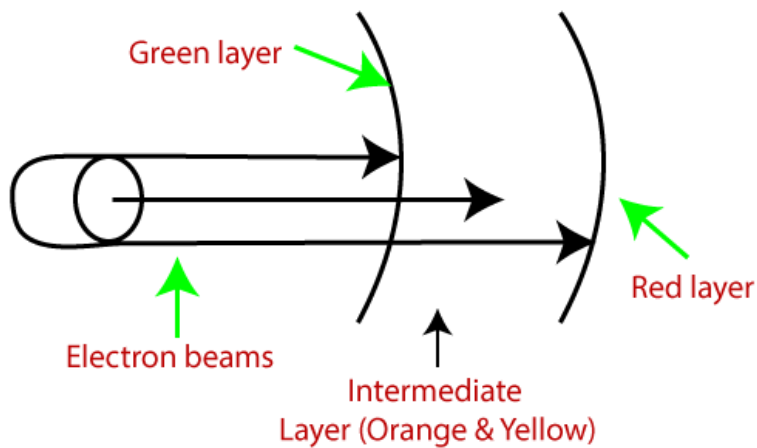
The two basic color display producing techniques are:

1. **Beam-Penetration Method:** It is used with a **random scan** monitor for displaying pictures. There are two phosphorus layers- Red and Green are coated inside the screen. The color shown depends on how far the electron beam penetrates the phosphorus surface.

A powerful electron beam penetrates the CRT, it passes through the red layer and excites the green layer within.

A beam with slow electrons excites only the red layer.

A beam with the medium speed of electrons, a mixture of red and green light is emitted to display two more colors- orange and yellow.



Advantages:

1. Better Resolution
2. Half cost
3. Inexpensive

Disadvantages:

1. Only four possible colors
2. Time Consuming

2.Shadow-Mask Method: It is used with a **raster scan** monitor for displaying pictures. It has more range of color than the beam penetration method. It is used in television sets and monitors.

Structure:

1. It has three phosphorus color dots at each position of the pixel.

First Dot: **Red** color

Second Dot: **Green** color

Third Dot: **Blue** color

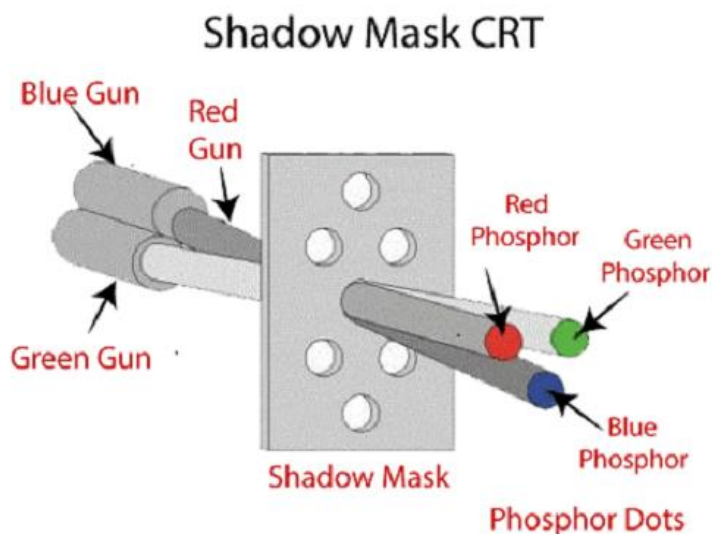
1. It has three different guns. Each for one color.
2. It has a metal screen or plate just before the phosphorus screen, named “**Shadow-Mask.**”
3. It also has a shadow grid just behind the phosphorus coated screen with tiny holes in a triangular shape.

Working: A Shadow Mask is a metal plate with tiny holes present inside a color monitor.

A Shadow Mask directs the beam by consuming the electrons so that the beam hits only the desired point and displays a resulting picture.

It has three different guns. These guns direct their beams to shadow mask, which allows them to pass. It is a task of a shadow mask to direct the beam on its particular dot on the screen and produce a picture on the screen.

