Major Application of Computer Graphics

1. Graphical User Interface

Most software packages have the Graphical Interface. A major component of the graphical interface is a window. User can display multiple windows. Each window can contain a different process. To make a particular window active, we click in that window using some interactive pointing device.

Graphical interfaces also display menus and icons. An icon is a graphical symbol that is designed to process some option. The advantages of icons are that they take up less space and are easy to understand. Menus contain lists of textual description and icons.

2. Computer Art

Computer graphics are widely used in both fine and commercial art applications. Artists use a variety of computer methods, including special-purpose hardware, paintbrush programs, mathematical packages, animation packages, etc. that provide facilities for designing object shapes and specifying object motions.

The picture is usually painted electronically on a hardware device called graphics tablet using a stylus, which can stimulate different brush strokes, brush widths, and colours. A pressure-sensitive stylus converts changing hand pressure into variable line widths, brush sizes and colour gradations. Some software allows the artist to create watercolour, pastel or oil brush effects that stimulate different drying times. Some computer technologies use three-dimensional modelling packages, texture mapping, etc.

Computer art can be used for designing logos, other designs, TV advertising, etc.

3. Presentation Graphics

Presentation graphics are used to summarise financial, statistical, mathematical, scientific and economic data for research reports, managerial reports, and other type of reports. Some examples of presentation graphics are bar charts, line graphs, surface graphs, pie charts, etc. showing relationships between multiple parameters.

4. Computer-Aided Design

A major use of computer graphics is in design processes, particularly for engineering and architectural systems. Computer-aided design (CAD) methods are now used in design of automobiles, buildings, aircraft, and many other products. For some applications, objects are first displayed as *wireframes* (frames of objects shown as wires) that shows the overall shape and internal features of objects.

Software packages for CAD applications generally provide a multi-window setting where various windows can show enlarged sections or different views of objects. Animations are also used in CAD applications.

When object designs are complete, or nearly complete, realistic lighting and *surface rendering* (creating outer bodies of objects) are applied to produce displays that will show the appearance of final product.
Architects use interactive graphics methods to draw floor layout plans, such as, showing the positioning of rooms, doors, windows, stairs, and other building features. Also electrical wiring, fire warning systems, etc can also be drawn.

5. Education and Training

Computer-generated models of physical system, population trends, financial system, economic systems or equipment are often used as educational aids. Computer based training (CBT) tools are used in educational institutions to teach various applications.

For some training applications, special systems are designed, such as simulators for practice sessions or training of aircraft pilots, heavy-equipment operators, ship captains, and air traffic control personnel. The simulator provides the situation similar to the original conditions. Most simulators provide graphic screens for visual operation and a control panel.

6. Entertainment

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

Scenes can be generated using advanced modelling, surface rendering and other image processing techniques. Graphics and image processing techniques can be used to produce a transformation of one person or object to another, known as *Morphing*.

7. Visualisation

Scientists, engineers, medical personnel, business analysts and others often need to analyse large amount of information to study the behaviour of certain processes. Scanning large amount of data to determine various results is a difficult and time-consuming process. But if the data are converted to a visual form, the results can be easily assessed.

Producing graphical representations for scientific, engineering and medical data and processes is referred to as *Scientific Visualisation.* The term *Business Visualisation* is used in connection with data sets related to commerce, industry, and other non-scientific areas.
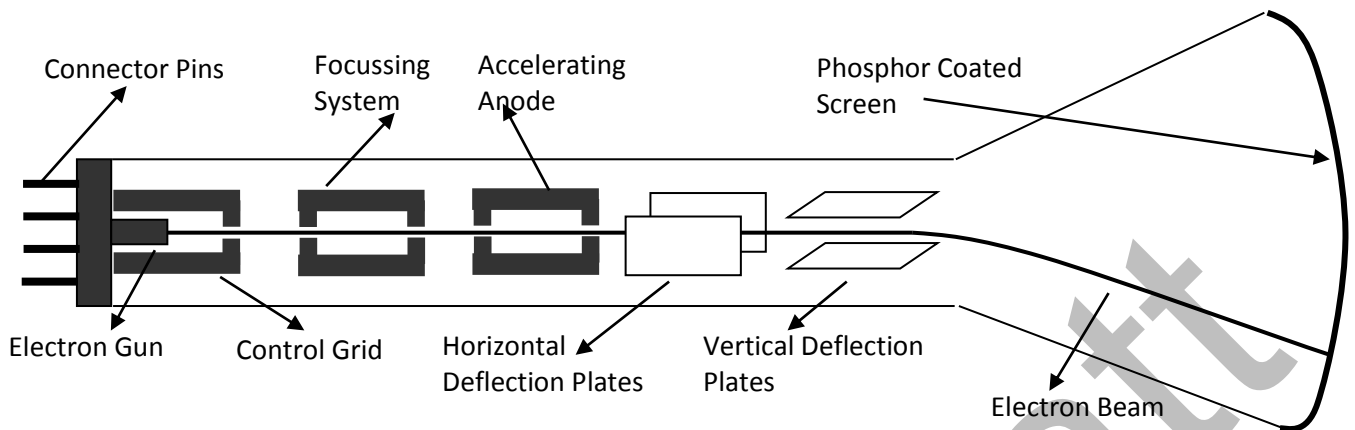
8. Image Processing

