

Syllabus

Basic concepts in Computer Graphics – Types of Graphic Devices – Interactive Graphic inputs – Raster Scan and Random Scan Displays.

BASIC CONCEPTS IN COMPUTER GRAPHICS

Computers have become a powerful tool for the rapid and economical production of pictures. There is virtually no area in which graphical displays cannot be used to some advantage. Advances in computer technology have made interactive computer graphics a practical tool. Computer graphics used routinely in such diverse areas as science, engineering, medicine, business, industry, government, art, entertainment, advertising, education etc. ***Computer Graphics is the Creation, Manipulation and Storage of geometric objects & their images.***

Different types of Computer Graphics

Computer Graphics can be broadly divided into two

- 1. Non Interactive Computer Graphics (Passive Computer Graphics):** In non-interactive computer graphics the user does not have any kind of control over the image. Image is merely the product of static stored program and will work according to the instructions given in the program linearly. The image is totally under the control of program instructions not under the user. eg. Titles shown on TV
- 2. Interactive Computer Graphics:** Interactive Computer Graphics involves a two way communication between computer and user. Here the observer is given some control over the image by providing him with an input device, so that he can signal his requests. The computer on receiving signals from the input device can modify the displayed picture appropriately. To the user it appears that the picture is changing instantaneously in response to his commands. He can give a series of commands, each one generating a graphical response from the computer. In this way he maintains a conversation, or dialogue, with the computer.

Application of Computer Graphics

- 1. Computer Aided Design (CAD):** Used in design of buildings, automobiles, aircraft, watercraft, spacecraft, computers, textiles & many other products. Objects are displayed in wire frame outline form. Software packages provide multi-window Environment. Graphics design package provides standard shapes (useful for repeated placements). Animations are also used in CAD applications. Realistic displays of architectural design permits simulated “walk” through the rooms (virtual reality systems)
- 2. Presentation Graphics:** Used to produce illustrations for reports or generate slides for use with projectors. Commonly used to summarize financial, statistical,

mathematical, scientific, economic data for research reports, managerial reports & customer information bulletins. Examples : Bar charts, line graphs, pie charts, surface graphs, time chart

3. **Computer Art:** Used in fine art & commercial art. Includes artist's paintbrush programs, paint packages, CAD packages and animation packages. These packages provide facilities for designing object shapes & specifying object motions. Examples: Cartoon drawing, paintings, product advertisements, logo design.

*Electronic painting:-*Picture painted electronically on a graphics tablet (digitizer) using a stylus.

*Morphing:-*A graphics method in which one object is transformed into another

4. **Entertainment :**

Movie Industry: Used in motion pictures, music videos, and television shows. Used in making of cartoon animation films

Game Industry: Focus on interactivity. Cost effective solutions, avoiding computations and other tricks.

5. **Education & Training:** Computer generated models of physical, financial and economic systems are used as educational aids. Models of physical systems, physiological systems, population trends, or equipment such as color-coded diagram help trainees understand the operation of the system. Some examples of specialized systems used for training applications are simulators for practice sessions or training of ship captains, aircraft pilots, heavy equipment operators, air traffic-control personnel.

6. **Visualization:**

Scientific Visualization: Producing graphical representations for scientific, engineering, and medical data sets and processes.

Business Visualization is used in connection with data sets related to commerce, industry and other non-scientific areas.

Techniques used- color coding, contour plots, graphs, charts, surface renderings & visualizations of volume interiors. Image processing techniques are combined with computer graphics to produce many of the data visualizations.

7. **Image Processing:** Image Processing applies techniques to modify or interpret existing pictures such as photographs and TV scans. Two principal applications of image processing are (1) Improving picture quality (2) Machine perception of visual information (as used in Robotics). Medical applications of Image Processing are Picture enhancements, Tomography, Simulations of operations, Ultrasonic & nuclear medicine scanners.

To apply image processing methods

- Digitize a photograph (or picture) into an image file
- Apply digital methods to rearrange picture parts to
 - Enhance color separations
 - Improve quality of shading
- Tomography – technique of X-ray photography that allows cross-sectional views of physiological systems to be displayed

- Computed X-ray tomography (CT) and position emission tomography (PET) use projection methods to reconstruct cross sections from digital data
- Computer-Aided Surgery is a medical application technique to model and study physical functions to design artificial limbs and to plan & practice surgery.