A Shadow Mask can display a wider range of pictures than beam penetration.



Advantages:

1. Display a wider range picture.
2. Display realistic images.
3. In-line arrangement of RGB color.

Disadvantages:

Difficult to cover all three beams on the same hole.

Poor Resolution.

3.Liquid crystal display (LCD): The LCD depends upon the light modulating properties of liquid crystals.

LCD is used in watches and portable computers. LCD requires an AC power supply instead of DC, so it is difficult to use it in circuits.

It generally works on flat panel display technology. LCD consumes less power than LED. The LCD screen uses the liquid crystal to turn pixels on or off.

Liquid Crystals are a mixture of solid and liquid. When the current flows inside it, its position changes into the desired color.

For Example: TFT(Thin Film Transistor)

Advantages:

1. Produce a bright image

2. Energy efficient
3. Completely flat screen

Disadvantages:

Fixed aspect ratio & Resolution

Lower Contrast

More Expensive

4.Light Emitting Diode (LED): LED is a device which emits when current passes through it. It is a semiconductor device.

The size of the LED is small, so we can easily make any display unit by arranging a large number of LEDs.

LED consumes more power compared to LCD. LED is used on TV, smartphones, motor vehicles, traffic light, etc.

LEDs are powerful in structure, so they are capable of withstanding mechanical pressure. LED also works at high temperatures.

Advantages:

1. The Intensity of light can be controlled.
2. Low operational Voltage.
3. Capable of handling the high temperature.

Disadvantages:

More Power Consuming than LCD.

5.Direct View Storage Tube (DVST): It is used to store the picture information as a charge distribution behind the phosphor-coated screen.

There are two guns used in DVST:

1.Primary Gun: It is used to store the picture information.

2.Flood / Secondary Gun: It is used to display a picture on the screen.

Advantages:

1. Less Time Consuming
2. No Refreshing Required

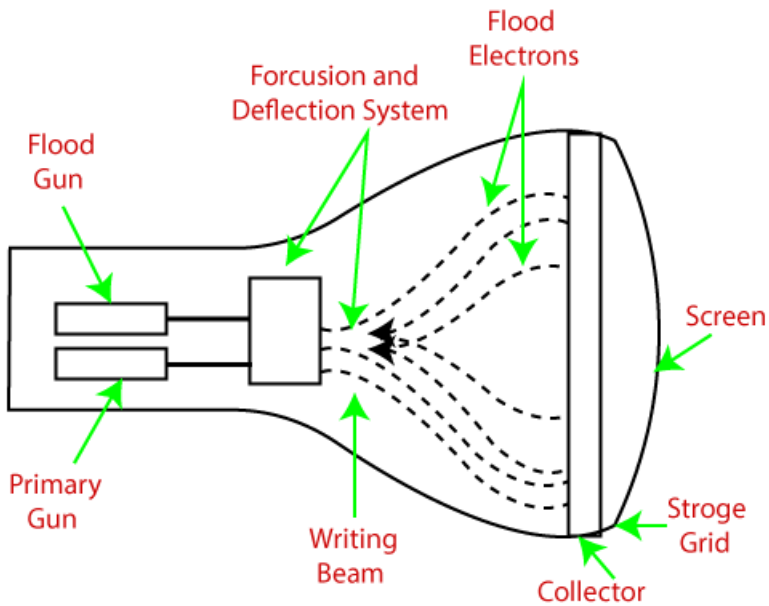
3. High-Resolution

4. Less Cost

Disadvantages:

The specific part of the image cannot be erased.

They do not display color.



Advantages:

5. Less Time Consuming

6. No Refreshing Required

7. High-Resolution

8. Less Cost

Disadvantages:

The specific part of the image cannot be erased.

They do not display color.

6. Plasma Display: It is a type of flat panel display which uses tiny plasma cells. It is also known as **the Gas-Discharge display**.

Components of plasma display:

1.Anode: It is used to deliver a positive voltage. It also has the line wires.

2.Cathode: It is used to provide negative voltage to gas cells. It also has fine wires.