Image processing applies techniques to modify or interpret existing pictures. Image processing can be applied for improving picture quality.

To apply image-processing methods, we first digitise a picture into an image file. Then various methods can be applied to rearrange picture parts, to improve colour separations or to improve the quality of shading. These techniques are used in commercial art applications that involve the retouching and rearranging of parts of photographs. Image processing is also applicable in satellite photos, medical applications, etc to improve the quality of the pictures.

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 many other technologies exist.

Refresh Cathode-Ray Tubes

Connector Pins   Focussing   Accelerating   Phosphor Coated
                  System   Anode   Screen

Electron Gun   Control Grid   Horizontal   Vertical Deflection
                                Deflection Plates Plates

                                                        Electron Beam

Basic Design of Cathode-Ray Tubes

A beam of electrons, emitted by an electron gun, passes through focussing 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, the picture is redrawn repeatedly by quickly directing the electron beam back over the same points. This type of display is called a **Refresh CRT**.

A component in a CRT, called an **Electron Gun** is used to generate electrons. It consists of the heated metal cathode. Heat is supplied to the cathode by directing a current through a coil of wire, called the filament. This causes the electrons to emit from the hot cathode surface. In the vacuum inside the CRT, the negatively charged electrons are then accelerated towards the phosphor coating by a high positive voltage.

The accelerating voltage to accelerate the electrons up to the screen, can be generated with a positively charged metal coating on the inside of the CRT envelope near the phosphor screen, or an **Accelerating Anode** can be used.

Setting voltage levels on the **Control Grid** controls intensity of the electron beam. A high negative voltage applied to the control grid will shut off the electron beam by repelling electrons. A smaller negative voltage on the control grid decreases the number of electrons passing through the grid. Since the amount of light emitted by the phosphor coating depends on the number of electrons striking the screen, we control the brightness of a display by varying the voltage on the control grid.

The **Focusing System** in a CRT is needed to force the electron beam to join into a small spot as it strikes the phosphor screen. Otherwise, the electrons will repel each other, and the beam would spread out as it approaches the screen. Focussing is done using electric or magnetic fields.

Deflection plates are used to move the electron beam to any position of the screen. Deflection of the electron beam can be controlled by electric or magnetic fields. Horizontal deflection is done by a pair of horizontal deflection coils and vertical deflection is done by another pair of coils.

When the electrons in the beam collide with the phosphor coating, the phosphor coating glows. Different kinds of phosphors are available for use in a CRT. After the CRT beam is removed, the amount of time phosphor continues to emit light is known as the **Persistence.**

The maximum number of points that can be displayed without overlap on a CRT is referred to as the **Resolution**. Another definition of resolution is the number of points per centimetre that can be drawn horizontally and vertically.

Another property of video monitors is **Aspect Ratio**. This number gives the ratio of vertical points to horizontal points necessary to produce equal-length lines in both directions on the screen. An aspect ratio of ¾ means that a vertical line plotted with three points have same length as a horizontal line plotted with four points.

Raster-Scan Displays

The most common type of graphics monitor using a CRT is the Raster-Scan display. In a raster- scan system, the electron beam moves across the screen one row at a time from top to bottom. As the electron beam moves across each row, the beam intensity is turned on and off to create a pattern of lighted spots. Scanning of the screen from top left to bottom right once is referred to as one **Frame**.