8. Graphical User Interfaces: A major component of a graphical interface is a window manager that allows a user to display multiple-window areas. Interfaces also display menus and icons for fast selection of processing options or parameter values. An icon is a graphical symbol that is designed to look like the processing option it represents. The advantages of icons are that they take up less screen space than corresponding textual descriptions and they can be understood more quickly if well designed. Menus contain lists of textual descriptions.

Graphics packages: A set of libraries that provide programmatically access to some kind of graphics 2D functions. Types of Graphics packages are:-

- GKS-Graphics Kernel System – first graphics package – accepted by ISO & ANSI
- PHIGS (Programmer’s Hierarchical Interactive Graphics Standard)-accepted by ISO & ANSI
- PHIGS + (Expanded package)
- Silicon Graphics GL (Graphics Library)
- Open GL
- Pixar Render Man interface
- Postscript interpreters
- Painting, drawing, design packages

TYPES OF GRAPHICS DEVICES

1. 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)**.

a) Refreshed Cathode ray Tubes

Basic operation of a CRT

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

The primary components of an electron gun in a CRT are the heated metal cathode and a control grid. Heat is supplied to the cathode by directing a current through a coil of wire, called the filament, inside the cylindrical cathode structure. This causes electrons to

be 'boiled off' the hot cathode surface. In the vacuum inside the CRT envelope, the free, negatively charged electrons are then accelerated toward the phosphor coating by a high positive voltage. The accelerating voltage can be generated with a positively charged metal coating on the side of the CRT envelope near the phosphor screen, or an accelerating anode can be used.

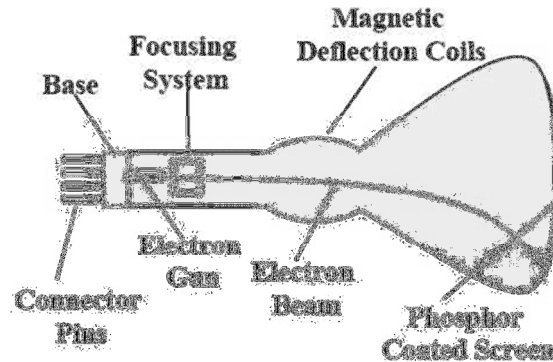


Fig . Basic design of a magnetic-deflection CRT

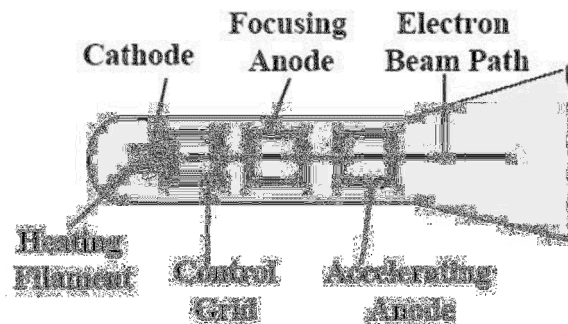


Fig. Operation of an electron gun with an accelerating anode

Spots of light are produced on the screen by the transfer of the CRT beam energy to the phosphor. When the electrons in the beam collide with the phosphor coating, they are stopped and the kinetic energy is absorbed by the phosphor. Part of the beam energy is converted by friction into heat energy, and the remainder causes electrons in the phosphor atoms to move up to higher quantum-energy levels. After a short time, the “excited” phosphor electrons begin dropping back to their stable ground state, giving up their extra energy as small quantum’s of Light energy. The frequency of the light emitted by the phosphor is proportional to the energy difference between the excited quantum state and the ground state.

Different kinds of phosphors are available for use in a CRT. Besides color, a major difference between phosphors is their persistence: how long they continue to emit light (that is, have excited electrons returning to the ground state) after the CRT beam is removed. Persistence is defined as the time it takes the emitted light from the screen to

decay to one-tenth of its original intensity. Lower persistence phosphors require higher refresh rates to maintain a picture on the screen without flicker. A phosphor with low persistence is useful for animation; a high-persistence phosphor is **useful** for displaying highly complex, static pictures.

The maximum number of points that can be displayed without overlap on a **CRT** is referred to as the **resolution**. Another precise definition of resolution is **the number of points per centimeter that can be plotted horizontally and vertically**. Resolution of a CRT is dependent on the type of phosphor, the intensity to be displayed, and the focusing and deflection systems. The physical size of a graphics monitor is given as the length of the screen diagonal. 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 3/4 means that a vertical line plotted with three points has the same length as a horizontal line plotted with four points.

b) Raster-Scan Displays

The most common type of graphics monitor employing a CRT is the raster-scan display. In a raster-scan system, the electron beam is swept 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 illuminated spots. 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 the screen points. Stored intensity values are then retrieved from the refresh buffer and "painted" on the screen one row (scan line) at a time.