3.Gas Plates: These plates work as capacitors. When we pass the voltage, the cell lights regularly.

4.Fluorescent cells: It contains small pockets of gas liquids when the voltage is passed to this neon gas. It emits light.

Advantages:

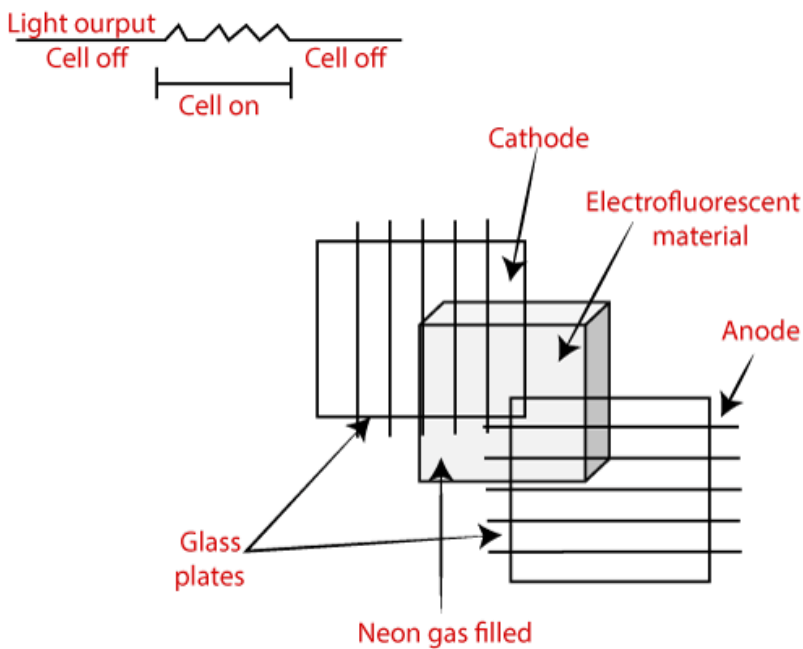
- 1. Wall Mounted
- 2. Slim
- 3. Wider angle

Disadvantages:

Phosphorus loses luminosity over time.

It consumes more electricity than LCD.

Large Size



Advantages:

- 4. Wall Mounted
- 5. Slim
- 6. Wider angle

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Large Size

7. 3D Display: It is also called stereoscope display technology. This technology is capable of bringing depth perception to the viewer.

It is used for 3D gaming and 3D TVs.

For Example: Fog Display, Holographic Display, Retina Display Etc.

Advantages:

- Impressive Picture Quality
- High Definition
- Motion Communicates

Disadvantage:

- Expensive
- Binocular Fusion

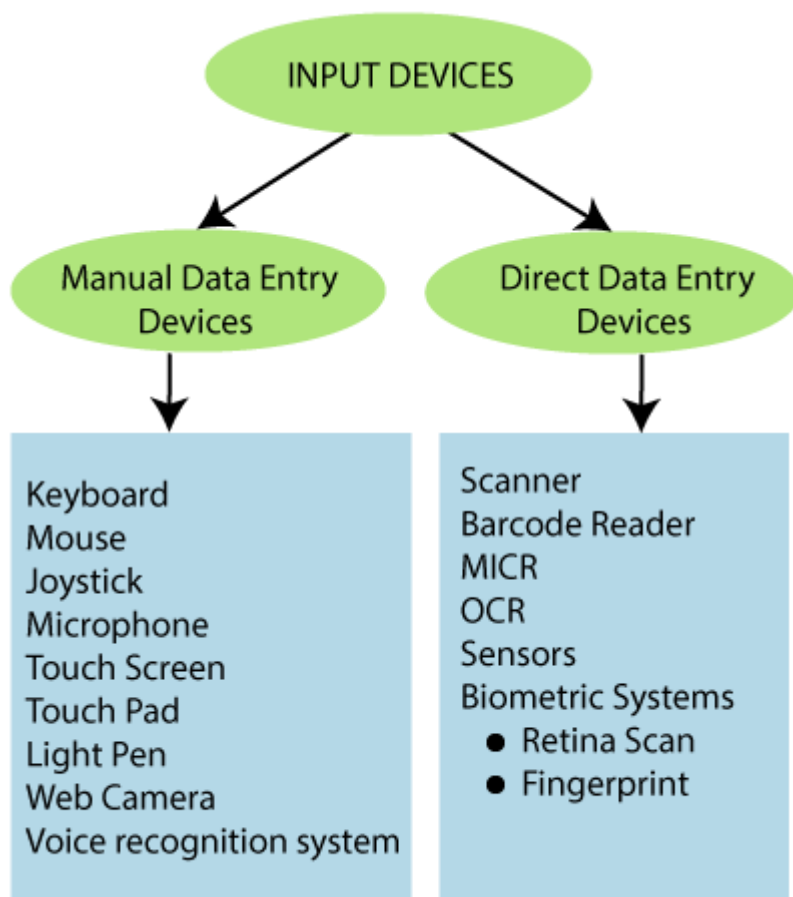
Q: 4. What is Input Devices in Computer Graphics?

