PARSHVANATH CHARITABLE TRUST'S

# A.P. SHAH INSTITUTE OF TECHNOLOGY

Department of Computer Science and Engineering

Data Science

**Class :- S.E.D.S.** **Semester:- III**

**Subject : Computer Graphics Lab** **A.Y:- 2022-23**

## Module 1: Introduction and Overview of Computer Graphics System

### 1.1) Introduction

Today there are very few aspects of our lives not affected by computers. Practically every cash or monetary transaction that takes place daily involves a computer. In many cases, the same is true of computer graphics. Whether you see them on television, in newspapers, in weather reports or while at the doctor's surgery, computer images are all around you. "A picture is worth a thousand words" is a well-known saying and highlights the advantages and benefits of the visual presentation of our data. We are able to obtain a comprehensive overall view of our data and also study features and areas of particular interest.

A well-chosen graph is able to transform a complex table of numbers into meaningful results. You know that such graphs are used to illustrate papers, reports and thesis, as well as providing the basis for presentation material in the form of slides and overhead transparencies. A range of tools and facilities are available to enable users to visualize their data, and this document provides a brief summary and overview.

Computer graphics can be used in many disciplines. Charting, Presentations, Drawing, Painting and Design, Image Processing and Scientific Visualization are some among them.

In particular, we will emphasize the following

a) Basic concepts of Computer Graphics
b) Different types of Computer Graphics
c) Origin of Computer Graphics

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d) Working of an interactive graphics display
e) Importance of speed in displaying pictures
f) The change in size an orientation of pictures
g) Applications of Computer Graphics

### 1.2) Basic concepts of Computer Graphics

I hope all of you are fond of video games and you may be good at playing them. Have you seen the game of ping-pong? It’s a game played by two people with a pair video game controller and a home television set. You can see that when a game is switched on, a small bright spot , representing a ball, is seen bouncing to and fro across the screen. Now each player uses his video game controller to position a ‘paddle’ to bounce the ball back to his opponent. The playerwho hits the ball past his opponent wins a point and the one who gains 15 points wins the game. Now how did you invent this video game? This has been done with the aid of Computer Graphics. Video games represent a major use in the home of computer graphics. Computer graphics helps to create and manipulate pictures with the aid of computers.

Computer graphics is concerned with all aspects of producing images using a computer. It concerns with the pictorial synthesis of real or imaginary objects from their computer-based models.

### 1.3) Different types of Computer Graphics

Computer Graphics can be broadly divided into two

a) Non Interactive Computer Graphics
b) Interactive Computer Graphi

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Non Interactive Computer Graphics: In non interactive computer graphics otherwise known as passive computer graphics, the observer has no control over the image. Familiar examples of this type of computer graphics include the titles shown on TV and other forms of computer art.

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 for example the video game controller of the ping pong game. This helps him to signal his request to the computer. 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.

Interactive computer graphics affects our lives in a number of indirect ways. For example, it helps to train the pilots of our airplanes. We can create a flight simulator which may help the pilots to get trained not in a real aircraft but on the grounds at the control of the flight simulator. The flight simulator is a mock up of an aircraft flight deck, containing all the usual controls and surrounded by screens on which we have the projected computer generated views of the terrain visible on take off and landing. Flight simulators have many advantages over the real aircrafts for training purposes, including fuel savings, safety, and the ability to familiarize the trainee with a large number of the world’s airports.

### 1.4) Origin of Computer Graphics

Years of research and development were made to achieve the goals in the field of computer graphics. In 1950 the first computer driven display was used to generate only simple pictures. This display made use of a cathode ray tube similar to the one used in television sets. During 1950's interactive computer graphics made little progress because the computers of that period were so unsuited to interactive use. These computers were used to perform only lengthy calculations.

The single vent that did the most to promote interactive computer graphics as an important new field was the publication in 1962 of a brilliant thesis by Ivan E. Sutherland. His thesis, entitled 'Sketchpad: A Man- Machine Graphical Communication System', proved to many readers that interactive computer graphics was a viable, useful, and exciting field of research. By the mid -1960's large computer graphics research projects were under taken at MIT, Bell Telephone Labs and General Motors. Thus the golden age of computer graphics began. In 1970's thee researches began to bear fruit. The instant appeal of computer graphics to users of all ages has helped it to spread into many applications throughout the world.

### 1.5) Working of an interactive graphics display

Interactive graphics display consists of three components

a) A display controller
b) A digital memory or frame buffer
c) A television monitor
d) A video controller

The display controller gets the inputs and commands from the user and determines the image to be displayed on the monitor. The display controller will divide the image into a number of pixels. This image which is to be displayed is stored in the frame buffer. The image will be stored as a matrix of intensity values. The image will be displayed onto the television monitor and the video controller will act as a simple interface that passes the contents of the frame buffer to the monitor. The image must be repeatedly passed to the monitor, 30 or more times a second. This helps you to maintain a steady picture on the screen.

In the frame buffer the image is stored as a pattern of binary digital numbers. These binary digital numbers represents a rectangular array of picture elements or pixels (a picture can be divided into a number of picture elements or pixels. You will learn more about pixels in the coming lectures.). So corresponding to each pixel you have a binary digital number in the frame buffer. If your image is a black and white image you can represent the black pixels by 0 s and white pixels by 1s. Therefore a 16 X 16 array of black and white pixels could be represented by the binary values stored in the 32 8- bit bytes. Now what happens to this data?

The video controller simply reads each successive byte of data from the frame buffer and converts its 0s and 1s into the corresponding video signal. This signal is then fed into the TV monitor, producing a black and white pattern on the screen. The video controller repeats this operation 30 times a second in order to maintain a steady picture on the TV screen.

Now what should be done to change or modify this image? All we need is to modify the frame buffer's contents. Set the frame buffer with a new set of values so that it represents the new image. In this way we can achieve effects like a rotating wheel and a wheel that grows and shrinks.

The figure given below gives an idea about the graphics display system

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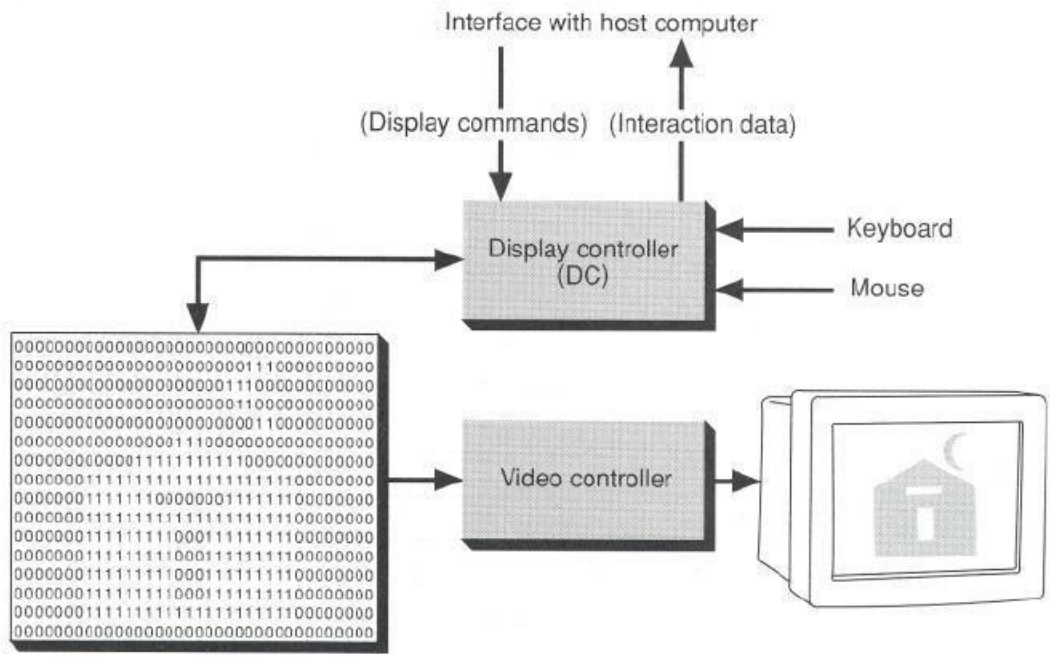


**Importance of speed in displaying pictures**

Why is speed so important in displaying pictures?