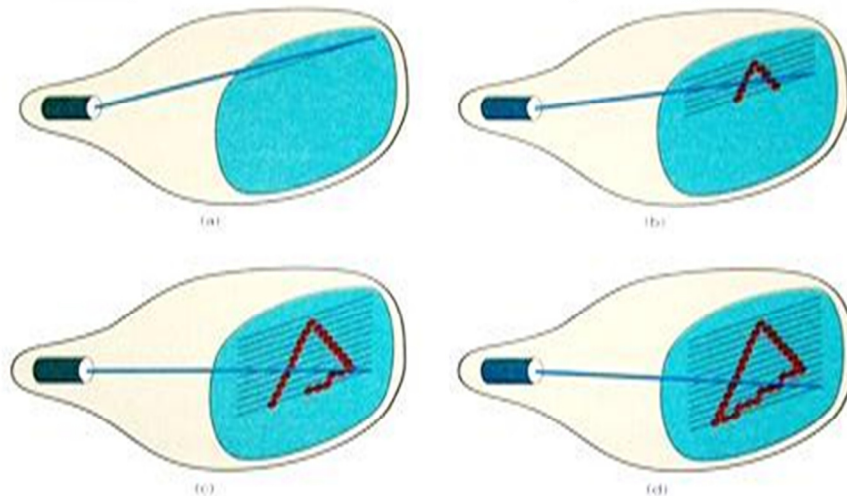


Fig. A raster-scan system displays an object as a set of discrete points across each scan line.

Each screen point is referred to as a **pixel** or **pel**. Intensity range for pixel positions depends on the capability of the raster system. In a simple black-and-white system, each screen point is either on or off, so only one bit per pixel is needed to control the intensity of screen positions. For a bi-level system, a bit value of 1 indicates that the electron beam is to be turned on at that position, and a value of 0 indicates that the beam intensity is to be off. Additional bits are needed when color and intensity variations can be displayed. On a

black-and-white system with one bit per pixel, the frame buffer is commonly called a **bitmap**. For systems with multiple bits per pixel, the frame buffer is often referred to as a **pixmap**. Refreshing on raster-scan displays is carried out at the rate of 60 to 80 frames per second. 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. At the end of each frame, the electron beam returns to the top left corner of the screen to begin the next frame. This is known as **vertical retrace**.

On some raster-scan systems, each frame is displayed in two passes using an **interlaced** refresh procedure. In the first pass, the beam sweeps across every other scan line from top to bottom. Then after the vertical retrace, the beam sweeps out the remaining scan lines.