An Input device is the piece of computer hardware equipment used to give input to the computer. The input can be in the form of graphics, text, sound, audio, video, and image, etc. **“Input devices are those devices through which we can give the data and instructions to the computer.”**

For Example-Mouse, Trackball, Keyboard, Light pen, etc.

Classification of Input Devices

- Manual data entry devices
- Direct data entry devices



Manual Data Entry Devices

Manual input devices are those peripheral devices through which the user can enter the data manually (by hand) at the time of processing.

It also includes–

Keyboard: It is the commonly used input device. It is designed to input text and characters.

A keyboard contains approx. 108 keys. **For Example**-Alphanumeric keys, Numeric keys, Function key, and cursor key, etc.

Types of keys: These keys include:

Alphanumeric keys: These are located in the center of the keyboard. These keys consist of alphabet (A-Z), Number (0-9), and symbols (@, #, \$, %, ^, &, *, !, =, +).

Numeric Keys: A part of keypad contains 17 numeric keys. In which we can include number up to 0-9, mathematics operator like +, -, /, *, and enter key.

Function keys: These keys are placed at the top of the keyboard. In which we can include F1, F2 up-to F12. The function key performs many tasks according to the software.

Cursor Keys: The cursor keys include Up, Down, Left, and Right. These are used to move the cursor on the screen.

Types of Keyboard: The type of keyboard is:

1. Normal Keyboard: These are the commonly used keyboard. It is used by the user in their PCs. It contains 108 keys. The normal keyboards are connected to the CPU through the wire.



2. Wireless Keyboard: The wireless keyboard connected to the computer without the wire. It works for a limited distance. It is more expensive than a normal keyboard. The user faces technical complexity in it.



3. Ergonomic Keyboard: It gives the user comfort and ease during the typing; that's why it is called the "Ergonomic keyboard." This keyboard is used to increase the efficiency of the user. It also reduces wrist pain during typing.



Advantages of Keyboards

1. Easy to use
2. Enable fast data input
3. Well tried technology

Disadvantages of Keyboards

1. Sometimes it is difficult to use

2. Need desk space to keep

Mouse: It is used as a popular pointing device. It is used to create images, graphics as well as to click on any button or menu. The mouse has two or three buttons.

Functions of the mouse:

- Clicking
- Double Clicking
- Right Clicking
- Dragging
- Scrolling

Types of Mouse

There are three type of mouse are as follow:

- Mechanical Mouse
- Optical Mouse
- Wireless Mouse

1. Mechanical Mouse: This mouse has a rubber ball at the bottom, when we rotate the mouse on the surface than the rubber ball also rotates inside the shell. Now the sensors inside the mouse give a signal to the computer.



2. Optical Mouse: It is a type of Non-mechanical mouse. A light beam is emitted from the surface below it. Based on the light beam, the mouse determines the distance and speed of the object.