Picture definition is stored in a memory area called the **Refresh Buffer** or **Frame Buffer**. This memory area holds the set of intensity values for all screen points. Stored intensity values are then taken back from the refresh buffer and put on the screen one row at a time. Each screen point is referred to as a **Pixel** or **Picture Element**.
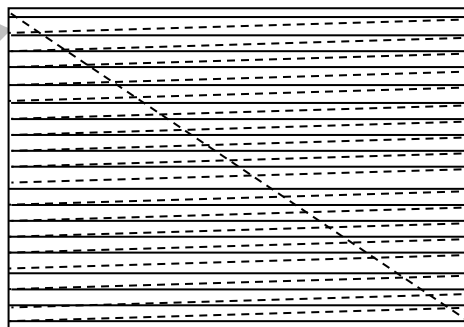

Figure showing scan lines, horizontal retrace
and vertical retrace in a Raster-Scan Display

The rate, at which the electron beam is refreshed on the phosphor-coated screen, in one second, is termed as the **Refresh Rate**. Refreshing on raster-scan displays is carried out at the rate of 60 to 80 times per second.

Sometimes, refresh rates are described in units of cycles per seconds or **Hertz (Hz)** where a cycle corresponds to one frame.

The scanning of the one row of the screen is called as a **Scan Line**. At the end of each scan line, the electron beam returns to the left side of the screen to begin displaying the next scan line. The return to the left of the screen, after refreshing each scan line, is called the **Horizontal Retrace** of the electron beam. And at the end of each frame, the electron beam returns to the top left corner of the screen from bottom right corner to begin the next frame. This is known as the **Vertical Retrace**. Raster scan systems produce jagged lines in cases where lines are at some angles and not horizontal or vertical.

A jagged line produced by Raster-scan system

On some raster-scan systems, each frame is displayed in two passes using an **Interlacing** procedure. In the first pass, the beam sweeps across every alternate line from top to bottom. Then after the vertical retrace, the beam sweeps out the remaining scan lines. Interlacing allows us to see the entire screen displayed in half the time it would have taken to sweep across all the lines at once from top to bottom. Interlacing is mainly used with slower refreshing rates as it can reduce flicker caused due to slow refresh rates. This is an effective technique for avoiding flicker.
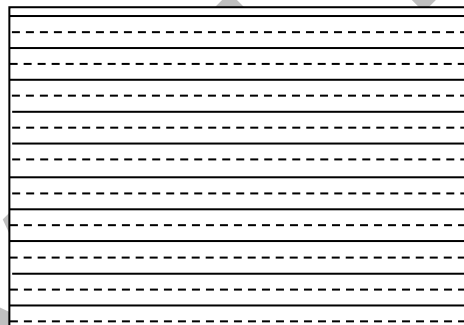

Figure showing interlacing scan lines on raster-scan display. First all solid scan lines are displayed then dashed scan lines are displayed.

Random-Scan Displays

In random-scan display systems, 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. So they are also known as **Vector Displays** or **Stroke-Writing Displays** or **Calligraphic Displays**. The lines of a picture can be drawn and refreshed in any order randomly.

Picture definition is stored as a set of line-drawing commands in a memory referred to as the **Refresh Display File** or **Display List** or **Display Program** or **Refresh Buffer**. To display the specified picture, the system draws each component line from the display file. Refresh rate depends on the number of lines to be displayed. Random-scan displays are designed to draw all the component lines of picture 30 to 60 frames per second.

Random-scan systems are designed for line-drawing applications and cannot display shaded scenes. Since picture definition is stored as set of line-drawing commands, random-scan displays generally have higher resolution than raster system. Also, random-scan displays produce smooth line drawings, whereas raster systems produce jagged lines.

Colour CRT Monitor

A CRT monitor displays colour picture by using combination of phosphor that emit different coloured light. The two basic techniques for producing colour displays with a CRT are:

1. **Beam Penetration Method:** The beam penetration method for displaying colour pictures is generally used with random-scan monitors. Two layers of phosphor, generally red and green, are coated onto the inside of the CRT screen, and the displayed colour depends on how far the electron beam passes into the phosphor layers. A beam of slow electrons strikes only the outer red layer and red colour is generated while a very fast beam will pass through the red layer and strike the inner green layer. At intermediate beam speeds, combination of red and green generate two additional colours, orange and yellow.