One reason behind this is that any display based on the CRT must be refreshed by repeatedly passing it to the monitor. The image must be transmitted to the display monitor point by point. If the image is not transmitted at least 25 times per second, the image will start to flicker in an unpleasant manner. If the speed of transmitting each picture element is less, then only fewer elements will be transmitted and only less information will be displayed.

The second reason is that the response of a computer program to the actions by its user should be very fast i.e. the response time should be very small. The speed of response depends on two factors.

1. The rate at which the computer can generate a fresh image in response to each action by its users.
2. The rate at which the image is transmitted to the display monitor.

Generally speaking, slow response always makes interactive graphics program more difficult to operate .Perhaps that's the reason why research efforts are made to improve the speed of interactive response.

**1.6) The change in size an orientation of pictures**

How are pictures made to rotate? How are pictures made to shrink? How are pictures made to grow? Pictures can be made to change the orientation and size. How are these changes possible?

These transformations or changes are based on standard mathematical techniques: coordinate geometry, trigonometry and matrix methods. These techniques tell us how to compute the new coordinates after applying the transformations. We will study more about transformations of objects in the coming lectures.

**1.7) Applications of Computer Graphics**

The following are also considered graphics applications:

<u>Paint programs</u>: Allow you to create rough freehand drawings. The images are stored as bit maps and can easily be edited. It is a graphics program that enables you to draw pictures on the display screen which is represented as bit maps (bit-mapped graphics). In contrast,

draw programs use vector graphics (object-oriented images), which scale better. Most paint programs provide the tools shown below in the form of icons. By selecting an icon, you can perform functions associated with the tool.In addition to these tools, paint programs also provide easy ways to draw common shapes such as straight lines, rectangles, circles, and ovals.

Sophisticated paint applications are often called image editing programs. These applications support many of the features of draw programs, such as the ability to work with objects. Each object, however, is represented as a bit map rather than as a vector image.

Illustration/design programs: Supports more advanced features than paint programs, particularly for drawing curved lines. The images are usually stored in vector-based formats. Illustration/design programs are often called draw programs.

Presentation graphics software: Lets you create bar charts, pie charts, graphics, and other types of images for slide shows and reports. The charts can be based on data imported from spreadsheet applications.

A type of business software that enables users to create highly stylized images for slide shows and reports. The software includes functions for creating various types of charts and graphs and for inserting text in a variety of fonts. Most systems enable you to import data from a spreadsheet application to create the charts and graphs. Presentation graphics is often called business graphics.

Animation software: Enables you to chain and sequence a series of images to simulate movement. Each image is like a frame in a movie. It can be defined as a simulation of movement created by displaying a series of pictures, or frames. A cartoon on television is one example of animation. Animation on computers is one of the chief ingredients of multimedia presentations. There are many software applications that enable you to create animations that you can display on a computer monitor.

There is a difference between animation and video. Whereas video takes continuous motion and breaks it up into discrete frames, animation starts with independent pictures and puts them together to form the illusion of continuous motion.

CAD software: Enables architects and engineers to draft designs. It is the acronym for computer- aided design. A CAD system is a combination of hardware and software that enables engineers and architects to design everything from furniture to airplanes. In addition to the software, CAD systems require a high-quality graphics monitor; a mouse, light pen, or digitizing tablet for drawing; and a special printer or plotter for printing design specifications.

CAD systems allow an engineer to view a design from any angle with the push of a button and to zoom in or out for close-ups and long-distance views. In addition, the computer keeps track of design dependencies so that when the engineer changes one value, all other values that depend on it are automatically changed accordingly.

Until the mid 1980s, all CAD systems were specially constructed computers. Now, you can buy CAD software that runs on general-purpose workstations and personal computers.

Desktop publishing: Provides a full set of word-processing features as well as fine control over placement of text and graphics, so that you can create newsletters, advertisements, books, and other types of documents. It means by using a personal computer or workstation high-quality printed documents can be produced. A desktop publishing system allows you to use different typefaces, specify various margins and justifications, and embed illustrations and graphs directly into the text. The most powerful desktop publishing systems enable you to create illustrations; while less powerful systems let you insert illustrations created by other programs.

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As word-processing programs become more and more powerful, the line separating such programs from desktop publishing systems is becoming blurred. In general, though, desktop publishing applications give you more control over typographical characteristics, such as kerning, and provide more support for full-color output.

A particularly important feature of desktop publishing systems is that they enable you to see on the display screen exactly how the document will appear when printed. Systems that support this feature are called WYSIWYGs (what you see is what you get).

Until recently, hardware costs made desktop publishing systems impractical for most uses. But as the prices of personal computers and printers have fallen, desktop publishing systems have become increasingly popular for producing newsletters, brochures, books, and other documents that formerly required a typesetter.

Once you have produced a document with a desktop publishing system, you can output it directly to a printer or you can produce a PostScript file which you can then take to a service bureau. The service bureau has special machines that convert the PostScript file to film, which can then be used to make plates for offset printing. Offset printing produces higher-quality documents, especially if color is used, but is generally more expensive than laser printing.

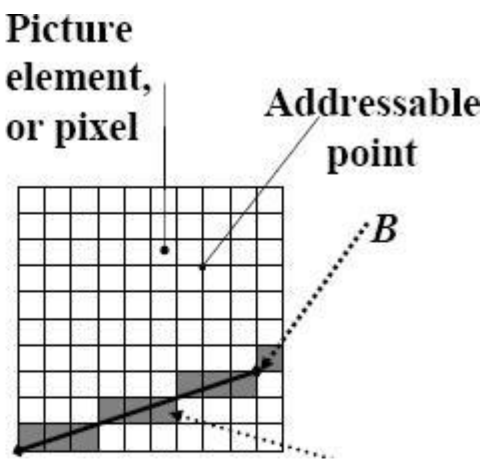
In general, applications that support graphics require a powerful CPU and a large amount of memory. Many graphics applications—for example, computer animation systems—require more computing power than is available on personal computers and will run only on powerful workstations or specially designed graphics computers. This is true of all three-dimensional computer graphics applications.

In addition to the CPU and memory, graphics software requires a graphics monitor and support for one of the many graphics standards. Most PC programs, for instance, require VGA graphics. If your computer does not have built-in support for a specific graphics system, you can insert a video adapter card.

The quality of most graphics devices is determined by their resolution—how many pixels per square inch they can represent—and their color capabilities.

**1.8) pixel**

A pixel (short for picture element, using the common abbreviation "pix" for "picture")




is one of the many tiny dots that make up the representation of a picture in a computer's memory. Each such information element is not really a dot, nor a square, but an abstract sample. With care, pixels in an image can be reproduced at any size without the appearance of visible dots or squares; but in many contexts, they are reproduced as dots or squares and can be visibly distinct when not fine enough. The intensity of each pixel is variable; in color systems, each pixel has typically three or four dimensions of variability such as red, green and blue, or cyan, magenta, yellow and black.

**1.9) pixel resolution**

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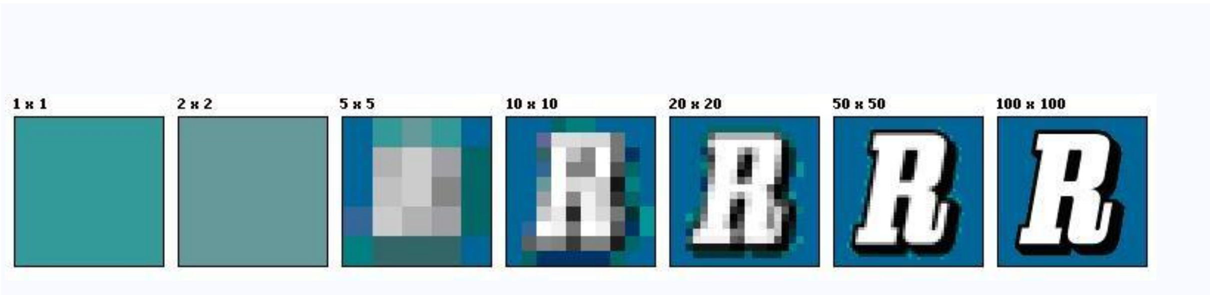
Pixel resolution

The term resolution is often used as a pixel count in digital imaging, even though American, Japanese, and international standards specify that it should not be so used, at least in the digital camera field. An image of N pixels high by M pixels wide can have any resolution less than N lines per picture height, or N TV lines. But when the pixel counts are referred to as resolution, the convention is to describe the pixel resolution with the set of two positive integer numbers, where the first number is the number of pixel columns (width) and the second is the number of pixel rows (height), for example as 640 by 480. Another popular convention is to cite resolution as the total number of pixels in the image, typically given as number of megapixels, which can be calculated by multiplying pixel columns by pixel rows and dividing by one million. Other conventions include describing pixels per length unit or pixels per area unit, such as pixels per inch or per square inch. None of these pixel resolutions are true resolutions, but they are widely referred to as such; they serve as upper bounds on image resolution.