3. Wireless Mouse: This mouse communicates to the computer with the help of radio-frequency.

It has two main components:

Transmitter- It is used to send the information of the mouse's speed and its click in the form of an electromagnetic signal.



Receiver: It connects to the computer and used to receive the signals sent by the transmitter.

Advantages of Mouse

1. Easy to use.
2. Less Expensive.
3. The Cursor moves faster than the arrow keys of the keyboard.

Disadvantages of Mouse

1. Required flat surface to move
2. Needs regularly cleaning
3. Damaged easily

Joystick: It is a pointing device. It is used to play video games. It has a rounded ball at both ends. The joystick can be moved in all directions.

The Joystick is similar to a mouse. It is also used in computer-aided designing (CAD).



Advantages of Joystick

1. Used in playing games
2. Fast Interface
3. Easy to Navigate

Disadvantages of Joystick

1. Sometimes difficult to control
2. Required hand Movement
3. It is not robust

Microphone: The microphone was introduced by “**Emile Berliner**” in 1877. It is also called “**Mic.**” The Microphone is used to take input in the form of audio.

The microphone is plugged into the specific port of the sound card in the computer system. Some microphones are wireless.



Touch Screen: It is an Electronic Visual Display, which is used to detect the touch of finger and hand in its display area.

It is most widely used with those computer machines that can interact with the user.

For Example: Smartphones, Tablet, Etc.



Type of Touch Screen: The types of the touch screen are:

1. **Resistive:** It is made up of hardened acrylic plastic. It is pressure sensitive. It has minimal clarity. It has a durability of 15 million touches.
2. **Capacitive:** It is made up of glass with coating. It activates by human body electricity. It has the best clarity. It has a durability of 60 million touches.
3. **Surface Acoustic Wave (SAW):** It is made up of a Glass with coating. SAW activates by wave absorption. It has medium clarity. It has a durability of 30 million touches.

Advantages of Touch Screen

1. Simple User Interface
2. Speed
3. Durability
4. Improve Accessibility

Disadvantages of Touch Screen

1. Screen Size
2. Sensitivity Issue
3. Accidental Dialing

Touch Pad: It is a flat pad used in laptops on which we slide the finger to move the cursor. It is a touch-sensitive area.

It is also called “Trackpad.” It is used to translate the motion and position of the user’s finger. It also includes two buttons:

Left Click: It is used to select the option.

Right Click: It is used to display the options on the screen.

**Advantages:**

1. No Mouse Needed
2. No need of a wire-like mouse

Disadvantages:

1. Lacks of the scroll wheel
2. Less sensitive than a mouse

Light Pen: It is a tool that is light sensitive. It is used to draw pictures and graphics on the computer screen. It is also used to select the objects.

The pictures made by the light pen can be stored in the computer and can be improved as needed.

**Advantages:**

1. It allows the user to select any object.
2. It does not have any coating.
3. Easy to Use
4. Available in different colors

Disadvantages:

1. Works only with CRT screens
2. Not very accurate drawing

3. Sensitive with dust

Web Camera: It is a hardware input device. It is a video camera that is used to transmit pictures or videos in real-time to a computer network.

It is connected with laptops, or we can connect it with the computer through USB cable. It is also called a small digital camera.



Advantages:

1. It can connect with people across the world.
2. Easy to use
3. It uses both sound and video

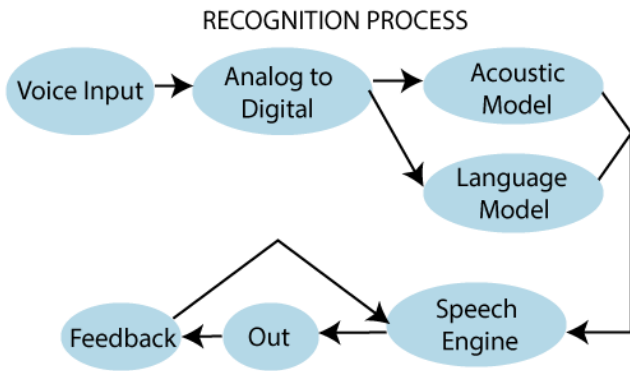
Disadvantages:

1. Poor Quality Images
2. Limited Features

Voice Recognition System: It is also called the “**Speech Recognition System.**” It is a computer software program that takes human speech as an input, converts that into digital form, and act on it.