   The advantage of beam Penetration method is that it is an economical way to produce colour in random-scan monitors. The disadvantage of beam penetration method is that it produces only four colours, and the quality of pictures is not as good as other methods.

2. **Shadow Mask Method:** Shadow-Mask method is commonly used in raster-scan systems because they produce a much wider range of colours than the beam penetration method.

   A Shadow-mask CRT has three phosphor colour dots at each pixel position arranged in the form of a triangle. This type of arrangement is called the **Delta** arrangement. One phosphor dot emits a red light, another emits a green light, and the third emits a blue light. This type of CRT has three electron guns, one for each colour dot, and a shadow-mask grid just behind the phosphor-coated screen.

   The three electron beams are deflected and focused as a group onto the shadow mask, which contains a series of holes aligned with the phosphor-dot patterns. When the three beams pass through a hole in the shadow mask, they activate a dot triangle, which appears as a small colour spot on the screen. The phosphor dots in the triangles are arranged so that each electron beam can activate only its corresponding colour dot when it passes through the shadow mask.

   Another configuration for the three electron guns is an **In-line** arrangement in which the three electron guns, and the corresponding red-green-blue colour dots on the screen, are aligned along one scan line instead of in a triangular pattern. This in-line arrangement of electron guns is easier to keep in alignment and is commonly used in high-resolution colour CRTs.
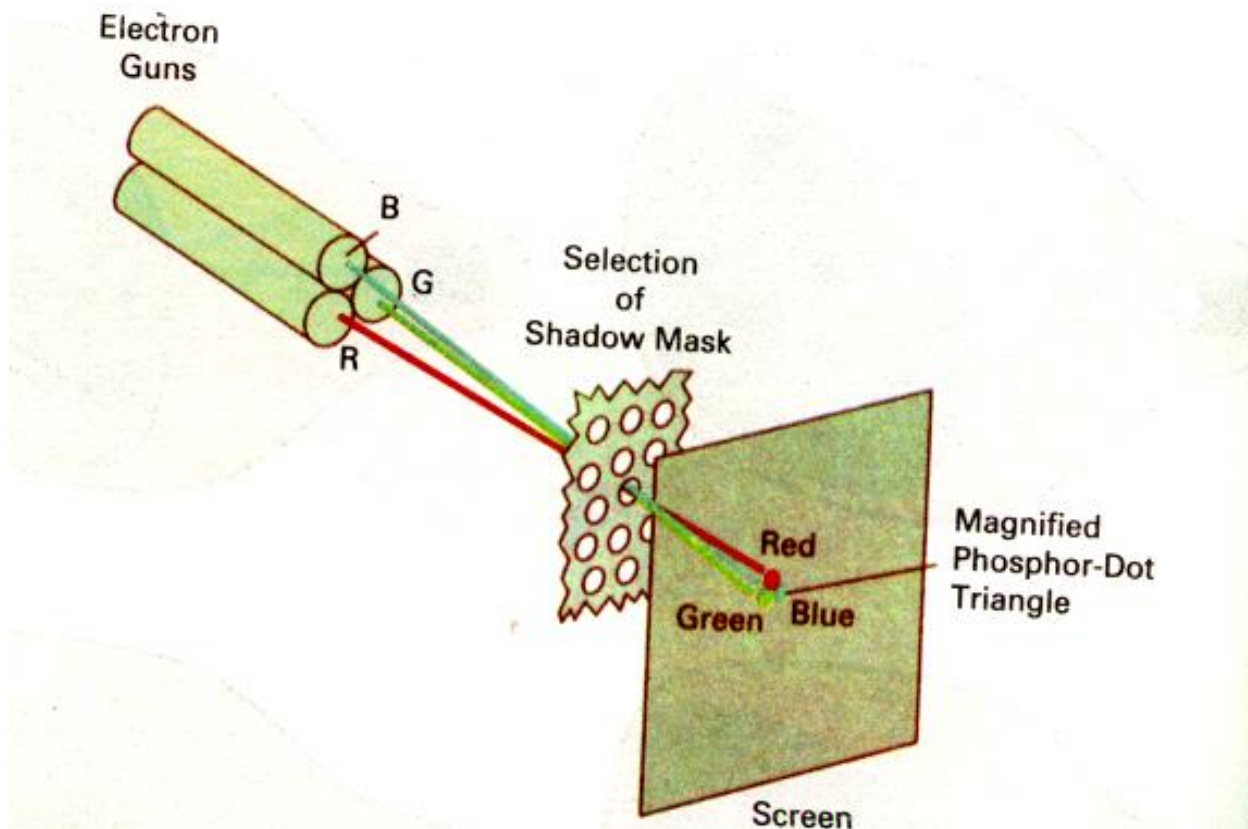
We obtain colour variations in a shadow-mask CRT by varying the intensity levels of the three electron beams. By turning off the red and green guns, we get only the colour coming from the blue phosphor. Other combinations of beam intensities produce a small light spot for each pixel position, since our eyes merges the three colours into one. The colour we see depends on the amount of electrons that strike red, green, and blue phosphors. A white area is the result of activating all three dots with equal intensity. Yellow is produced with the green and red dots only.