Below is an illustration of how the same image might appear at different pixel resolutions, if the pixels were poorly rendered as sharp squares (normally, a smooth image reconstruction from pixels would be preferred, but for illustration of pixels, the sharp squares make the point better).




Resolution in various media

- DVDs have roughly 500 lines (or TV lines, or lines per picture height).
- High definition television has 1,080 lines.
- 35mm movie film is scanned for release on DVD at 1080 or 2000 lines as of 2005.
- 35mm optical camera negative motion picture film can resolve up to 6,000 lines.
- 35mm projection positive motion picture film has about 2,000 lines which results from the analogue printing from the camera negative of an interpositive, and possibly an internegative, then a projection positive.
- Newer films are scanned at 4,000 lines, called 4K scanning, anticipating any advances in digital projection or higher resolution in flat panel display.

## 1.10) Image resolution

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Image resolution describes the detail an image holds. The term applies equally to digital images, film images, and other types of images. Higher resolution means more image detail. Image resolution can be measured in various ways. Basically, resolution quantifies how close lines can be to each other and still be visibly resolved. Resolution units can be tied to physical sizes (e.g. lines per mm, lines per inch) or to the overall size of a picture (lines per picture height, also known simply as lines, or TV lines). Furthermore, line pairs are often used instead of lines. A line pair is a pair of adjacent dark and light lines, while a line counts both dark lines and light lines. A resolution of 10 lines per mm means 5 dark lines alternating with 5 light lines, or 5 line pairs per mm. Photographic lens and film resolution are most often quoted in line pairs per mm.

Image resolution on raster displays

A television or raster image display with 525 scan lines makes a picture with somewhat less than 525 TV lines of resolution. The ratio of lines of resolution to the number of format lines in known as the Kell factor, after Raymond D. Kell, who worked out details of visual resolution in scanned systems at RCA in the 1930s.

### 1.11) Graphics Primitives and Attributes

Even the most complex computer-generated graphic images are produced by a relatively small set of Graphics Primitives. The usual sets of basic primitives provided in Graphics Packages are:

1. A single point.

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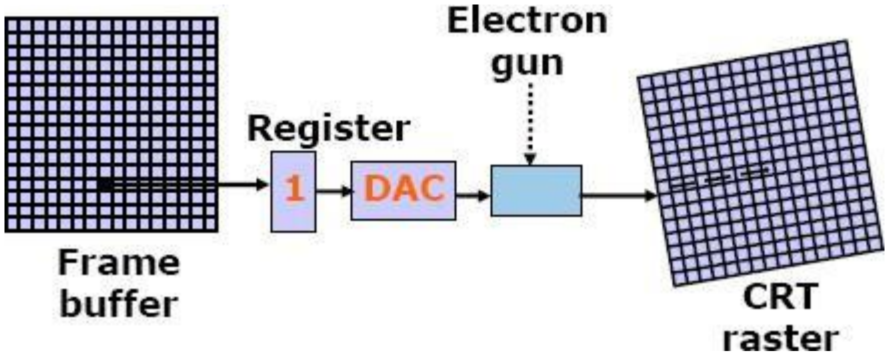
2. A line with given end-points.
3. A polyline i.e. a line joining a sequence of points.
4. A filled polygonal area with given points as vertices.
5. Text.

There may be additional, but not essential, primitives such as rectangles, circles, curves of various types, images etc.

Associated with each graphics primitive is a set of Attributes. The attributes of a primitive determine its appearance on the output device. For example a line commonly has attributes such as colour, width, style (full, dotted, dashed etc.) etc.

### 1.12) Frame Buffer

. A frame buffer is a large, contiguous piece of computer memory. At a minimum there is one memory bit for each pixel in the rater; this amount of memory is called a bit plane. The picture is built up in the frame buffer one bit at a time. You know that a memory bit has only two states, therefore a single bit plane yields a black-and white display. You know that a frame buffer is a digital device and the CRT is an analog device. Therefore, a conversion from a digital representation to an analog signal must take place when information is read from the frame buffer and displayed on the raster CRT graphics device. For this you can use a digital to analog converter (DAC).Each pixel in the frame buffer must be accessed and converted before it is visible on the raster CRT.



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**A single bit-plane black white frame buffer raster CRT graphics device N-bit colour Frame buffer**

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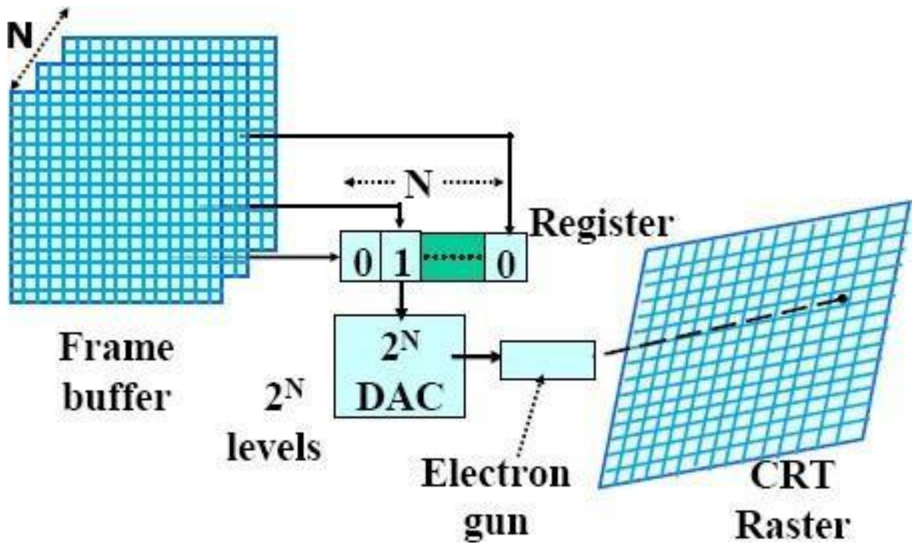
Color or gray scales are incorporated into a frame buffer rater graphics device by using additional bit planes. The intensity of each pixel on the CRT is controlled by a corresponding pixel location in each of the N bit planes. The binary value from each of the N bit planes is loaded into corresponding positions in a register. The resulting binary number is interpreted as an intensity level between 0 (dark) and $2^n$ -1 (full intensity). This is converted into an analog voltage between 0 and the maximum voltage of the electron gun by the DAC. A total of $2^N$ intensity levels are possible. Figure given below illustrates a system with 3 bit planes for a total of 8 ($2^3$) intensity levels. Each bit plane requires the full complement of memory for a given raster resolution; e.g., a 3-bit plane frame buffer for a 1024 X1024 raster requires 3,145,728 (3 X 1024 X1024) memory bits.