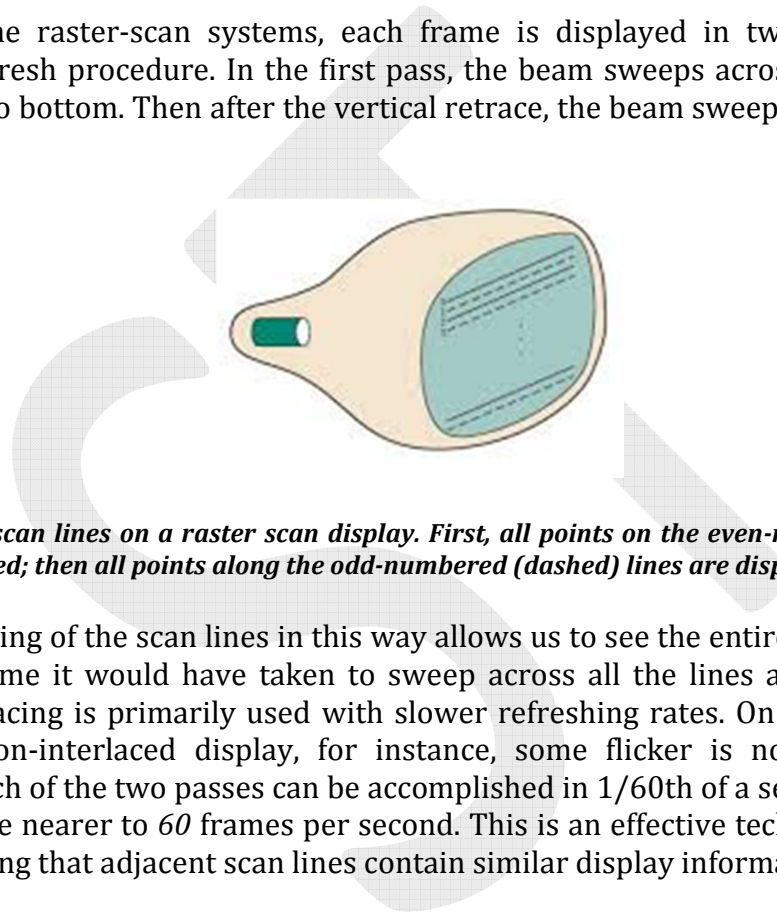


Fig. Interlacing scan lines on a raster scan display. First, all points on the even-numbered (solid) scan lines are displayed; then all points along the odd-numbered (dashed) lines are displayed.

Interlacing of the scan lines in this way allows us to see the entire screen displayed in one-half the time it would have taken to sweep across all the lines at once from top to bottom. Interlacing is primarily used with slower refreshing rates. On an older, 30 frame per-second, non-interlaced display, for instance, some flicker is noticeable. But with interlacing, each of the two passes can be accomplished in 1/60th of a second, which brings the refresh rate nearer to 60 frames per second. This is an effective technique for avoiding flicker, providing that adjacent scan lines contain similar display information.

c) Random-Scan Displays

When operated as a random-scan display unit, a CRT has the electron beam directed only to the parts of the screen where a picture is to be drawn. Random scan monitors draw a picture one line at a time and for this reason are also referred to as **vector displays (or stroke-writing or calligraphic displays)**. The component lines of a picture can be drawn and refreshed by a random-scan system in any specified order. A pen plotter operates in a similar way and is an example of a random-scan, hard-copy device. Refresh rate on a random-scan system depends on the number of lines to be displayed. Picture definition is now stored as a set of line drawing commands in an area of memory referred to as the **refresh display file**. The display file is also called as the **display list, display program, or refresh buffer**. To display a specified picture, the system cycles through the set of commands in the display file, drawing each component line in turn. After all line drawing

commands have been processed, the system cycles back to the first line command in the list.

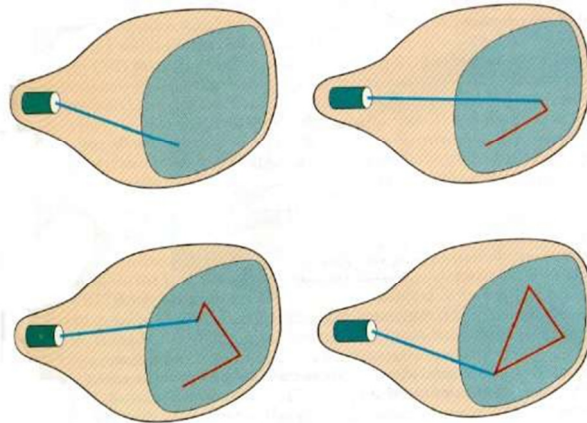


Fig. A random-scan system draws the component lines of an object in any order specified

Random-scan displays are designed to draw all the component lines of a picture 30 to 60 frames per second. Random-scan systems are designed for line drawing applications and cannot display realistic shaded scenes. Since picture definition is stored as a set of line drawing instructions and not as a set of intensity values for all screen points, vector displays generally have higher resolution than raster systems. Also, vector displays produce smooth line drawings because the CRT beam directly follows the line path. A raster system, in contrast, produces jagged lines that are plotted as discrete point sets.

d) Color -CRT Monitors

A CRT monitor displays color pictures by using a combination of phosphors that emit different-colored light. By combining the emitted light from the different phosphors, a range of colors can be generated. The two basic techniques for producing color displays with a CRT are

- 1. Beam-penetration method &**
- 2. Shadow-mask method**

Beam-penetration method

The beam-penetration method for displaying color pictures has been used with **random-scan monitors**. Two layers of phosphor, usually red and green, are how far the electron beam penetrates into the phosphor layers. A beam of slow electrons excites only the outer red layer. A beam of very fast electrons penetrates through the red layer and excites the inner green layer. At intermediate beam speeds, combinations of red and green light are emitted to show two additional colors, orange and yellow. The speed of the electrons, and hence the screen color at any point, is controlled by the beam-acceleration voltage.

Beam penetration has been an inexpensive way to produce color in random-scan monitors, but only four colors are possible, and the quality of pictures is not as good as with other methods.