Colour systems in graphics systems are known as **RGB Monitors**. High quality raster-graphics system 24 bits per pixel in the frame buffer, allowing nearly 17 million colour choices for each pixel. An RGB system with 24 bits of storage per pixel is generally referred to as **Full-colour System** or **True-colour System**.

Direct View Storage Tube

A Direct View Storage Tube (DVST) stores the picture information inside the CRT just behind the phosphor-coated screen. Two electron guns are used in DVST. One, the primary gun, is used to store the picture pattern and the second, the flood gun, maintain the picture display.

The advantage is that as no refreshing is needed, very complex pictures can be displayed at very high resolutions without flicker. Disadvantage of DVST systems are that they generally do not display colour and that selected parts of the screen or picture cannot be erased. For these reasons, storage systems have been mostly replaced by raster systems.

Flat Panels

Although most graphics monitors are still constructed with CRTs, other technologies are emerging that may soon replace CRT monitors. The term **flat-panel** display refers to a class of video devices that have reduced volume, weight, and power requirements compared to a CRT. A significant feature of flat-panel displays is that they are thinner than CRTs, and we can hang them on walls or wear them on our wrists. Since we can even write on some flat-panel displays, they will soon be available as pocket notepads. Current uses for flat-panel displays include small TV monitors, calculators, pocket video games, laptop computers, armrest viewing of movies on airlines, as advertisement boards in elevators, and as graphics displays in applications requiring rugged, portable monitors.

We can separate flat-panel displays into two categories: **emissive displays** and **nonemissive displays**. The **emissive displays** (or emitters) are devices that convert electrical energy into light. Plasma panels, thin-film electroluminescent displays, and light-emitting diodes are examples of emissive displays. **Nonemmissive displays** (or nonemitters) use optical effects to convert sunlight or light from some other source into graphics patterns. The most important example of a nonemissive flat-panel display is a liquid-crystal device.

Plasma panels, also called gas-discharge displays, are constructed by filling the region between two glass plates with a mixture of gases that usually include neon. A series of vertical conducting ribbons is placed on one glass panel, and a set of horizontal ribbons is built into the other glass panel. Firing voltages applied to a pair of horizontal and vertical conductors cause the gas at the intersection of the two conductors to break down into glowing plasma of electrons and ions. Picture definition is stored in a refresh buffer, and the firing voltages are applied to refresh the pixel 60 times per second.

LCD

Liquid-crystal displays (LCDs) are commonly used in small systems, such as calculators and portable, laptop computers. These non- emissive devices produce a picture by passing polarized light from the surroundings or from an internal light source through a liquid-crystal material that can be aligned to either block or transmit the light.

The term liquid crystal refers to the fact that these compounds have a crystalline arrangement of molecules, yet they flow like a liquid. Flat-panel displays commonly use nematic (threadlike) liquid-crystal compounds that tend to keep the long axes of the rod-shaped molecules aligned. Two glass plates, each containing a light polarizer at right angles to the other plate, sandwich the liquid-crystal material.