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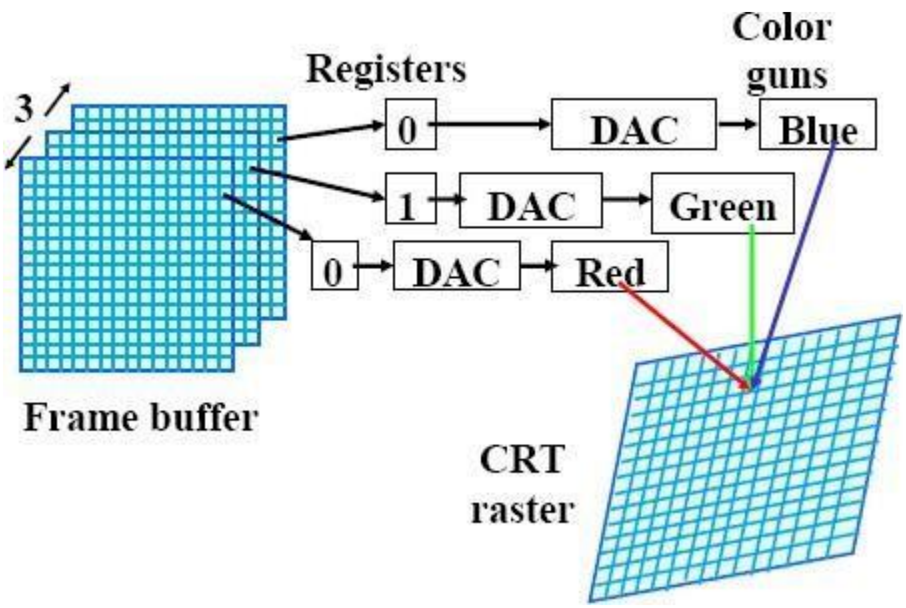
**An N- bit plane gray level frame buffer**

Because there are three primary colors, a simple color frame buffer is implemented with three bit planes, one for each primary color. Each bit plane drives an individual color gun for each of the three primary colors used in color video. These three primaries (red, green, and blue) are combined at the CRT to yield eight colors.




**Simple Color buffer**

1.13) **Display devices**

**The working of a Cathode Ray Tube**

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.

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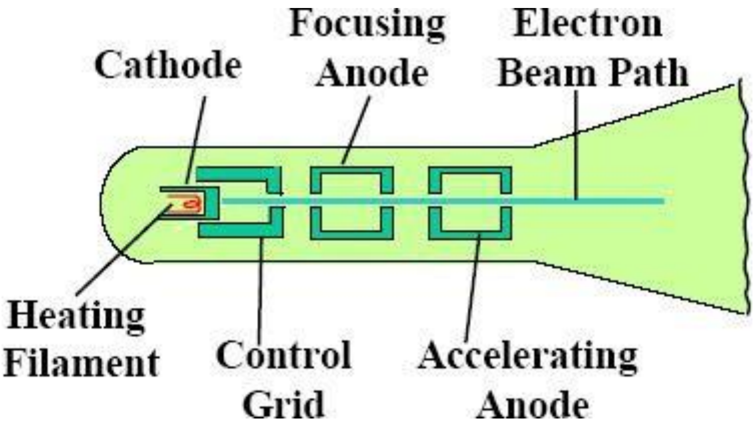
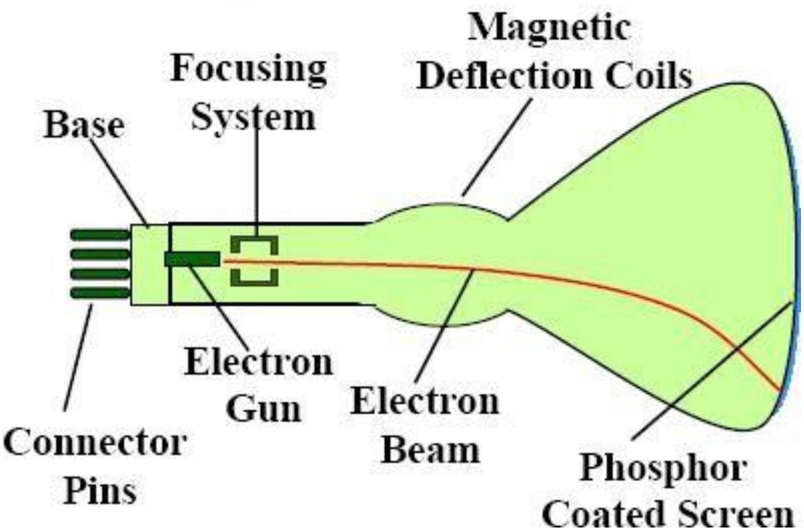
The Cathode Ray Tube




**Operation of an electron gun with an accelerating anode**



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## Basic design of a magnetic deflection CRT

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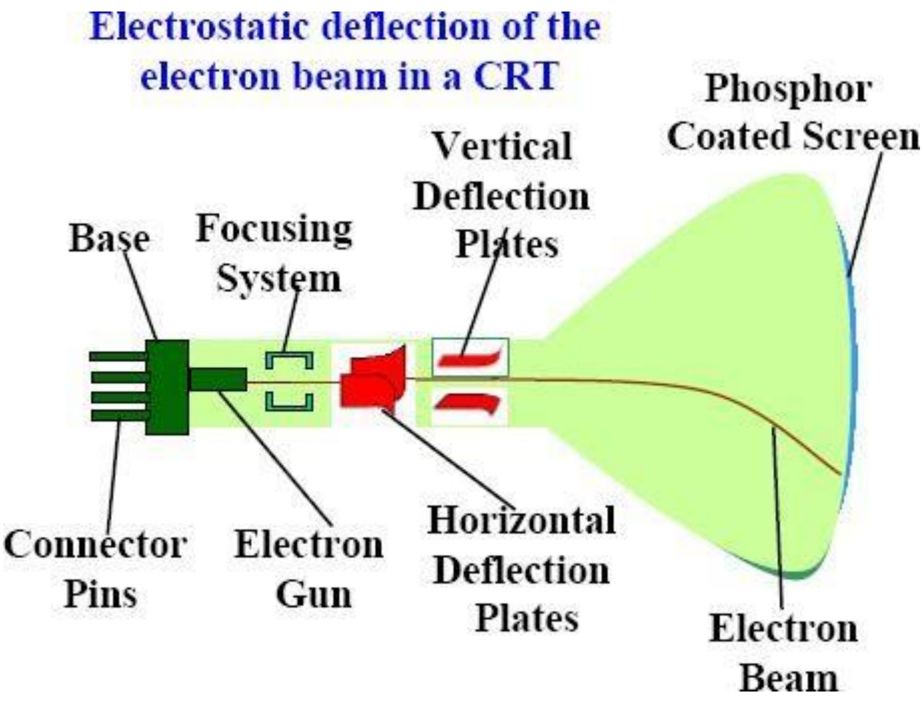



The electron gun emits a beam of electrons which are focused to a point on the screen phosphor. The beam is positioned on the screen by a deflection system which operates in the horizontal and vertical directions. The intensity of the beam is controlled by the intensity signal on the control grid. When the phosphor is hit by the electron beam it absorbs energy and jumps to a higher quantum-energy level. As it returns to its normal level it emits visible light i.e. it phosphoresces. In the phosphors used in graphics devices the persistence of the phosphorescence is typically 10-60 microseconds.

Before the human visual system can see a transient image it must be continually redrawn (refreshed) at a rate higher than the critical fusion frequency of the human visual system. To allow the human visual system to see a continuously refreshed image without flicker the refresh rate has to be at least 60 c/s.

To allow continuous refreshing of an image there must be some stored representation of the image from which the refresh system can obtain the graphical information required to re-draw the image. This representation nowadays is invariably a set of values of intensity/colour at each of a discrete set of points laid out in a rectangular array covering the screen.

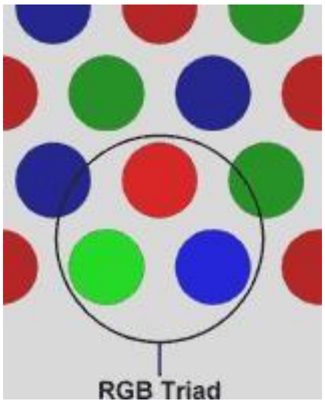
While it may seem a disadvantage to continually refresh the image there are some very important advantages of such refresh type systems. For example it is possible to edit an image by changing the stored representation between refresh cycles for what appears to be instantaneous updating of the image. Compare this with some earlier systems in which the only way to carry out an edit was to clear the whole screen and then redraw the whole image. Also by changing the stored representation between refresh cycles animation is possible.