The principal problem with the beam penetration CRT is the need to change the beam-accelerating potential by significant amounts in order to switch colors. The hardware and software must be designed to introduce adequate delays between changes in color, so that there is time for voltages to settle.

Shadow-mask methods

Shadow-mask methods are commonly used in raster scan systems because they produce a much wider range of colors than the beam penetration method. A shadow-mask CRT has three phosphor color dots at each pixel position. 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 color dot, and a shadow-mask grid just behind the phosphor-coated screen.

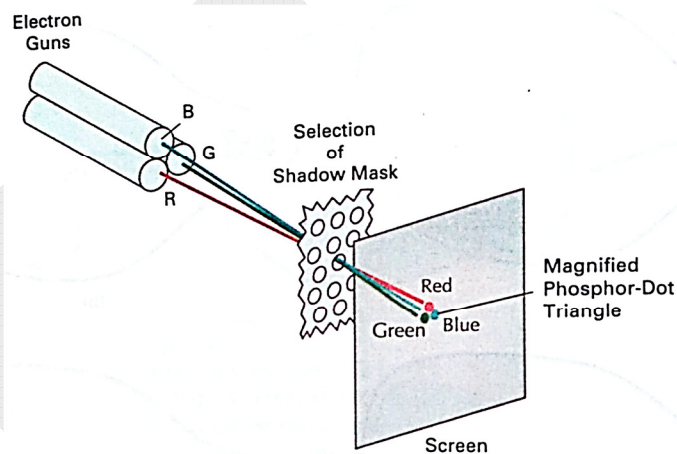


Fig. Operation of a delta-delta, shadow-mask CRT. Three electron guns, aligned with the triangular color dot patterns on the screen, are directed to each dot triangle by a shadow mask

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 color spot on the screen. The phosphor dots in the triangles are arranged so that each electron beam can activate only its corresponding color 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 color 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 color CRTs.

We obtain color 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 color coming from the blue phosphor. The color we see depends on the amount of excitation of the red, green, and blue phosphors.

White → Red + Green + Blue (with equal intensity)

Yellow → Green + Red

Magenta → Blue + Red
 Cyan → Blue + Green

e) Direct-View Storage Tubes

An alternative method for maintaining a screen image is to store the picture information inside the CRT instead of refreshing the screen. A direct-view storage tube (DVST) stores the picture information as a charge distribution just behind the phosphor-coated screen. Two electron guns are used in a DVST. One, the **primary gun**, is used to store the picture pattern; the second, the **flood gun**, maintains the picture display.

A DVST monitor has both disadvantages and advantages compared to the refresh CRT. Because no refreshing is needed, very complex pictures can be displayed at very high resolutions without flicker. Disadvantages of DVST systems are that they ordinarily do not display color and that selected parts of a picture cannot be erased. To eliminate a picture section, the entire screen must be erased and the modified picture redrawn. The erasing and redrawing process can take several seconds for a complex picture. For these reasons, storage displays have been largely replaced by raster systems.

2. Raster-Scan Systems

Interactive raster graphics systems typically employ several processing units. It consists of a CPU, a special-purpose processor, called the **video controller** or **display controller**, is used to control the operation of the display device. Organization of a simple raster system is shown in Fig. Here the frame buffer can be anywhere in the system memory, and the video controller accesses the frame buffer to refresh the screen.

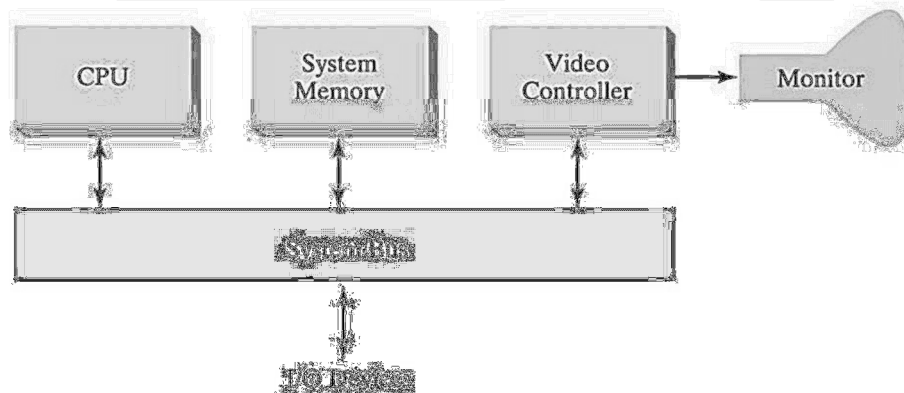


Fig. Architecture of a simple raster graphics system

Another commonly used organization is one in which a fixed area of the system memory is reserved for the frame buffer, and the video controller is given direct access to the frame-buffer memory.