Rows of horizontal transparent conductors are built into one glass plate, and columns of vertical conductors are put into the other plate. The intersection of two conductors defines a pixel position. Polarized light passing through the material is twisted so that it will pass through the opposite polarizer. The light is then reflected back to the viewer. To turn off the pixel, we apply

a voltage to the two intersecting conductors to align the molecules so that the light is not twisted. This type of flat-panel device is referred to as a **passive-matrix LCD**. Picture definitions are stored in a refresh buffer, and the screen is refreshed at the rate of 60 frames per second, as in the emissive devices. Back lighting is also commonly applied using solid-state electronic devices, so that the system is not completely dependent on outside light sources. Colors can be displayed by using different materials or dyes and by placing a triad of color pixels at each screen location.

Another method for constructing LCDs is to place a transistor at each pixel location, using thin-film transistor technology. The transistors are used to control the voltage at pixel locations and to prevent charge from gradually leaking out of the liquid-crystal cells. These devices are called **active-matrix LCD**.

Input Devices

Various devices are available for data input on graphics computers.

1. Keyboard: An alphanumeric keyboard on a graphic system is used primarily as a device for entering text strings. The keyboard is an efficient device for inputting non-graphic data. Keyboards can also be provided with features to facilitate entry of screen coordinates, menu selections, or graphic functions.

Cursor-control keys to control screen cursor, function keys to enter frequently used operations in a single keystroke and numeric keypad for fast entry of numeric data are common feature of general-purpose keyboards.

2. Mouse: A mouse is small hand-held box used to position the screen cursor. Wheels or rollers on the bottom of the mouse can be used to record the amount and direction of movement. A mouse can be picked up and put down at another point without change in cursor position. Two or three buttons are usually included on the top of the mouse for signalling the execution of some operation.

A similar device called the *Z Mouse* includes three buttons, a thumbwheel on the side, a trackball on the top and the standard mouse ball under it. We can pick up an object, rotate it, and move it in any direction, and other three- dimensional application is possible using the Z mouse.

3. Trackball and Spaceball: A trackball is a ball that can be rotated with the fingers or palm of the hand to produce screen-cursor movement. Potentiometers attached to the ball measure the amount and direction of rotation. Trackballs are often mounted on keyboards or other devices such as the Z mouse.

Spaceballs are used for three-dimensional positioning, animation, CAD, and other applications. Unlike the trackball, the spaceball does not actually move. Special instruments measure the amount of pressure applied to the spaceball to provide input for positioning and orientation as the ball is pushed in various directions.

4. Joysticks: A joystick consists of a small vertical lever mounted on a base that is used to steer the screen cursor around. Most joysticks select screen positions with actual stick movement, but some work by measuring the pressure applied on the stick.

The distance that the stick is moved in any direction from its centre position corresponds to screen cursor movement in that direction. Potentiometers at the base of the joystick measure the amount of movement and the springs present at the base of the joystick return the stick to the centre position when it is released. One or more buttons act as input switches to signal certain actions once a screen position has been selected.

Pressure-sensitive joysticks, also called *Isometric Joysticks*, have a non-movable stick. Pressure on the stick is measured with strain gauges and converted to movement of the cursor in the direction specified. Joysticks are generally used for computer games.

5. Data Glove: A Data Glove is constructed with a series of sensors that detect hand and finger motions. Specialised instruments are used to provide information about the position and orientation of the hand. Input from the glove can be used to position or manipulate objects in a three-dimensional scene. A two-dimensional projection of the scene can be viewed on a video monitor.

6. Digitizers: Digitizer is a common device for drawing, painting or selecting coordinate positions on an object.

One type of digitizer is the *Graphic Tablet*, which is used to input two-dimensional coordinates by activating a *Hand Cursor* or *Stylus*. A hand cursor contains cross hairs for seeing positions, while stylus is a pencil-shaped device that is pointed at positions on the tablet. Electromagnetic transmissions or sound waves are used to detect position of the stylus.

7. Image Scanners: Drawings, graphs, colour and black-and-white photos or text can be stored for computer processing with an image scanner. An optical scanning mechanism is passed over the information to be stored. The amount of colours are then recorded and stored in an array.

We can apply various image-processing methods and transformations such as rotate, change size, etc. to modify the array representations of the picture. For scanned text input, various editing operations can be performed on the stored documents. Some scanners are able to scan either graphical representations or text, and they come in a variety of sizes and capabilities. Scanners can be hand-held scanner, flatbed scanner or drum scanner.