### 1.14) Shadow Mask CRT

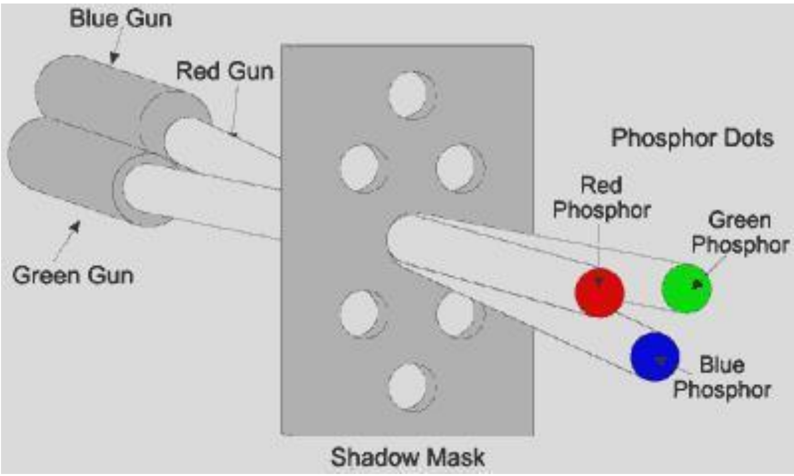
In Shadow Mask CRT tiny holes in a metal plate separate the colored phosphors in the layer behind the front glass of the screen. The holes are placed in a manner ensuring that electrons from each of the tube's three cathode guns reach only the appropriately-colored phosphors on the display. All three beams pass through the same holes in the mask, but the angle of approach is different for each gun. The spacing of the holes, the spacing of the phosphors, and the placement of the guns is arranged so that for example the blue gun only has an unobstructed path to blue phosphors. The red, green, and blue phosphors for each pixel are generally arranged in a triangular shape (sometimes called a "triad"). All early color televisions and the majority of computer monitors, past and present, use shadow mask technology.

Traditionally, shadow masks have been made of materials which temperature variations cause to expand and contract to the point of affecting performance. The energy the shadow mask absorbs from the electron gun in normal operation causes it to heat up and expand, which leads to blurred or discolored (see doming) images. The invar shadow mask is composed of the nickel-iron alloy invar. Therefore it expands and contracts much less than other materials in response to temperature changes. This property allows displays made with this technology to provide a clearer, more accurate picture. It also reduces the amount of long-term stress and damage to the shadow mask that can result from repeated expand/contract cycles, thus increasing the display's life expectancy.

In other words, In Shadow Mask CRT, before the stream of electrons produced by the CRT's cathode reach the phosphor coated faceplate, it encounters the shadow mask, a sheet of metal etched with a pattern of holes. The mask is positioned in the glass funnel of the CRT during manufacture and the phosphor is coated onto the screen so that electrons coming from the red, green and blue gun positions only land on the appropriate phosphor.



Stray electrons strike the shadow mask and are absorbed by it, generating a great deal of heat, which in turn causes the metal to expand. To allow flatter CRTs to be made, the metal most commonly used now for shadow masks is Invar, an alloy of iron and nickel. The metal has a low coefficient of expansion and its name derives from the supposed invariability of its dimensions when heat is applied. In reality, its dimensions are not completely invariable and the build up of heat in a shadow mask can lead to a form of distortion known as doming, where the centre of the mask bulges towards the faceplate slightly.




An alternative to the shadow mask which is less prone to distortion, the aperture grille , was included as part of the design of Trinitron CRTs by Sony in 1968 and Mitsubishi in its Diamondtron products in the early 1990s.

**Importance of Refresh Rates**

When choosing a monitor, one of the factors that the customer usually considers is the refresh rate. A high refresh rate is important in providing a clear picture and avoiding eye fatigue.

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What is a refresh rate and why is a monitor's refresh rate important?

An image appears on screen when electron beams strike the surface of the screen in a zig- zag pattern. A refresh rate is the number of times a screen is redrawn in one second and is measured in Hertz (Hz). Therefore, a monitor with a refresh rate of 85 Hz is redrawn 85 times per second. A monitor should be "flicker-free meaning that the image is redrawn quickly enough so that the user cannot detect flicker, a source of eye strain. Today, a refresh rate of 75 Hz or above is considered to be flicker-free

**How are refresh rates calculated?**

Factors in determining refresh rates

A refresh rate is dependent upon a monitor's horizontal scanning frequency and the number of horizontal lines displayed.The horizontal scanning frequency is the number of times the electron beam sweeps one line and returns to the beginning of the next in one second. Horizontal scanning frequency is measured in kilohertz (kHz).A monitor with a horizontal scanning frequency of 110 kHz means 110,000 lines are scanned per second.

The number of horizontal lines on the screen depends upon the monitor's resolution. If a monitor is set to a resolution of 1024 x 768 then there are 768 horizontal lines (1024 is the number of pixels on one line). For a monitor set to a 1280 x 1024 resolution, there are 1024 horizontal lines.

Additionally, the time it takes for the electron beam to return to the top of the screen and begin scanning again must be taken into account. This is roughly 5% of the time it takes to scan the entire screen. Therefore, the total is multiplied by 0.95 to calculate the maximum refresh rate.

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How to calculate maximum refresh rates?

The following formula is used to calculate maximum refresh

rates fV = fH / # of horizontal lines x 0.95

fV = vertical scanning frequency (refresh

rate) fH = horizontal scanning frequency

Example: A monitor with a horizontal scanning frequency of 96 kHz at a resolution of 1280 x 1024 would have the following refresh rate based on the calculation above.

fV = 96,000 / 1024 x 0.95

fV = 89.06

This figure is rounded down to produce a maximum refresh rate of 89Hz.

If the same monitor is set to a resolution of 1600 x 1200, then the equation will be as

follows: fV = 96,000 / 1200 x 0.95

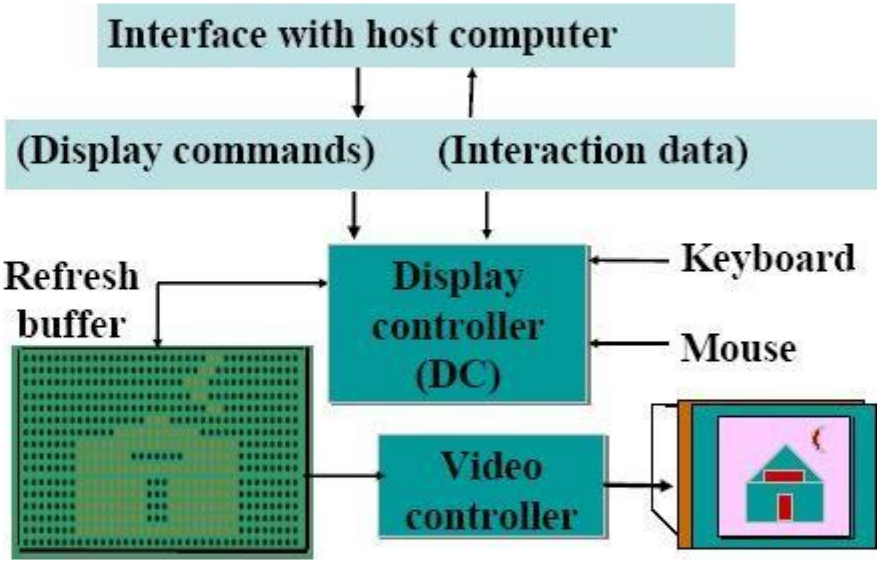
fV = 76

The maximum refresh rate at this resolution is 76 Hz.

### 1.15) Raster Graphics Display Architecture

The figure which describes the architecture of Raster graphics is given below. It includes:

1. Display controller
2. Refresh Buffer
3. Video Controller
4. CRT monitor




1.15.1) **Raster Graphics**

A raster graphics image, digital image, or bitmap, is a data file or structure representing a generally rectangular grid of pixels, or points of color, on a computer monitor, paper, or other display device. The color of each pixel is individually defined; images in the RGB color space, for instance, often consist of colored pixels defined by three bytes—one byte each for red, green and blue. Less colorful images require less information per pixel; an image with only black and white pixels requires only a single bit for each pixel. Raster graphics are distinguished from vector graphics in that vector graphics represent an image through the use of geometric objects such as curves and polygons.