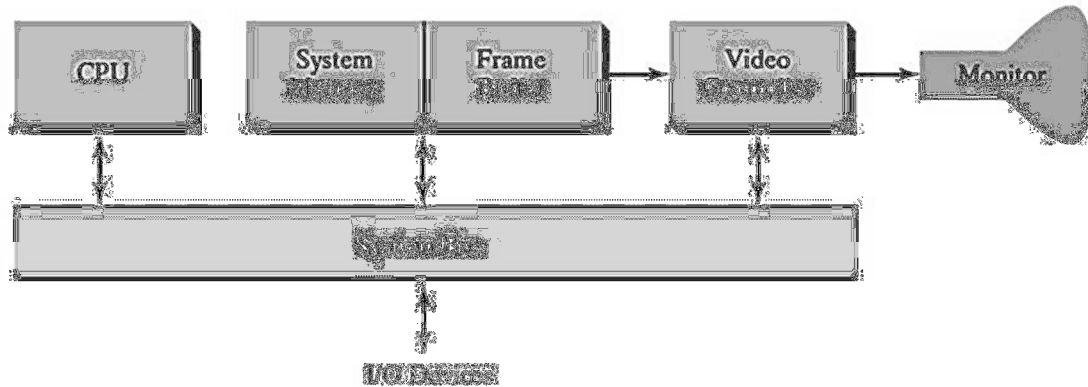


Fig. Architecture of a raster system with a fixed portion of the system memory reserved for the frame buffer

Frame-buffer locations, and the corresponding screen positions, are referenced in **Cartesian coordinates**. For many graphics monitors, the coordinate origin is defined at the lower left screen corner.



Fig. The origin of the coordinate system for identifying screen positions is usually specified in the lower-left corner.

The screen surface is then represented as the first quadrant of a two-dimensional system, with positive x values increasing to the right and positive y values increasing from bottom to top. Scan lines are then labeled from y_{max} , at the top of the screen to 0 at the bottom. Along each scan line, screen pixel positions are labeled from 0 to x_{max} .

a) Video-controller

Basic video-controller refresh operations

Two registers are used to store the coordinates of the screen pixels. Initially, the x register is set to 0 and the y register is set to y_{max} . The value stored in the frame buffer for this pixel position is then retrieved and used to set the intensity of the CRT beam. Then the x register is incremented by 1, and the process repeated for the next pixel on the top scan line. This procedure is repeated for each pixel along the scan line. After the last pixel on the top scan line has been processed, the x register is reset to 0 and the y register is decremented by 1. Pixels along this scan line are then processed in turn, and the procedure is repeated for each successive scan line. After cycling through all pixels along the bottom

scan line ($y = 0$), the video controller resets the registers to the first pixel position on the top scan line and the refresh process starts over.

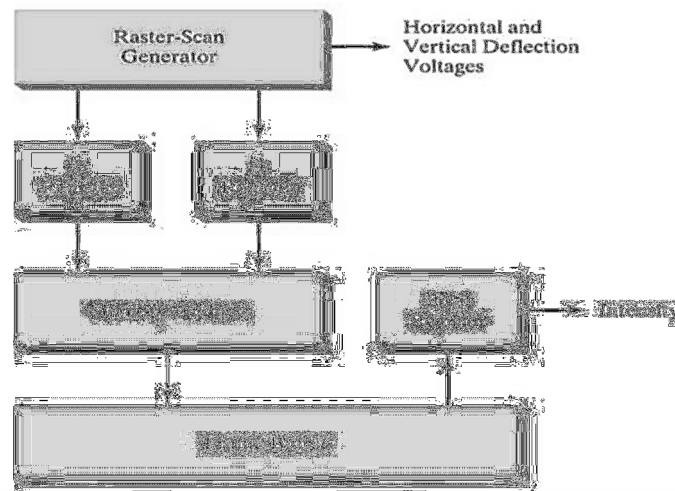


Fig. Basic video-controller refresh operations

To speed up pixel processing, video controllers can retrieve multiple pixel values from the refresh buffer on each pass. The multiple pixel intensities are then stored in a separate register and used to control the CRT beam intensity for a group of adjacent pixels. When that group of pixels has been processed, the next block of pixel values is retrieved from the frame buffer.