8. Touch Panel: Touch panels allow displayed objects or screen positions to be selected with the touch of a finger. An application of touch panels is for the selection of processing options that are represented with graphical icons. Touch input can be recorded using optical, electrical or acoustical methods.

Optical touch panels employ a line of infrared light-emitting diodes along one vertical edge and along one horizontal edge of the frame. The opposite vertical and horizontal edges contain light detectors. These detectors are used to record which beams are stopped when the panel is touched. The two crossing beams that are stopped identify the horizontal and vertical coordinates of the screen position selected.

In acoustical touch panels, high frequency sound waves are generated in the horizontal and vertical direction across a glass plate. Touching the screen causes part of wave to be reflected from the finger. The screen position at the point of contact is calculated by measuring the time interval between transmission of wave and its reflection.

An electrical touch panel is constructed with two transparent plates separated by a small distance. When the outer plate is touched it is forced into contact with the inner plate. This contact created a voltage that is converted to the coordinate values of the screen position.

9. Light Pen: Light pen is a pencil shaped device used to select screen position by detecting the light coming from points on the CRT screen. They are sensitive to light emitted from the phosphor coating on screen. A light pen when pointed at a spot on the screen generates an electrical pulse when electron beam lights up that spot that causes the coordinate position of the electron beam to be recorded. Recorded light pen coordinates can be used to select a processing option.

Light pens have several disadvantages also. Light pens cannot detect positions inside black areas. Light pens sometimes give false readings due to background lighting in the room. Our hand also gets tired on long use of light pen.

10. Voice Systems: Speech recognisers are used in some graphic computers as input devices to accept voice commands.

These systems operate by matching an input with a dictionary of words and phrases stored inside the computer. A dictionary is created for a particular user by having the user speak the command to be used into the system. The system analyses the word and makes a frequency pattern for the word in the dictionary along with the function to be performed. Later, when a voice command is given, the system searches the dictionary for the matching frequency pattern and performs the corresponding function.

If a different user has to use the system, the dictionary must be made again with that user's voice patterns.

Hardcopy Devices

We can obtain hard-copy output i.e. output on paper or as photograph, for our images in several formats. To put images on film, we can simply photograph a scene displayed on a video monitor. And we can put pictures on paper by directing picture to a printer or a pen-plotter.

The quality of pictures from a device depends on dot size and number of dots per inch that can be displayed. High-quality printers have more dots per inch.

1. Printers: Printers produce output by either impact or non-impact methods. *Impact Printers* press characters press character faces against an inked ribbon onto the paper. Examples of impact printers are Dot-Matrix Printer, Line Printer, and Chain Printer.
A dot-matrix printer consists of a head containing a rectangular array of protruding wire pins, with the number of pins depending on the quality of the printer. Individual characters or graphics pattern are obtained by retracting certain pins so that the remaining pins form the pattern to be printed. The head moves across the paper and the pins do the printing.

Non-Impact Printers does not strike against the paper. They use laser techniques, ink sprays, photocopier process, electrostatic methods and electro thermal process to get images onto paper. Examples of non-impact printers are Laser Printer, Ink-Jet Printer, etc.

Ink-jet methods produce output by spraying ink in horizontal rows across a roll of paper wrapped on a drum. The electrically charged ink is deflected by an electric field to produce patterns.

An electrostatic device places a negative charge on the paper, one row at a time in the form of pattern to be printed. Then the paper is exposed to a positively charged toner and it gets attracted to the negatively charged areas on paper and produces the specified output. Electro thermal methods use heat in a print head to output patterns on heat-sensitive paper. We can get some colours on an impact printer by using different colour ribbons. Non-impact printers use various techniques to produce a range of colour patterns.

Pen Plotter: A Pen Plotter has one or more pens mounted on a carriage or a crossbar that crosses a sheet of paper. Pens with different colours and widths are used to produce a variety of shading and line styles. Different types of pen such as ball-point, ink pens are also used with a pen plotter. Plotter paper can be flat or be rolled onto a drum. Crossbars can be either moveable or stationary, with the pen moving sidewise along the bar.

Graphics Software

There are two general classifications for computer software: **General programming packages** and **special purpose applications packages**. A general graphics programming package provides an extensive set of graphics functions that can be used in a high level programming language such as C or FORTRAN.