A colored raster image (or pixmap) will usually have pixels with between one and eight bits for each of the red, green, and blue components, though other color encodings are also used, such as four- or eight-bit indexed representations that use vector quantization on the (R, G, B) vectors. The green component sometimes has more bits than the other two to allow for the human eye's greater discrimination in this component.

The quality of a raster image is determined by the total number of pixels (resolution), and the amount of information in each pixel (often called color depth). For example, an image that stores 24 bits of color information per pixel (the standard for all displays since around 1995) can represent smoother degrees of shading than one that only stores 16 bits per pixel, but not as smooth as one that stores 48 bits (technically; this would not be discernible by the human eye). Likewise, an image sampled at 640 x 480 pixels (therefore containing 307,200 pixels) will look rough and blocky compared to one sampled at 1280 x 1024 (1,310,720 pixels). Because it takes a large amount of data to store a high-quality image, data compression techniques are often used to reduce this size for images stored on disk. Some techniques sacrifice information, and therefore image quality, in order to achieve a smaller file size. Compression techniques that lose information are referred to as "lossy" compression.

Raster graphics cannot be scaled to a higher resolution without loss of apparent quality. This is in contrast to vector graphics, which easily scale to the quality of the device on which they are rendered. Raster graphics are more practical than vector graphics for photographs and photo- realistic images, while vector graphics are often more practical for typesetting or graphic design. Modern computer monitors typically display about 72 to 130 pixels per inch (PPI), and some modern consumer printers can resolve 2400 dots per inch (DPI) or more; determining the most appropriate image resolution for a given printer resolution can be difficult, since printed output may have a greater level of detail than can be discerned on a monitor.

PARSHVANATH CHARITABLE TRUST'S

# A.P. SHAH INSTITUTE OF TECHNOLOGY

**Department of Computer Science and Engineering**

**Data Science**

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**Class :- S.E.D.S.** **Semester:- III**

**Subject : Computer Graphics Lab** **A.Y:- 2022-23**

**Rasterization**

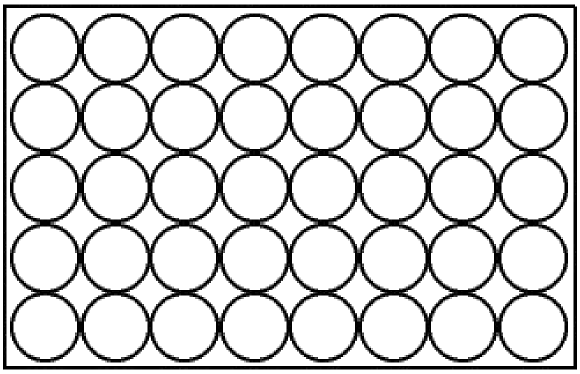
Rasterization is the task of taking an image described in a vector graphics format (shapes) and converting it into a raster image (pixels or dots) for output on a video display or printer.

Raster Display

System

Components

- The screen is subdivided into a matrix of pixels (smallest addressable units).



screen

Raster scanline -- A line of pixels along the screen

- Frame (refresh) buffer -- Block of memory used to store the screen pattern

- How it works

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1. The DISPLAY PROCESSOR produces the raster image in the frame buffer from the commands

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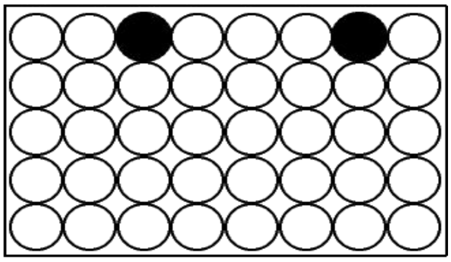
2. The VIDEO CONTROLLER moves the beam row wise across the pixels setting it on and off according to the content of the frame buffer
3. The display must be refreshed to avoid flickering (raster image redisplayed 30 to 60 times per second)

```
Move(2,0)
Line(4,4)
Move(-4,0)
Line(4,-4)
```

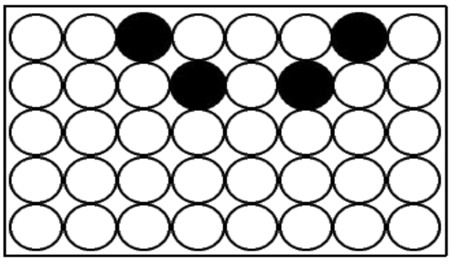
commands in display list

```
00100010
00010100
00001000
00010100
00100010
```

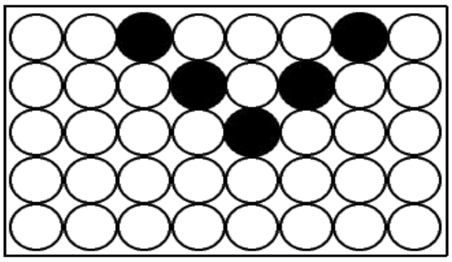
frame buffer



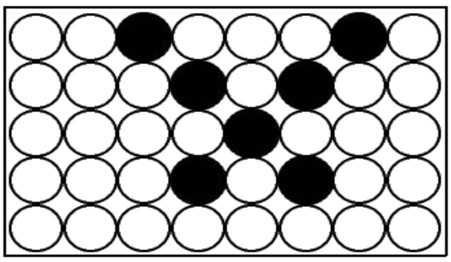
screen after 1 scan lines



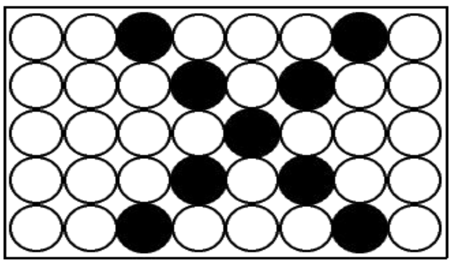
screen after 2 scan lines



screen after 3 scan lines



screen after 4 scan lines



screen after 5 scan lines

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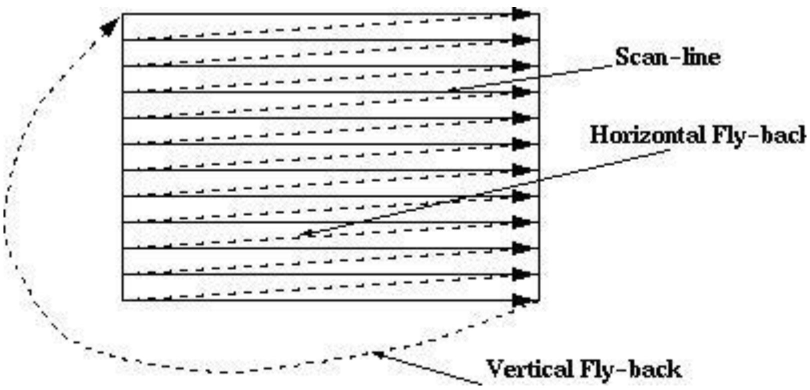
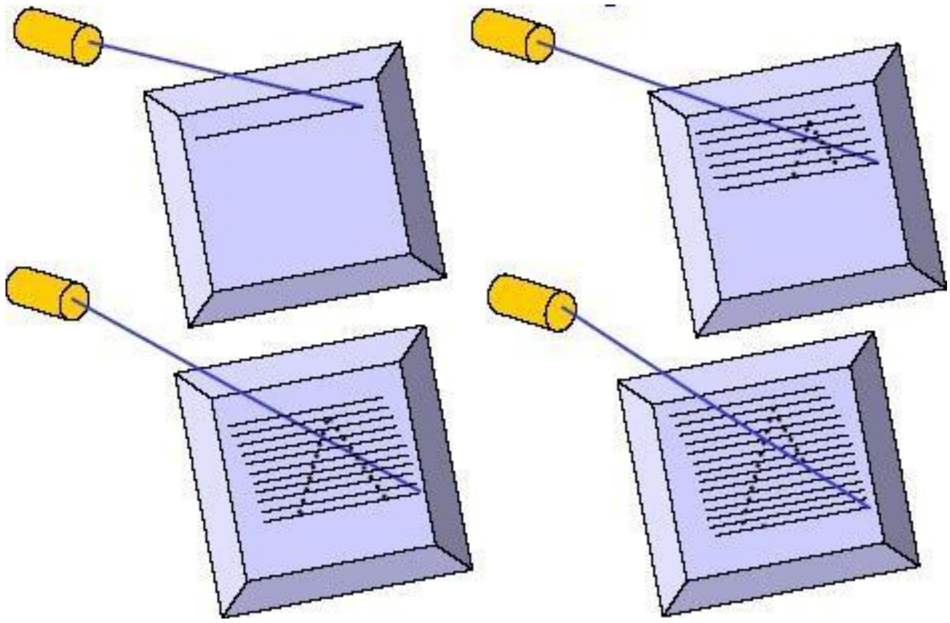
**Raster Scan Display**