A number of other operations can be performed by the video controller, besides the basic refreshing operations. For various applications, the video controller can retrieve pixel intensities from different memory areas on different refresh cycles.

In high quality systems, for example, two frame buffers are often provided so that one buffer can be used for refreshing while the other is being filled with intensity values. Then the two buffers can switch roles. This provides a fast mechanism for generating real-time animations. Also, some transformations can be accomplished by the video controller. Areas of the screen can be enlarged, reduced etc. during the refresh cycles. In addition, they can contain lookup table, so that pixel values in the frame buffer are used to access the lookup table instead of controlling the CRT beam intensity directly. Some systems are designed to allow the video controller to mix the frame-buffer image with an input image from a television camera or other input device.

b) Raster-Scan Display Processor

The organization of a raster system containing a separate display processor, sometimes referred to as a **graphics controller** or a **display coprocessor**. The purpose of the display processor is to free the CPU from the graphics chores. In addition to the system memory, a separate display processor memory area can also be provided.

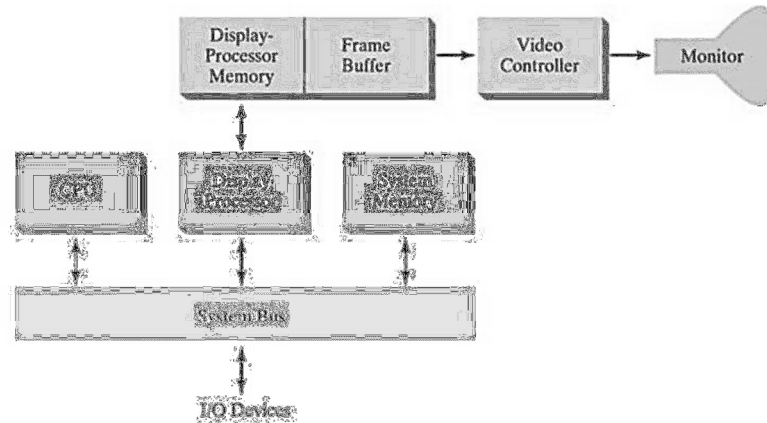


Fig. Architecture of a raster-graphics system with a display processor

A major task of the display processor is digitizing a picture definition 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**. Graphics commands specifying straight lines and other geometric objects are scan converted into a set of discrete intensity points.

Display processors are also designed to perform a number of additional operations. These functions include generating various line styles, displaying color areas, and performing certain transformations and manipulations on displayed objects. Also, they are designed to interface with interactive input devices, such as a mouse.

To reduce memory requirements in raster systems, methods have been devised for organizing the frame buffer as a linked list and encoding the intensity information. One way to do this is to store each scan line as a set of integer pairs. One number of each pair indicates an intensity value, and the second number specifies the number of adjacent pixels on the scan line that are to have that intensity. This technique is called **run-length encoding**. This can result in a considerable saving in storage space if a picture is to be constructed mostly with long runs of a single color each. Another approach is to encode the raster as a set of rectangular areas called cell encoding. The disadvantages of encoding runs are that intensity changes are difficult to make and storage requirements actually increase as the length of the runs decreases. In addition, it is difficult for the display controller to process the raster when many short runs are involved.

3. RANDOM-SCAN SYSTEMS

The organization of a simple random-scan (vector) system is shown in Fig.

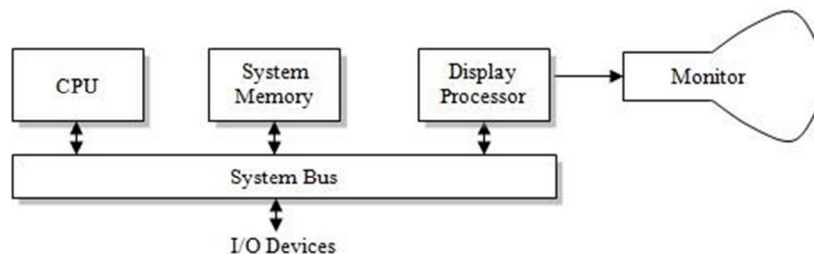


Fig. Architecture of a simple random scan system.