An example of a general graphics programming package is the GL (Graphics Library) system on Silicon Graphics equipment. Basic functions in a general package include those for generating picture components (straight lines, polygons, circles, and other figures), setting color and intensity values, selecting views, and applying transformations. By contrast, application

graphics packages are designed for nonprogrammers, so that users can generate displays without worrying about how graphics operations work. The interface to the graphics routines in such packages allows users to communicate with the programs in their own terms. Examples of such applications packages are the artist's painting programs and various business, medical, and CAD systems.

Coordinate Representation

General graphics packages are designed to be used with **Cartesian coordinate** specifications. If coordinate values for a picture are specified in some other reference frame, they must be converted to Cartesian coordinates before they can be input to the graphics package.

We can construct the shape of individual objects, such as trees or furniture, in a scene within separate coordinate reference frames called **modeling coordinates**, or sometimes **local coordinates** or **master coordinates**. Once individual object shapes have been specified, we can place the objects into appropriate positions within the scene using a reference frame called **world coordinates**. Finally, the world-coordinate description of the scene is transferred to one or more output-device reference frames for display. These display coordinate systems are referred to as **device coordinates**, or screen coordinates. Modeling and world- coordinate definitions allow us to set any convenient floating-point or integer dimensions without being hampered by the constraints of a particular output device. Generally, a graphics system first converts world-coordinate positions to normalized device coordinates, in the range from 0 to 1, before final conversion to specific device coordinates. This makes the system independent of the various devices that might be used at a particular workstation.

Graphics Functions

A general graphics package provides users with functions to deal with output, attributes, transformation, viewing, input or general control operations.

The basic building blocks for pictures, such as character strings, points, lines, circles, polygon, etc. are known as *Output Primitives*. Functions for generating output primitives are the basic tools for constructing pictures.

Attributes are the properties of the output primitives. An attribute describes how a particular primitive is to be displayed. They include intensity, color, line style, text style, and area filling patterns.

We can change the size, position or orientation of an object using *Geometric Transformation*. *Viewing Transformations* are used to specify the part of a picture that has to be transferred to an output device and portion of the output display area that is to be used.

Interactive graphics applications use various kinds of input devices, such as a mouse, a keyboard, etc. *Input* functions are used to control and process the data flow from the interactive devices.

A graphics package contains a number of **General Control Operations**, such as clearing a display screen, initializing parameters, etc.
Pictures can be subdivided into component parts, called structures or segments or objects. Function for processing structures carry out operations such as creation, modification and transformation of structures.

Software Standards:

The primary goal of standardized software is portability. When packages are designed with standard graphics functions, software can be moved easily from one hardware system to another. Without standards, programs designed for one hardware system often cannot be transferred to another system without extensive rewriting of the programs.

The first graphics software standard developed was the **Graphics Kernel System (GKS)**, which was adopted by the International Standards Organisation (ISO), the American National Standards Institute (ANSI) and various other standards organisation. GKS was originally designed as a two-dimensional graphics package, but later on three-dimensional GKS extension was developed.

The second software standard to be developed was the **Programmer's Hierarchical Interactive Graphics Standard (PHIGS)**. Increased capabilities for object modelling, colour specifications, surface rendering and picture manipulation are provided in PHIGS. Later an extension of PHIGS, called PHIGS+, was developed to provide three – dimensional surface shading capabilities.

Standard graphics functions are defined as a set of specifications that is independent of any programming language. A language binding is then defined for a particular programming language. This binding gives the syntax for accessing the various standard graphics functions from this language.

Separate standards have been developed for other areas such as methods for storing and transmitting pictures, methods for a graphics interface to output devices. Standardisation for device interface methods is given in the **Computer Graphics Interface (CGI)**. The standard for storing and transporting pictures is specified in the **Computer Graphics Metafile (CGM)** system.

Compiled By: Mr. Navtej Bhatt, Lecturer,
            BCA Department, V.P. & R.P.T.P. Science College, VV Nagar
Class: BCA SEM V
Subject: US05CBCA02 – Computer Graphics

Declaration: This material is developed only for the reference for lectures in the classrooms. Students are required library reading for more study. This study material compiled from Book "Computer Graphics by Donald Hearn & M. Pauline Baker, PHI, 1995