Raster Scan methods have increasingly become the dominant technology since about 1975. These methods use the TV type raster scan. The growth in the use of such methods has been dependent on rapidly decreasing memory prices and on the availability of cheap scan generating hardware from the TV industry. The screen is coated with discrete dots of phosphor, usually called pixels, laid out in a rectangular array. The image is then determined by how each pixel is intensified. The representation of the image used in servicing the refresh system is thus an area of memory holding a value for each pixel. This memory area holding the image representation is called the frame buffer. The values in the frame buffer are held as a sequence of horizontal lines of pixel values from the top of the screen down. The scan generator then moves the beam in a series of horizontal lines with fly- back (non-intensified) between each line and between the end of the frame and the beginning of the next frame. This is illustrated below.



Unlike random-scan which is a line drawing device, refresh CRT is a point-plotting device. Raster displays store the display primitives (lines, characters, shaded and patterned areas) in

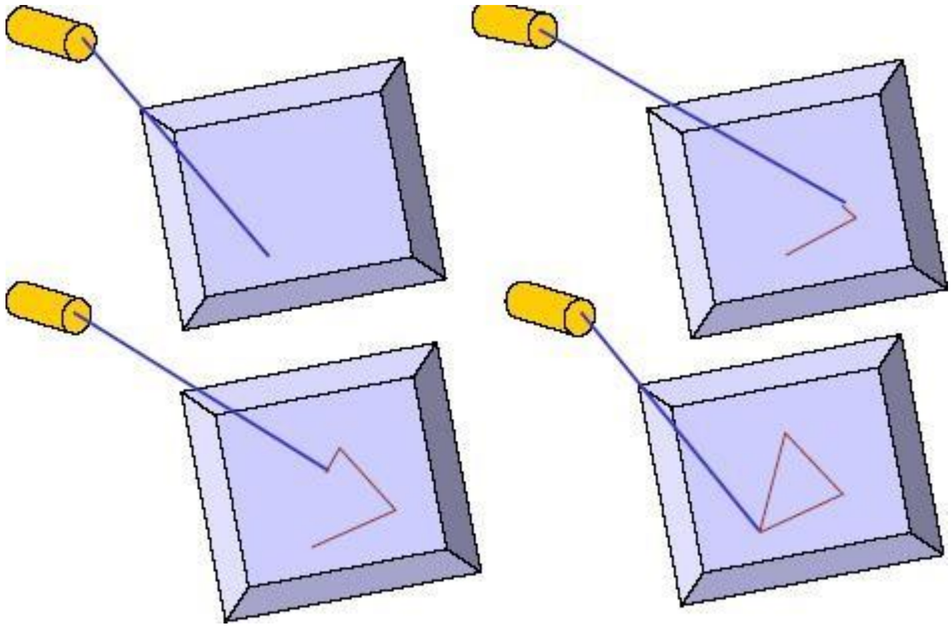


a refresh buffer. Refresh buffer (also called frame buffer) stores the drawing primitives in terms of points and pixels components

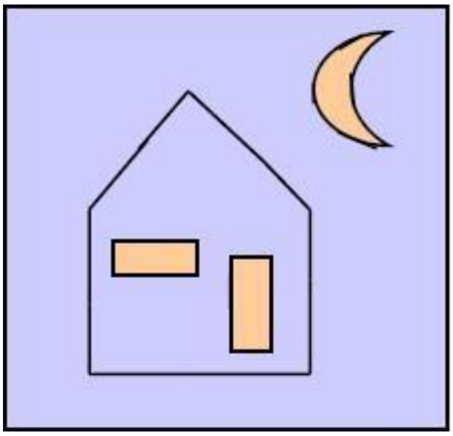
This scan is synchronized with the access of the intensity values held in the frame buffer. The maximum number of points that can be displayed without overlap by a system is called the resolution and is quoted as the number of points per horizontal line versus the number of horizontal lines. Typical resolutions are 640*480, 1024*768, and 1280*1024. The maximum resolution is determined by the characteristics of the monitor and/or by the memory capacity available for storing the frame buffer.

### 1.16) Random Scan Display

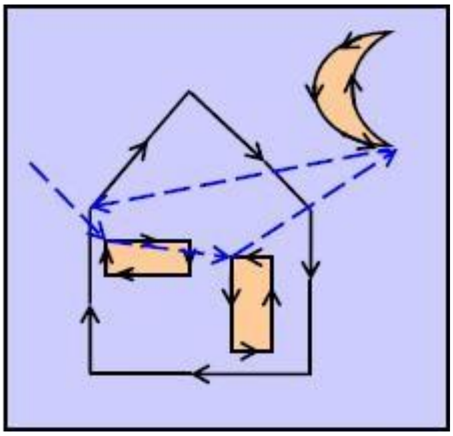
Random scan displays, often termed vector Vector, Stroke, and Line drawing displays, came first and are still used in some applications. Here the characters are also made of sequences of strokes (or short lines). The electron gun of a CRT illuminates straight lines in any order. The display processor repeatedly reads a variable 'display file' defining a sequence of X,Y coordinate pairs and brightness or color values, and converts these to voltages controlling the electron gun.



In random scan display an electron beam is deflected from endpoint to end-point. The order of deflection is dictated by the arbitrary order of the display commands. The display must be refreshed at regular intervals – minimum of 30 Hz (fps) for flicker-free display.



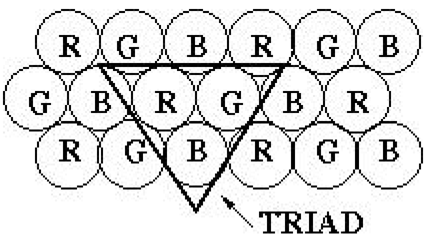
Ideal line drawing



Random Scan Display

**Color in Raster Graphics**

To handle colour the phosphor is applied to the screen in small triads of red, green and blue phosphor dots, each triad representing one pixel. The CRT then has an electron gun for each of the additive primary colours red, green and blue. When the three primary colour



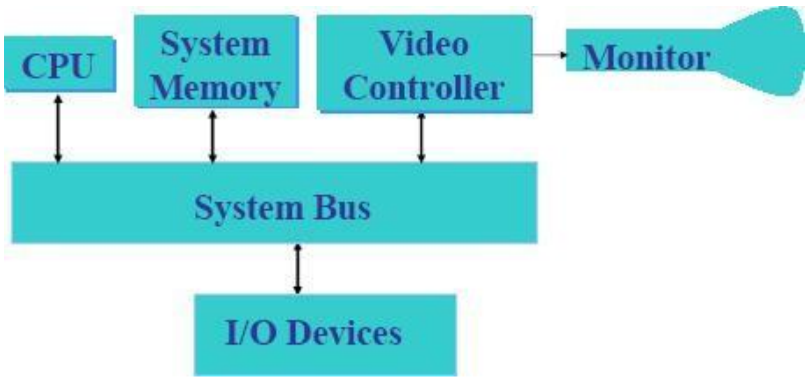

dots are intensified the human visual system combines the triad of primary colours into a single perceived colour.

To ensure the beams hit the correct elements of each triad there is a thin perforated metal sheet (the shadow mask) behind the phosphor that ensures each of the three beams hits the correct element of the triad.