Voice recognition system is used to operate mobile phones through voice command.

For Example: Google Assistant, SIRI (Apple) Etc.



Advantages:

1. Improves Efficiency
2. Easy to use for anyone
3. Easy to Understand

Disadvantages:

1. Vocal Problems
2. Requires more storage to store voice files
3. Noise Interference

Direct Data Entry Devices

Direct data devices are those peripheral devices through which we can directly input the data from the source and transfer that to the computer system.

It also includes:

- **Scanner:** It is an input device. It is used to scan documents such as photographs. It is used to input any shape or written data on a page directly into the computer.

Its main advantage is that the user does not have to type the information.



Advantages:

1. High-Resolution Images
2. Easy to handle

3. Fast image analysis
4. Image portability

Disadvantages:

1. High Cost
2. The Need for internet and power supply
3. Difficult to manage large digital files

Barcode Reader: It is also known as “**Price Scanner**” or “**Point-of-sale scanner.**” A barcode is a particular type of code. It contains a series of thick and thin lines, which are called “**Bars.**” The bar contains the information.

We can read the barcode through an optical scanner called “**Barcode Reader.**” The user can connect the barcode reader with the computer through a serial cable.



Advantages:

1. Fast Speed
2. Accuracy
3. Portable

Disadvantages:

1. Require a clear line of sight
2. Expensive

MICR: It is also called “**Magnetic Ink Character reader.**” It is widely used in the processing of cheques in the bank. MICR is used for reading magnetic ink printed characters.

This machine is fast and automatic. There should be a nil chance of making mistakes.



Advantages:

1. More secure than OCR
2. More accurate than OCR
3. Allow overwrite cheques

Disadvantages:

1. Only a limited character set
2. Expensive

OCR: It is also called “**Optical Character Recognition.**” It is a technique which is used to read a special type of symbols, letters, or the numbers. The light source can read the characters.

The OCR can read characters printed from typewriters, the character of the cash register, and the character of the credit card. The OCR fonts are stored on the computer.



Advantages:

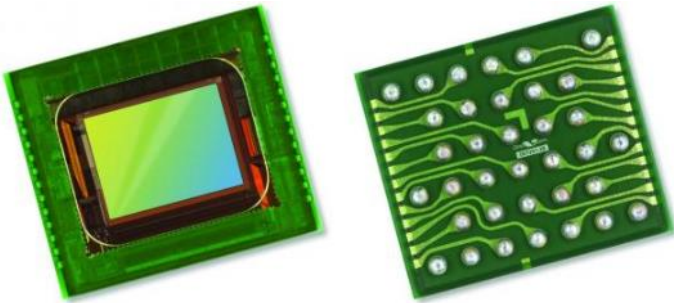
1. Faster data entry
2. Printed document converted into text files

Disadvantages:

1. Cannot recognize all type of text

2. Poor or Old documents cannot be recognized

Sensors: A Sensor can be treated as an input device that is used to detect and change the force, pressure, any other physical quantity, and sends the data to the computer.



Advantages of Sensors

1. Sensitivity
2. Reliability
3. High-Resolution

Disadvantages of Sensors

1. Affected by temperature and humidity
2. Difficulties in designing

Biometric System: A biometric system is defined as an input system that is used to identify a person. A biometric machine can identify a person by face, eyes, voice, finger, or thumb impression.

It is a secure system; it means no biometric data can be stolen.

Uses of Biometric System:

1. Biometric Door Lock
2. Biometric Attendance system
3. Biometric ATM



A biometric system also includes:

1. **Finger Scanner:** It is used to identify the person by his thumb or finger.
2. **Hand Scanner:** It is used to identify the person by his palm impression.