An application program is input and stored in the system memory along with a graphics package. Graphics commands in the application program are translated by the graphics package into a display file stored in the system memory. This display file is then accessed by the display processor to refresh the screen. The display processor cycles through each command in the display file program once during every refresh cycle. Display processor is also referred to as a display processing unit or a graphics controller. Graphics patterns are drawn on a random-scan system by directing the electron beam along the component lines of the picture. Lines are defined by the values for their coordinate endpoints, and these input coordinate values are converted to x and y deflection voltages. A scene is then drawn one line at a time by positioning the beam to fill in the line between specified endpoints.

INTERACTIVE GRAPHICS INPUT

Graphics programs use several kinds of input data. Picture specifications need values for coordinate positions, values for the character-string parameters, scalar values for the transformation parameters, values specifying menu options, and values for identification of picture parts.

Any of the input devices can be used to input the various graphical data types, but some devices are better suited for certain data types than others. To make graphics packages independent of the particular hardware devices used, input functions can be structured according to the data description to be handled by each function.

Logical Classification of Input Devices

The various kinds of input data are summarized in the following six logical device classifications

- i) **LOCATOR** -a device for specifying coordinate position (x,y)
- ii) **STROKE** -a device for specifying a series of coordinate positions.
- iii) **STRING** -a device for specifying text input.
- iv) **VALUATOR** -a device for specifying scalar values.
- v) **CHOICE** -a device for selecting menu options.
- vi) **PICK** -a device for selecting picture components.

i)Locator Devices

A standard method for interactive selection of a coordinate point is by positioning the screen cursor. We can do this with a mouse, joystick, trackball, space ball etc. Keyboards can be used for locator input in several ways. A general-purpose keyboard usually has four cursor-control keys that move the screen cursor up, down, left, and right. A joystick, trackball etc. can be mounted on the keyboard for relative cursor movement. Light pens have also been used to input coordinate positions.

ii)Stroke Devices

This class of logical devices is used to input a sequence of coordinate positions. Stroke-device input is equivalent to multiple calls to a locator device. Many of the physical devices used for generating locator input can be used as stroke devices.

Continuous movement of a mouse, trackball, joystick, or tablet hand cursor is translated into a series of input coordinate values. The graphics tablet is one of the more common stroke devices. Button activation can be used to place the tablet in to "continuous" mode. As the cursor is moved across the tablet surface, a stream of coordinate values is generated.

iii)String Devices

The primary physical device used for string input is the keyboard. Other physical devices can be used for generating character patterns in a "text-writing" mode. For this input, individual characters are drawn on the screen with a stroke or locator-type device.

iv)Valuator Devices

This logical class of devices is employed in graphics systems to input scalar values. Valuator devices are used for setting various graphics parameters, such as rotation angle and for setting physical parameters associated with a particular application such as temperature settings, voltage levels etc.

A typical physical device used to provide valuator input is a **set of control dials**. Floating-point numbers within any predefined range are input by rotating the dials. Dial rotations in one direction increase the numeric input value, and opposite rotations decrease the numeric value. Rotary potentiometers convert dial rotation into a corresponding voltage.

Any keyboard with a set of numeric keys can be used as a valuator device. A user simply types the numbers directly in floating-point format, although this is a slower method. Joystick, trackball and interactive devices can be adapted for valuator input. For one direction of movement, increasing scalar values can be input. Movement in the opposite direction decreases the scalar input value.

Another technique for providing valuator input is to display sliders, buttons, rotating scales, and menus on the video monitor.

v)Choice Devices

Graphics packages use menus to select programming options, parameter values etc. A choice device is defined as one that enters a selection from a list (menu) of alternatives. Commonly used choice devices are a set of buttons; a cursor positioning device, such as a mouse, trackball etc. For screen selection of listed menu options, we can use cursor-control devices. When a coordinate position (x, y) is selected, it is compared to the coordinate extents of each listed menu item. A menu item with vertical and horizontal boundaries at the coordinate values x_{\min} , x_{\max} , y_{\min} & y_{\max} is selected if the input coordinates (x, y) satisfy the inequalities

$$x_{\min} \leq x \leq x_{\max}, \quad y_{\min} \leq y \leq y_{\max}$$

Alternate methods for choice input include keyboard and voice entry. A standard keyboard can be used to type in commands or menu options.

vi) Pick Devices

Graphical object selection is the function of this logical class of devices. Pick devices are used to select parts of a scene that are to be transformed or edited in some way. With a mouse or joystick, we can position the cursor over the primitives in a displayed structure and press the selection button.