**1.17) Raster Scan Systems**

You know that interactive raster graphics system typically employs several processing units. In addition to central processing unit, or CPU, there is a special –purpose processor, called the video controller or display controller. It is used to control the operation of the display device.

Here the frame buffer can be anywhere in the system memory, and the video




controller accesses the frame buffer to refresh the screen.

**Architecture of a simple raster graphics system**

**Video Controller**

In commonly used raster systems a fixed area is reserved for the frame buffer, and the video controller is given direct access to the frame buffer memory. Frame buffer locations and the corresponding screen positions are referenced in Cartesian coordinates.

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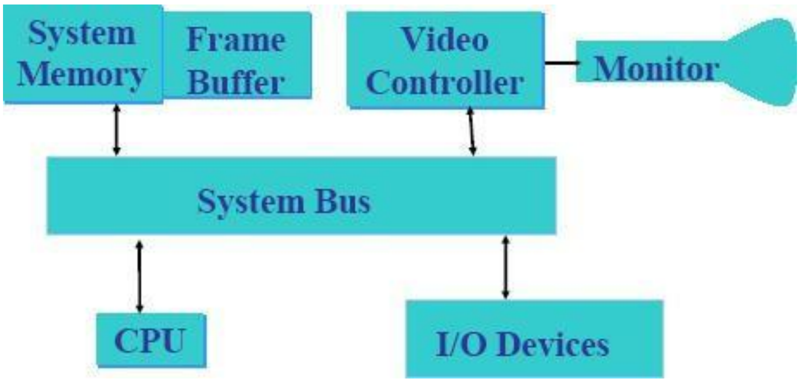



**Architecture of a raster system with a fixed portion of the system memory reserved for the frame buffer**

For the graphics monitor, the origin I defined at the lower left screen corner. The screen is represented as a two dimensional system i.e. the x values increasing to the right and the y values increasing from bottom to top. Each scan line is labeled as $y_{max}$ at the top of the screen to 0 at the bottom. Along each scan line, screen pixel positions are labeled from 0 to $x_{max}$.

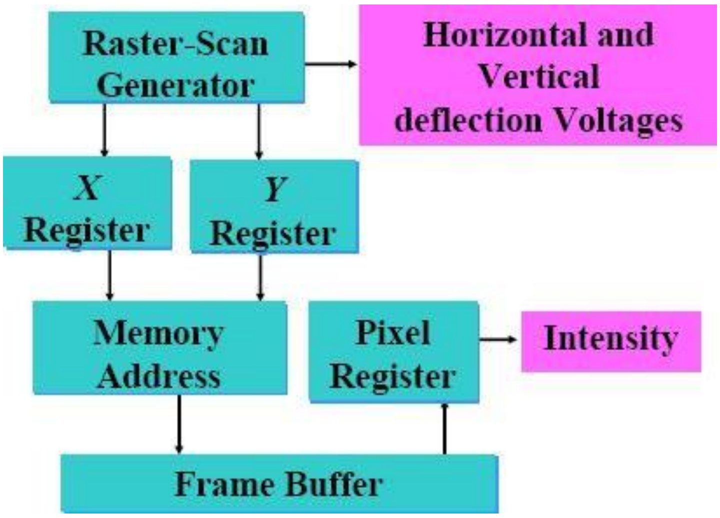
**Refresh operation of the video buffer**

In the basic refresh operation, two registers are used. The purpose of this registers are 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 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 is repeated for each pixel along the scan line.

After the last pixel on the top of the scan line has been processed, the x register is reset to

0and the y register is decremented by 1. The pixels along this scan line are then processed and the procedure is repeated for each successive scan line.

After cycling through all the 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 refresh process starts over.

As you know, a screen has to be refreshed at the rate of 60 frames per second. So this cannot be accommodated in RAM chips. Therefore the cycle time is too low and as a result the pixel processing is too slow. Now what can be done to speed up this process? Multiple pixels can be retrieved in one pass i.e. video controller retrieve multiple pixel values from the refresh buffer on each pass.

Then how do you store all these different intensity values? They are stored using separate registers and are 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.

In high quality systems two buffers are used so that one is used for refreshing and other is being filled with intensity values. Then the two buffers can switch the roles. This

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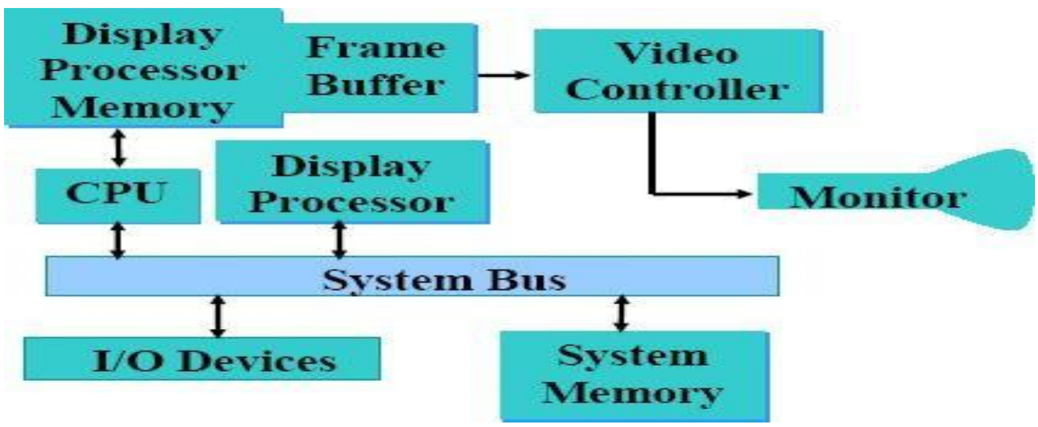
provides a fast mechanism for generating real time animations, since different views of moving objects can be successively loaded into the refresh buffer.

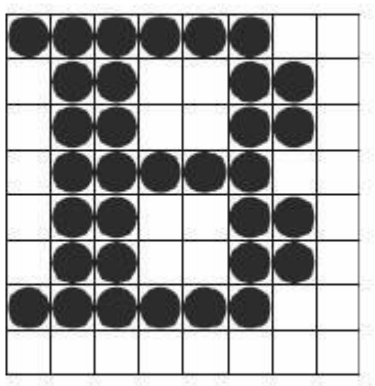
**Raster Scan Display processor**

Raster Scan system may contain a separate display processor.

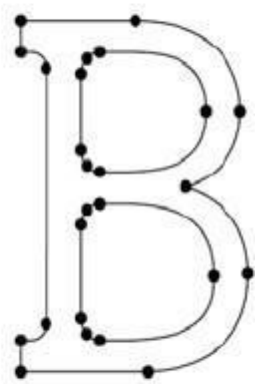
Raster Scan Display processor is sometimes referred to as graphics controller or a display coprocessor. The purpose of this processor is to free the CPU from the graphics tasks. But what is its major task? Its major task is to digitize a picture definition given in an application program into a set of pixel intensity values for storage in the frame buffer. This digitization process is called scan conversion. Graphics commands specifying straight lines and other geometric shapes can be can converted into a set of intensity points. When you scan convert a straight line segment we have to locate the pixel positions closest to the line path and store the intensity for each position in the frame buffer.

Characters can be defined with rectangular grids or they can be defined with outlines. The array size for character grids can vary from about 5 by 7 or 9 by 12.





defined as a grid of pixel position



defined as a curve outline

Display processor are deigned to perform different other functions. They are

- To generate various line styles (dashed , dotted, or solid)
- To display colour areas
- To perform certain manipulations and transformations on displayed objects
- To interface with interactive input devices, such as mouse How is the frame buffer implemented?

It is implemented as a linked list and encodes 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 have that intensity. This technique is called run length encoding.

### 1.18) **Random Scan Systems**

In Random Scan Systems 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. Sometimes the display processor in the random scan system is 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 picture. Lines are defined by the values for their coordinate endpoints, and these input coordinate values are converted to x and y deflection voltage. A scene is then drawn one line at a time by positioning the beam to fill in the line between specified endpoints.