Advantages of Biometrics

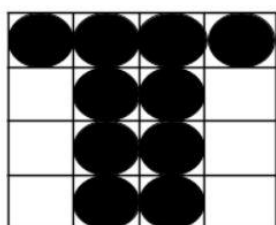
1. More secure than passwords
2. Accuracy
3. Uniqueness

Disadvantages of Biometrics

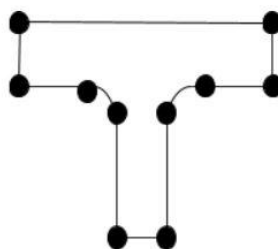
1. Costly
2. Missing or injured body part problem

Q: 5. Display Processor in Computer Graphics

Display Processor is the interpreter or a hardware that converts display processor code into picture. The Display Processor converts the digital information from CPU to analog values. The main purpose of the Digital Processor is to free the CPU from most of the graphic chores. The Display Processor digitize a picture definitions given in an application program into a set of pixel intensity values for storage in the frame buffer. This digitization process is called Scan Conversion.



A Character (T)
defined in a grid of
pixel positions.



A Character (T)
defined as a curve
outline.

- Display processors includes functions such as generating various line styles, displaying color area and performing transformations and manipulations on display object.
- Display Processor was used before the GPU (Graphics Display Processor).
- Video Controller is the most widely used Display device that is based on CRT (Cathode Ray Tube).
- In addition with the system memory, Display Processor have a separate memory area.

Display

Devices:

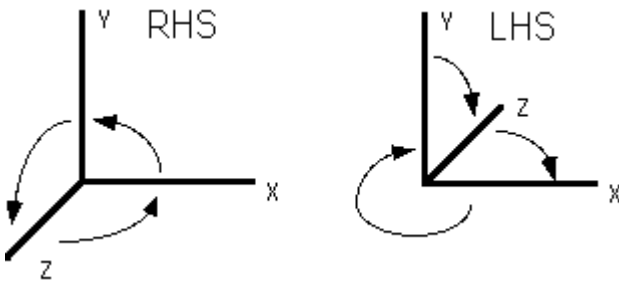
There are large number of Display Devices available to free the CPU from graphic chores:

- Refresh Cathode Ray Tube
- Random Scan and Raster Scan
- Color CRT Monitors
- Direct View Storage Tubes
- Flat Panel Display
- Lookup Table

Q: 6. Coordinate System Representation in Graphics

In a 2-D coordinate system the X axis generally points from left to right, and the Y axis generally points from bottom to top. (Although some windowing systems will have their Y coordinates going from top to bottom.)

When we add the third coordinate, Z, we have a choice as to whether the Z-axis points into the screen or out of the screen:



Right Hand Coordinate System (RHS)

Z is coming out of the page

Counterclockwise rotations are positive

if we rotate about the X axis : the rotation Y->Z is positive

if we rotate about the Y axis : the rotation Z->X is positive

if we rotate about the Z axis : the rotation X->Y is positive

Left Hand Coordinate System (LHS)

Z is going into the page

Clockwise rotations are positive

if we rotate about the X axis : the rotation Y->Z is positive

if we rotate about the Y axis : the rotation Z->X is positive

if we rotate about the Z axis : the rotation X->Y is positive

so basically its the same thing ...

The important thing to note is what coordinate system is being used by the package you are working with, both for the creation of models and the displaying of them. Also note that if the two packages use different coordinate systems, then the model(s) may need to be inverted in some fashion when they are loaded in for viewing.

OpenGL generally uses a right-hand coordinate system.

Multiple Coordinate Systems in a Graphics Program

In a typical graphics program, we may need to deal with a number of different coordinate systems, and a good part of the work (and the cause of many headaches) is the conversion of coordinates from one system to another. We'll learn about the conversion process a little later, but in the meantime, here is a list of some of the coordinate systems you may encounter:

- **World Coordinate System** - Also known as the "universe" or sometimes "model" coordinate system. This is the base reference system for the overall model, (generally in 3D), to which all other model coordinates relate.
-
- **Object Coordinate System** - When each object is created in a modelling program, the modeller must pick some point to be the origin of that particular object, and the orientation of the object to a set of model axes. For example when modelling a desk, the modeller might choose a point in the center of the desk top for the origin, or the point in the center of the desk at floor level, or the bottom of one of the legs of the desk. When this object is moved to a point in the world coordinate system, it is really the origin of the object (in object coordinate system) that is moved to the new world coordinates, and all other points in the model are moved by an equal amount. Note that while the origin of the object model is usually somewhere on the model itself, it does not have to be. For example, the origin of a doughnut or a tire might be in the vacant space in the middle.
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- **Hierarchical Coordinate Systems** - Sometimes objects in a scene are arranged in a hierarchy, so that the "position" of one object in the hierarchy is relative to its parent in the hierarchy scheme, rather than to the world coordinate system. For example, a hand may be positioned relative to an arm, and the arm relative to the torso. When the arm moves, the hand moves with it, and when the torso moves, all three objects move together.
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- **Viewpoint Coordinate System** - Also known as the "camera" coordinate system. This coordinate system is based upon the viewpoint of the observer, and changes as they change their view. Moving

an object "forward" in this coordinate system moves it along the direction that the viewer happens to be looking at the time.

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- **Model Window Coordinate System** - Not to be confused with desktop windowing systems (MS Windows or X Windows), this coordinate system refers to the subset of the overall model world that is to be displayed on the screen. Depending on the viewing parameters selected, the model window may be rectangular or a distorted viewing frustum of some kind.
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- **Screen Coordinate System** - This 2D coordinate system refers to the physical coordinates of the pixels on the computer screen, based on current screen resolution. (E.g. 1024x768)
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- **Viewport Coordinate System** - This coordinate system refers to a subset of the screen space where the model window is to be displayed. Typically the viewport will occupy the entire screen window, or even the entire screen, but it is also possible to set up multiple smaller viewports within a single screen window.

Homogeneous Coordinates

The rotation of a point, straight line or an entire image on the screen, about a point other than origin, is achieved by first moving the image until the point of rotation occupies the origin, then performing rotation, then finally moving the image to its original position.

The moving of an image from one place to another in a straight line is called a translation. A translation may be done by adding or subtracting to each point, the amount, by which picture is required to be shifted.

Example of representing coordinates into a homogeneous coordinate system: For two-dimensional geometric transformation, we can choose homogeneous parameter h to any non-zero value. For our convenience take it as one. Each two-dimensional position is then represented with homogeneous coordinates $(x, y, 1)$.

Translation of point by the change of coordinate cannot be combined with other transformation by using simple matrix application. Such a combination is essential if we wish to rotate an image about a point other than origin by translation, rotation again translation.

To combine these three transformations into a single transformation, homogeneous coordinates are used. In homogeneous coordinate system, two-dimensional coordinate positions (x, y) are represented by triple-coordinates.

Homogeneous coordinates are generally used in design and construction applications. Here we perform translations, rotations, scaling to fit the picture into proper position.

Following are matrix for two-dimensional transformation in homogeneous coordinate:

1. Translation $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ t_x & t_y & 1 \end{bmatrix}$ or $\begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{bmatrix}$

2. Scaling $\begin{bmatrix} S_x & 0 & 0 \\ 0 & S_y & 0 \\ 0 & 0 & 1 \end{bmatrix}$

3. Rotation (clockwise) $\begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$

4. Rotation (anti-clock) $\begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$

5. Reflection against X axis $\begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

6. Reflection against Y axis $\begin{bmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

7. Reflection against origin $\begin{bmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

8. Reflection against line Y=X $\begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

9. Reflection against Y= -X $\begin{bmatrix} 0 & -1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

10. Shearing in X direction $\begin{bmatrix} 1 & 0 & 0 \\ Sh_x & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

11. Shearing in Y direction $\begin{bmatrix} 1 & Sh_y & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

12. Shearing in both x and y direction $\begin{bmatrix} 1 & Sh_y & 0 \\ Sh_x & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

